Korean J. Food Sci. Ani. Resour.
Vol. 31, No. 3, pp. 389~397(2011)

ARTICLE

Effects of Salt Concentration in Soybean Sauce on the Physicochemical Properties of Pre-rigor Ground Hanwoo Muscle

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Abstract

This study was conducted to examine the effect of salt concentration in soybean sauce (*ganjang*) on pre-rigor ground Hanwoo (Korean native cattle) muscle. Although adding soybean sauce reduced pH of pre-rigor Hanwoo muscle, it improved the water holding capacity (WHC), cooking loss, total protein solubility, myofibrillar fragmentation index (MFI), 2-thiobarbituric acid (TBA) values, and textural properties by increasing salt concentration in the soybean sauce. In particular, adding soybean sauce inhibited lipid oxidation despite increasing salt concentration. An increased salt concentration in the soybean sauce in pre-rigor Hanwoo muscle tended to make the meat have lower lightness and higher redness and yellowness values. Although soybean sauce had a significantly lower pre-rigor salting effect than sodium chloride in terms of cooking loss and total protein solubility ($p<0.05$), soybean sauce improved myofibrillar fragmentation and lipid oxidation when compared with sodium chloride. Furthermore, no significant differences in textural properties were observed between adding soybean sauce and sodium chloride at the same salt concentrations. Therefore, soybean sauce can be a functional curing material for pre-rigor muscle.

Key words: soybean sauce, pre-rigor muscle, Hanwoo, pre-rigor salting effect

Introduction

In Korea, soybean sauce has been utilized as a marinade source on a variety of Korean traditional meat products, such as *bulgogi* (Korean style barbecued beef), *galbi-jjim* (braised short ribs), and *tteok-galbi* (grilled short rib patties), which are traditionally produced by using Korean native cattle (Hanwoo). Demand for these meat products by foreigners has been increasing due to the characteristic flavor and taste of meats containing soybean sauce. Soybean sauce is a fermented food derived from soybean and Korean soybean sauce has been named *ganjang*. This soybean sauce contains a high salt concentration (approximately 15-20%), water (approximately 50-70%), and various compounds derived from the soybeans during fermentation such as isoflavon, amino acids, organic acids, and melanoidin (Jeon *et al*., 2002; Kim *et al*., 2002; Shim *et al*., 2008). Melanoidin is produced by maillard reaction, and the color characteristics of the soybean sauce are affected by melanoidins (Moon, 1991). In addition, the melanoidin in soybean sauce has an antioxidative effect against lipid oxidation of beef meat (Choi *et al*., 1990). Recently, many studies have examined the effects of soybean sauce on the physicochemical properties and quality characteristics of meat and meat products (Choi *et al*., 2006; Jin *et al*., 2004; Kim *et al*., 2011).

Utilization of pre-rigor muscles, which are treated by hot-boned processing or accelerated processing, has many advantages, including a reduction in cooler space, decrease of energy cost and an increase in final yield as well as the improvement of meat functionalities (Hamm, 1981; Pisula and Tyburcy, 1996). Bernthal *et al*. (1989) reported that pre-rigor meat containing salt has better physicochemical properties than post-rigor meat. In addition, Boles and Swan (1997) showed that the type of brine ingredients affects the meat properties of both pre- and post-rigor beef. However, the effects of soybean sauce concentration on pre-rigor Hanwoo (Korean native cattle) muscle have not yet established. Although there is

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a study exploring the effects of soybean sauce on physicochemical properties of frozen Hanwoo patties (Kim *et al*., 2011), limited research has been conducted for the comparison of pre-rigor ground Hanwoo muscle containing various concentrations of soybean sauce. Thus, it is necessary to evaluate the effect of soybean sauce concentrations as a functional marinade ingredient on pre-rigor ground Hanwoo muscle for globalization of Korean food and the improvement of quality properties in Korean meat products

Therefore, the objective of this study was to investigate the effects of various soybean sauce concentrations on the physicochemical properties of pre-rigor Hanwoo muscle.

Materials and Methods

Raw material collection and sample preparation

A total of twelve Hanwoo cows (each of four Hanwoo cows in three replications, 24 mon of age; live weights, 774.2 kg; slaughter weights, 470.0 kg) were slaughtered at a local municipal slaughterhouse. After splitting and bleeding, the carcasses were transferred to the cutting room. Individual *Semimembranosus* muscles (SM) were removed immediately from the carcasses, and trimmed of visible fat and connective tissue. SMs were placed in polyethylene bags in insulated ice bag and transported to the Meat Science Laboratory at Konkuk University, Korea. SMs were initially ground through an 8 mm plate (PM-100, Mainca, Spain) within 1 h from the beginning of slaughter, and then randomly assigned to five treatment groups.

Commercial soybean sauce (Fermented soybean sauce, Sempio Foods Co., Korea) was purchased from the local market (Table 1). Soybean sauce solutions, which were diluted with ice water, were made at three different target salt concentrations (0.5, 1.0, and 2.0% w/w) based on the sample weight, and sodium chloride solution was also prepared (2.0% of total salt concentration based on the sample weight). These soybean sauce and sodium chloride solutions were individually added to pre-rigor ground Hanwoo muscle (Table 2). Samples were mixed by hand for 5 min, and then analyzed immediately, except for 2-thiobarbituric acid (TBA) values. All the analysis was performed in triplicate.

Table 1. Physicochemical properties of soybean sauce

pH	NaCl (%)	TN[1)] (%)	CIE L^*	CIE a^*	CIE b^*
4.95	16.0	1.55	8.64±0.32[2)]	-0.32±0.34	1.89±0.20

[1)]TN: total nitrogen
[2)]All values are mean±SD.

Table 2. Formulation for the samples preparation

(Unit: %)

Ingredient	Control	Treatments[3)]			
		TS	T1	T2	T3
Pre-rigor Hanwoo muscle	80	80	80	80	80
Soybean sauce solution[1)]	-	-	20	20	20
Sodium chloride solution[2)]	-	20	-	-	-
Ice water	20	-	-	-	-
Total	100	100	100	100	100
Total salt concentration	0.0	2.0	0.5	1.0	2.0

[1)]Soybean sauce solution: liquid soybean sauce diluted by ice water
[2)]Sodium chloride solution: purified sodium chloride dissolved in ice water
[3)]Treatments: Control, pre-rigor ground Hanwoo muscle was mixed with ice water (total salt concentration, 0%); TS, pre-rigor ground Hanwoo muscle was mixed with sodium chloride solution (total salt concentration, 2%); T1, T2, and T3, pre-rigor ground Hanwoo muscle was individually mixed with soybean sauce solution (total salt concentration, 0.5, 1.0, and 2.0%, respectively).

pH measurements

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). All determinations were performed in triplicate.

Instrumental color evaluation

Instrumental color was determined using a colorimeter (Minolta Chroma meter CR-210, Japan; illuminate C, calibrated with a white plate, CIE L^*=+97.83, CIE a^*=-0.43, CIE b^*= +1.98). Six measurements for each of five locations were taken. CIE L^* (lightness), CIE a^* (redness), and CIE b^* (yellowness) values were recorded.

Water holding capacity (WHC)

Water holding capacity (WHC) was determined in triplicate by filter paper pressed method (Grau and Hamm, 1953). Sample of 0.3 g was weighed onto a Whatman No. 2 filter paper and pressed between two plexiglass plate for 3 min. The areas of pressed water and sample were measured using planimeter (Koizumi, Type KP-21, Japan). WHC was calculated as follows:

WHC (%) = area of pressed sample /area of pressed water × 100

Cooking loss

All samples weighed (50 g) and were cooked in a constant-temperature water bath (75°C, 30 min). The cooked samples were cooled to room temperature. After cooling, the cooked samples were reweighed. Cooking loss was determined by calculating the weight differences before and after cooking as follows.

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

Total protein solubility

The solubility of the total (sarcoplasmic + myofibrillar) protein was determined following the modification of procedures described by Helander (1957). To determine total soluble protein, 2 g of sample was weighed into a centrifuge tube, and then 20 mL of ice-cold 1.1 M KI in 0.1 M phosphate buffer (pH 7.4) was added. The sample and buffer were homogenized together on ice for 20 s using a homogenizer (Model AM-7, Nihonseiki Kaisha Ltd., Japan) set at 1,500 rpm, and were left to stand on a shaker in a dark room at 4°C overnight. The mixtures were centrifuged at 6,000 g for 15 min and the protein concentrations of the supernatants were determined by the biuret method (Gornall *et al*., 1949) using bovine serum albumin (Sigma Chemical Co., USA) as a standard.

Myofibrillar fragmentation index (MFI)

Myofibrils was obtained according to the method of Olson and Parrish (1976) using MFI buffer (20 mM K_2HPO_4/KH_2PO_4, pH 7.0, 100 mM KCl, 1 mM EDTA, 1 mM NaN_3). The myofibrils were suspended in MFI buffer. An aliquot of myofibril suspension was diluted with the MFI buffer to 0.5 mg/mL protein concentration and the absorbance of this suspension measured at 540 nm. MFI values were recorded as absorbance units per 0.5 mg/mL myofibril protein concentration multiplied by 200.

2-Thiobarbituric acid (TBA) value

Lipid oxidation was assessed in triplicate by the TBA method of Tarladgis *et al*. (1960) with minor modifications. After manufacturing, all samples were stored at 4°C for 24 h for use of the analysis of lipid oxidation. A 10 g sample was blended with 50 mL distilled water for 2 min and then transferred to a distillation tube. The cup used for blending was washed with an additional 47.5 mL of distilled water, which was added to the same distillation flask with 2.5 mL 4 N HCl and a few drops of an antifoam agent (KMK-73, Shin-Etsu Silicone Co., Ltd., Korea). The mixture was distilled and 50 mL distillate was collected. 5 mL of 0.02 M 2-thiobarbituric acid in 90% acetic acid (TBA reagent) was added to test tube containing 5 mL of the distillate and mixed well. The tubes were capped and heated in a boiling water bath 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). The TBA values were calculated as mg malondialdehyde (MDA)/kg meat.

TBA (MDA mg/kg) = (optical density of sample − optical density of blank) × 7.8

Texture profile analysis (TPA)

Texture profile analysis (TPA) was performed at room temperature with a texture analyzer (TA-XT2*i*, Stable Micro Systems, England). Cooked meat samples were taken from the central portion of each meat. Prior to analysis, samples were allowed to equilibrate to room temperature (20°C, 3 h). The conditions of texture analysis were as follows: pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g. The calculation of TPA values was obtained by graphing a curve using force and time plots. Values for hardness (kg), springiness, cohesiveness, gumminess (kg), and chewiness (kg) were determined as described by Bourne (1978).

Statistical analysis

An analysis of variance was performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS Institute, Inc., 1999). Duncan's multiple range test ($p<0.05$) was used to determine differences between treatment means.

Results and Discussion

The pH value and instrumental color evaluation

Table 3 shows the pH and instrumental color of raw pre-rigor ground Hanwoo (Korean native cattle) muscle containing various salt concentrations in soybean sauce. The pH value is an important factor in raw meat and influences the quality characteristics of the final meat products (Park and Kwon, 1998). These are especially

Table 3. Effect of salt concentration in soybean sauce on pH values and instrumental color of pre-rigor ground Hanwoo muscle

Trait	Control	Treatments[1)]			
		TS	T1	T2	T3
pH	6.63±0.12^{A}	6.65±0.04^{A}	6.23±0.03^{B}	6.08±0.02^{C}	5.95±0.03^{D}
CIE L*	36.80 ±2.45^{A}	33.11±1.04^{B}	31.35±1.19^{BC}	31.26±1.19^{BC}	30.95±2.07^{C}
CIE a*	12.89±1.85^{C}	17.51±1.38^{A}	16.24±1.27^{B}	16.77±1.71^{AB}	16.85±1.67^{A}
CIE b*	8.04±0.64^{B}	7.16±0.43^{C}	7.13±0.65^{C}	7.66±0.64^{C}	9.41±0.80^{A}

All values are mean±SD.

$^{A-D}$Means in the same row with different letters are significantly different (p<0.05).

[1)]Treatments: Control, pre-rigor ground Hanwoo muscle was mixed with ice water (total salt concentration, 0%); TS, pre-rigor ground Hanwoo muscle was mixed with sodium chloride solution (total salt concentration, 2%); T1, T2, and T3, pre-rigor ground Hanwoo muscle was individually mixed with soybean sauce solution (total salt concentration, 0.5, 1.0, and 2.0%, respectively).

predominant aspects for pre-rigor muscle, where high pH values and ATP concentrations influence the processing quality of pre-rigor muscle (Hamm, 1977). The pH values of the control and TS were 6.63 and 6.65, respectively. This result is in agreement with many previous studies, which have shown that the differences of pH value immediately after salting did not affected by NaCl concentration (Bernthal *et al*., 1989). Bernthal *et al*. (1989) reported that higher NaCl concentrations contributed to the formation of higher ultimate pH values in pre-rigor beef homogenates. Hamm (1977) suggested that the higher pH values of salted pre-rigor meat were due to the denaturation of glycolytic enzyme. However, the addition of soybean sauce solutions caused a significant decrease in the pH values of pre-rigor ground Hanwoo muscle even though the salt concentrations were higher (p<0.05). At the same total salt concentration, T3 had significantly lower pH values than TS (p<0.05). The pH value of soybean sauce solutions added to the T1, T2, and T3 showed 5.26, 5.17, and 5.01, respectively. Jeon *et al*. (2002) reported that the low pH value of the soybean sauce is caused by the proliferation of lactic acid bacteria during the fermentation period, which might be the reason for a low pH value of meats treated with soybean sauce (T1, T2, and T3). A similar result was reported by Kim *et al*. (2011) where the pH value of frozen Hanwoo patties containing soybean sauce was lower than the pH value of those made with sodium chloride for both pre- and post-rigor Hanwoo muscle.

The differences in lightness (CIE L*), redness (CIE a*), and yellowness (CIE b*) values of pre-rigor Hanwoo by the addition of the soybean sauce were partially significant (p<0.05). All treatments, regardless of salting materials, exhibited a significantly lower lightness and higher redness than the control (p<0.05). A similar result was previously observed by Farouk and Swan (1997). In this study, they reported that pre-rigor salted minces had a darker and less yellow color than unsalted minces and suggested that salting and mincing decreased the lightness and yellowness due to an increase in lipid oxidation and protein denaturation in the muscle. T3 treatment had darker and T1 treatment had less red color than the TS treatment. When the soybean sauce was added to pre-rigor ground Hanwoo muscle, a higher yellowness value was observed as the addition level of soybean sauce increased, and the T3 treatment produced the highest yellowness value. These results were most likely due to the brown color of the soybean sauce, which may have contributed to the increase in the yellowness value of meat and meat products. Kim *et al*. (2011) reported that Hanwoo patties made with pre-rigor muscle and soybean sauce showed darker, less fiery, and browner when compared with sodium chloride treatments.

The water holding capacity (WHC) and cooking loss

The water holding capacity (WHC) of meat was affected by changes in various physical and biochemical factors such as the net charge effect, genetic factors, steric effects, and post-mortem proteolysis, especially, when the pH value was close to the isoelectric point of myofibrillar protein, which produced a poor WHC (Huff-Lonergan and Lonergan, 2005). Generally, the pre-rigor muscle had a superior WHC due to the high pH value and ATP concentration (Pisula and Tyburcy, 1996). In addition, the salted pre-rigor muscle had a higher WHC than unsalted pre-rigor muscle (Bernthal *et al*., 1989). Fig. 1 showed the WHC for raw pre-rigor ground Hanwoo (Korean native cattle) muscle containing various salt concentrations in soybean sauce. All treatments had a significantly higher WHC than the control (p<0.05) except T1 which was not significantly differences from the control (p>0.05). The "pre-rigor salting effect" which leads to high functional-

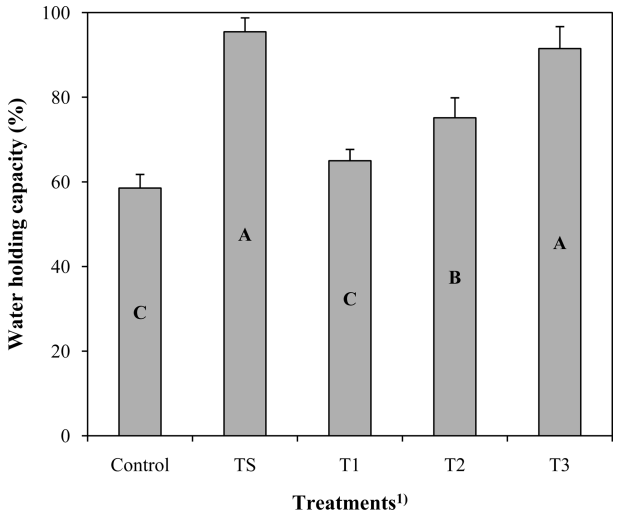

Fig. 1. Effects of salt concentration in soybean sauce on water holding capacity of pre-rigor ground Hanwoo muscle. [1)]Treatments: Control, pre-rigor ground Hanwoo muscle was mixed with ice water (total salt concentration, 0%); TS, pre-rigor ground Hanwoo muscle was mixed with sodium chloride solution (total salt concentration, 2%); T1, T2, and T3, pre-rigor ground Hanwoo muscle was individually mixed with soybean sauce solution (total salt concentration, 0.5, 1.0, and 2.0%, respectively).

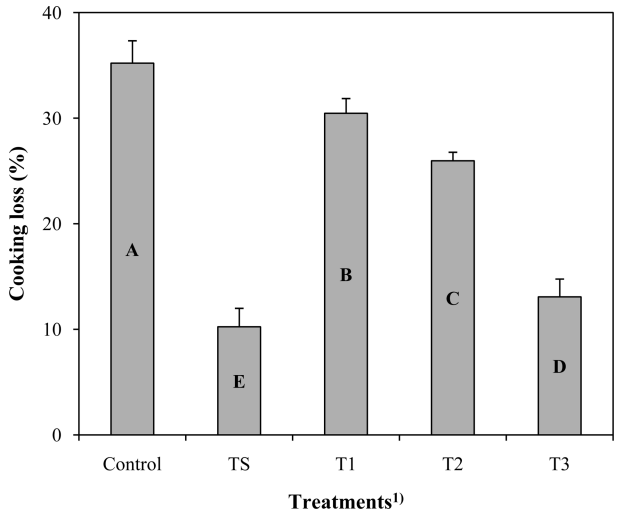

Fig. 2. Effects of salt concentration in soybean sauce on cooking loss of pre-rigor ground Hanwoo muscle. [1)]Treatments: Control, pre-rigor ground Hanwoo muscle was mixed with ice water (total salt concentration, 0%); TS, pre-rigor ground Hanwoo muscle was mixed with sodium chloride solution (total salt concentration, 2%); T1, T2, and T3, pre-rigor ground Hanwoo muscle was individually mixed with soybean sauce solution (total salt concentration, 0.5, 1.0, and 2.0%, respectively).

ity of pre-rigor muscle was observed in a previous study at least 1.8% (Hamm, 1981) or 2.0% (Bernthal *et al*., 1989) of a NaCl concentration. The WHC of pre-rigor Hanwoo treated with soybean sauce was consistently increased as the salt concentration in the soybean sauce increased, and T3 treatment having the lowest pH value had the eventually a higher WHC when compared with T1 and T2. This phenomenon resulted from the increased salt concentration rather than pH effect; thus, the WHC of pre-rigor muscle containing soybean sauce was more affected by the salt concentration than their low pH values. A similar result was reported by Bernthal *et al*. (1989), who found that pre-rigor ground treated with 2 and 4% NaCl had a higher WHC than the other NaCl treatments (0.0, 0.5, and 1.0%).

The cooking loss of pre-rigor ground Hanwoo muscle containing various salt concentrations in soybean sauce is shown in Fig. 2. The control had the highest cooking loss among the treatments whereas TS had a lower cooking loss than the soybean sauce treatments ($p<0.05$). However, an increase of salt concentration in the soybean sauce resulted in lowering the cooking loss of pre-rigor ground Hanwoo meat. Farouk and Swan (1997) reported that batters prepared with pre-rigor salted mince had a higher cooking yield than those made with unsalted mince. Bernthal *et al*. (1989) suggested that the increase in cooking yield of pre-rigor meat by the addition of salt may be due to a high WHC. Similarly, Offer and Trinick (1983) and Paterson *et al*. (1988) suggested that salt could influence the net charge and meat protein solubility in the muscle. Our results were similar to those of previous reports, which demonstrated that a lower cooking loss by increasing the salt levels of soybean sauce in pre-rigor ground Hanwoo meat resulted from an increase in the WHC. Furthermore, these results suggest that the addition of soybean sauce to pre-rigor Hanwoo muscle showed similar effects as seen on salting the muscle with sodium chloride at same salt concentration.

The total protein solubility and myofibrillar fragmentation index (MFI)

The total protein solubility and myofibrillar fragmentation index (MFI) are shown in Table 4. Statistical analysis indicated that TS had the highest total protein solubility, and increases of the salt concentration in soybean sauce resulted in gradually an increase in the total protein solubility ($p<0.05$). A similar result was reported by Bernthal *et al*. (1991) who found that an increase in extractable protein was observed when the NaCl concentrations in ground beef were increased. With related to rigor status, Farouk and Swan (1997) reported that pre-rigor muscle

Table 4. Effect of salt concentration in soybean sauce on total protein solubility and MFI[1)] of pre-rigor ground Hanwoo muscle

Trait	Control	Treatments[2)]			
		TS	T1	T2	T3
Total protein solubility (mg/g)	55.06±2.34^{E}	75.36±1.72^{A}	60.42±2.71^{D}	66.84±2.79^{C}	70.12±1.51^{B}
MFI	20.35±1.02^{B}	14.67±1.53^{C}	15.30±0.74^{C}	30.95±2.07^{A}	32.26±1.19^{A}

All values are mean±SD.
$^{A-E}$Means in the same row with different letters are significantly different (p<0.05).
[1)]MFI: myofibrillar fragmentation index
[2)]Treatments: Control, pre-rigor ground Hanwoo muscle was mixed with ice water (total salt concentration, 0%); TS, pre-rigor ground Hanwoo muscle was mixed with sodium chloride solution (total salt concentration, 2%); T1, T2, and T3, pre-rigor ground Hanwoo muscle was individually mixed with soybean sauce solution (total salt concentration, 0.5, 1.0, and 2.0%, respectively).

had higher protein (as actin and actomyosin) extractability than post-rigor muscle and Trautman (1966) also found that the decrease in pH was associated with a linear decrease in protein solubility. However, in this study, although the lowest pH value was observed in T3 treatment, T3 had the highest total protein solubility among the samples containing soybean sauce. This result indicates that the total protein solubility of pre-rigor meat, especially the salt-soluble proteins, was more influenced by increasing effects of the salt concentration in the soybean sauce rather than the lowering of the pH by soybean sauce.

The myofibrillar fragmentation index (MFI) is related to the degradation of myofibrils in the vicinity of the Z-disc during aging or ripening (Olson and Parrish, 1976) Parrish *et al*. (1973) reported that the development of MFI was affected by the storage periods and temperature. In addition, changes in the quality of meat post-mortem relative to the degradation of myofibrillar proteins are mainly influenced by endogenous proteinases, and degradation of myofibrillar proteins is an important factor in meat tenderness including sarcomere length, ionic strength, and characteristics of animals (Koohmaraie, 1994). The TS and T1 had the lowest MFI and T2 and T3 showed the highest MFI (p<0.05), while the control was in between. Sárraga *et al*. (1989) suggested that the presence of NaCl may inhibit enzyme activity such as Ca-dependent protease, cathepsin D and L in porcine muscle. According to Song *et al*. (2001), protease activity in soybean sauce is decreased by heat sterilization, however, was recovered during storage. Thus, higher MFI of T2 and T3 in this study may be affected by various proteases, produced from microorganisms during the fermentation process of soybean sauce (Baek *et al*., 2010).

2-Thiobarbituric acid (TBA) values

The 2-thiobabituric acid (TBA) values of pre-rigor ground Hanwoo muscle containing various salt concentrations in soybean are shown in Table 5. Generally, the addition of salt to meat and meat products promotes lipid oxidation. In a previous study, Torres *et al*. (1988) reported that NaCl at a concentration of at least 0.5% catalyzed lipid oxidation in pre-rigor beef muscle. In addition, Lee *et al*. (1997) reported that the accelerated lipid oxidation through the addition of sodium chloride was due to the release of iron ions from heme pigments in myoglobin. In this study (Table 5), it seems likely that the addition of sodium chloride rather than soybean sauce treatment to the pre-rigor ground Hanwoo meat is at least responsible for elevating the TBA values. TS produced with 2.0% of sodium chloride had the highest TBA values than the control and the soybean sauce treatments (T1, T2, and T3). However, the addition of soybean sauce (T2 and T3) at greater than 1.0% lowered the TBA values

Table 5. Effect of salt concentration in soybean sauce on TBA[1)] values of pre-rigor ground Hanwoo muscle after 24 h of processing

Trait	Control	Treatments[2)]			
		TS	T1	T2	T3
TBA value (MDA mg/kg)	0.18±0.04^{C}	0.35±0.02^{A}	0.26±0.04^{B}	0.18±0.03^{C}	0.15±0.03^{C}

All values are mean±SD.
$^{A-C}$Means in the same row with different letters are significantly different (p<0.05).
[1)]TBA: 2-thiobarbituric acid
[2)] Treatments: Control, pre-rigor ground Hanwoo muscle was mixed with ice water (total salt concentration, 0%); TS, pre-rigor ground Hanwoo muscle was mixed with sodium chloride solution (total salt concentration, 2%); T1, T2, and T3, pre-rigor ground Hanwoo muscle was individually mixed with soybean sauce solution (total salt concentration, 0.5, 1.0, and 2.0%, respectively).

Table 6. Effect of salt concentration in soybean sauce on textural properties of cooked pre-rigor ground Hanwoo muscle

Trait	Control	Treatments[1)]			
		TS	T1	T2	T3
Hardness (kg)	0.78±0.04^{D}	0.98±0.08^{A}	0.83±0.06^{C}	0.95±0.05^{B}	1.02±0.10^{A}
Springiness	0.73±0.04^{B}	0.83±0.04^{A}	0.74±0.05^{B}	0.77±0.07^{AB}	0.82±0.04^{A}
Cohesiveness	0.47±0.06^{C}	0.62±0.05^{A}	0.47±0.05^{C}	0.58±0.07^{B}	0.64±0.03^{A}
Gumminess (kg)	0.40±0.04^{C}	0.64±0.06^{A}	0.41±0.06^{C}	0.50±0.04^{B}	0.66±0.10^{A}
Chewiness (kg)	0.29±0.08^{C}	0.54±0.06^{A}	0.30±0.05^{C}	0.45±0.04^{B}	0.56±0.07^{A}

All values are mean±SD.

$^{A-D}$ Means in the same row with different letters are significantly different ($p<0.05$).

[1)]Treatments: Control, pre-rigor ground Hanwoo muscle was mixed with ice water (total salt concentration, 0%); TS, pre-rigor ground Hanwoo muscle was mixed with sodium chloride solution (total salt concentration, 2%); T1, T2, and T3, pre-rigor ground Hanwoo muscle was individually mixed with soybean sauce solution (total salt concentration, 0.5, 1.0, and 2.0%, respectively).

of pre-rigor ground Hanwoo meat, which are similar ($p>0.05$) to the control. Torres *et al*. (1988) reported that TBA values in pre-rigor beef muscle were increased when the NaCl concentration was increased from 0.0 to 4.0%. Our results partially agree with the findings of their previous research (as in between the control and TS treatment). However, the T3 treatment, which had a salt concentration of 2.0%, produced the lowest TBA values relative to the other treatments, and the T1 had a higher TBA value compared to the control. At 0.5% of salt concentration in soybean sauce (T1), salt has a greater impact on the lipid oxidation than the antioxidative effect of soybean sauce. Moon and Cheigh (1986) reported similar results for ground beef cooked by microwave heating, and Shin and Lee (1990) also demonstrated that the antioxidative properties of soybean sauce were the highest among various seasonings. The results obtained in this study may be due to the presence of the antioxidative compounds in soybean sauce, such as melanoidin, phenolic compounds, and nitrogen based compounds (Moon, 1991). Also, Jeon *et al*. (2002) indicated that the antioxidative properties of soybean sauce were related to melanoidin, which is formed by the maillard reaction.

Texture profile analysis (TPA)

Table 6 shows the effects of salt concentration in soybean sauce on the texture properties of the pre-rigor ground Hanwoo muscle. The TS and T3 treatments had the highest values for all textural properties ($p<0.05$), and they were not significant ($p>0.05$). Similar result was obtained by Kim *et al*. (2011). In the case of soybean sauce treatments (T1, T2, and T3), the hardness was higher as the salt concentration in soybean sauce increased 0.5% to 2.0% ($p<0.05$). Knight (1992) reported that the addition of salt and phosphate enhanced the hardness due to the increased ionic strength and Claus *et al*. (1989) reported that an increase in the amount of salt soluble proteins tended to increase the hardness of the meat products. Similar results were reported by Claus and Sørheim (2006) and Mann *et al*. (1990). Knight (1992) reported that when the salt concentration in ground meat products was increased, the hardness increased and the structure changed substantially with the increased ionic strength. For these reasons, T3 had more firmness due to improve binding ability of meat particles as well as a higher WHC and MFI. In addition, the increase of salt concentration in soybean sauce significantly ($p<0.05$) influenced the increase in springiness, cohesiveness, gumminess, and chewiness of pre-rigor ground Hanwoo meat between T1 and T3.

The objective of this study was to investigate the effect of salt concentration in soybean sauce on the physicochemical properties of pre-rigor ground Hanwoo muscles. The WHC, cooking loss, total protein solubility, MFI, and textural properties of pre-rigor Hanwoo muscle were improved at a higher salt concentration in the soybean sauce. Also, the addition of soybean sauce was more effective at inhibiting the lipid oxidation. Although the soybean sauce produced a comparatively lower cooking loss and total protein solubility than sodium chloride at the same salt concentration, the soybean sauce can be used as a good curing source, considering the improvements in MFI and lipid oxidation of the pre-rigor ground Hanwoo muscle when treated with soybean sauce.

Acknowledgement

This work was supported by the Konkuk University.

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(Received 2011.4.17/Revised 2011.5.19/Accepted 2011.6.7)