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ARTICLE

Effects of Pre-rigor Salting on the Physicochemical and Textural Properties of Ground Duck Breast Muscle

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Abstract

The pre-rigor salting effects on physicochemical properties of ground duck breast muscle were evaluated in this study. The pre-rigor salting treatments were prepared within 30 min after slaughter, the duck breast muscles after post mortem 48 h were used to prepare the post-rigor treatments. The pre-rigor salting treatment had significantly higher pH value than post-rigor salting treatment ($p<0.001$), and all pre-rigor salting treatments showed a significant higher pH value. As a result, the pre-rigor salting treatment showed increased water holding capacity and decreased cooking loss compared to those in the post-rigor salting treatment. No significant differences in redness and yellowness were observed among the treatments ($p>0.05$). The increased solubility of salt-soluble proteins in the pre-rigor salting treatment leads to increase the hardness, gumminess, and chewiness. Also, the pre-rigor salted duck breast muscle had similar textural properties compared to those of post-rigor duck breast muscle containing sodium tri-polyphosphate (STPP). The 2-thiobarbituric acid (TBA) values of all treatments were ranged from 0.121 to 0.177 mg/kg. The lowest TBA value was observed for post-rigor duck breast muscle containing STPP, however, pre-rigor salting did not influence lipid oxidation of ground duck breast muscle. Therefore, the pre-rigor salting method, especially a single addition of sodium chloride to pre-rigor muscle, is more efficient method for improving cooking loss.

Key words: pre-rigor muscle, duck breast muscle, salting, phosphate

Introduction

Total duck consumption has risen steadily from 2001 to 2011 in Korea, and duck meat consumption per head rose from 1,020 g to 3,134 g during the period (Korea Duck Association, 2012). Duck meat is generally consumed as smoked duck, brine cured duck, or boiled in soup. Despite the spending pattern, the reasons for the increase in the amount of duck meat consumed are due to its nutritional value, as poultry meat, including duck is lower in saturated fatty acids and cholesterol compared with those in other animals. Thus, development of various duck meat products is needed to reflect the demand for healthy meat.

Addition of salt into the pre-rigor muscle provides superior processing quality. This method is an effective utilization of pre-rigor muscle, but the type of salt, salt concentration, and salting time are important factors. Previous studies evaluated the effects of sodium chloride (Bernthal *et al*., 1989), phosphate (Boles and Swan, 1997), calcium (Rees *et al*., 2002), and glucose (Young *et al*., 1988) on pre-rigor muscle. According to Hamm (1981), salt added to pre-rigor muscle inhibited actomyosin formation, and 2-4% salt concentration was suitable for this effect. Many studies on the pre-rigor salting effect evaluated beef and pork muscle. However, no studies are available about pre-rigor salting effects on duck muscle, because most duck meat is used as whole meat. However, a study on the effect of pre-rigor salting on ground duck breast muscle is needed to develop and improve the quality characteristics of ground duck meat products. Therefore, the objective of this study was to investigate the effect of pre-rigor salting on physicochemical properties of duck breast muscle to contribute to the development of various ground duck meat products.

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Materials and Methods

Raw material collection and sample preparation

A total of 48 Pekin ducks (*Anas platyrhynchos*, 42±2 d of age and approximately 3.2-3.4 kg live weight) were obtained from a local poultry processor and transported to the Konkuk University Meat Science Laboratory. To minimize the effects of catching and handling, feed was removed 12 h prior to processing, but they were allowed access to water until 2 h prior to processing (Alvarado and Sams, 2000). The birds were stunned electrically at 50 V for 10 s and killed by bleeding from a single unilateral neck for approximately 3 min. The duck carcasses (2.0-2.2 kg average carcass weight) were obtained within 15 min after slaughter, and then the breast muscle was immediately removed (*pectoralis major*). Each duck breast muscle was weighed (140.08±5.62 g average weight), and the removed duck breast muscle divide into two portions (pre- and post-rigor). One portion (post-rigor treatment) was vacuum-packaged into polyethylene bags and then stored in 4°C refrigerator for 48 h. The other portion (pre-rigor treatment) was ground through an 8 mm plate within 30 min and divide into three portions. One portion added 2% sodium chloride (pre-rigor S-W), another added 2% sodium chloride based on meat weight and 20% water (pre-rigor SW). The other pre-rigor treatment added 2% sodium chloride and 20% water and then was frozen in -25 °C freezer for 24 h (pre-rigor SWF). The pre-rigor S-W and SW treatments were stored in 4°C refrigerator for 48 h until the analysis. The 20% water was added to the pre-rigor S-W treatment before analyzing, the pre-rigor SWF treatment was thawed in 4°C refrigerator for 24 h to analysis. The post-rigor treatments (post-rigor SW and SWP) after post mortem 48 h were ground through an 8 mm plate. The post-rigor SW treatment added 2% sodium chloride and 20% water, and the post-rigor SWP treatment added 2% sodium chloride, 20% water, and 0.3% sodium tripolyphosphate (STPP) to evaluate substitution effect of pre-rigor salting. The calculated salt concentration and processing method of each treatment were shown in Table 1.

pH measurements

The pH values of ground duck breast muscle were determined with a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). The pH values of samples were measured by blending a 5 g sample with 20 mL distilled water for 60 s in a homogenizer at 8,000 rpm (Ultra-Turrax SK15, Janke & Kunkel, Germany).

Instrumental color evaluation

The color of samples were 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). Five measurements for each of five locations on surface of ground duck breast muscle were taken. CIE L^* (lightness), CIE a^* (redness), and CIE b^* (yellowness) values were recorded.

Water holding capacity (WHC)

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

Salt soluble protein solubility

The solubility of the salt soluble (myofibrillar) protein

Table 1. The calculated salt concentration and processing method of treatments

Treatments	Processing method at each rigor states		
	Pre-rigor	Post-mortem 48 h	Post-rigor
Pre-rigor S-W[1)]	1.96[2)]	S → 4°C storage → W	1.64
SW	1.64	S and W → 4°C storage	1.64
SWF	1.64	S and W → freezing → thawing	1.64
Post-rigor SW	-	4°C storage → S and W	1.64
SWP	-	4°C storage → S, W, and P	1.64 (0.3)

The number in parentheses refers to the concentration of sodium tripolyphosphate.
[1)]The ground pre-rigor treatments were salted within post-mortem 30 min, and the ground post-rigor treatments were salted at post-mortem 48 h. S-W, pre-rigor salting (2% sodium chloride) and the addition of 20% water after post-mortem 48 h; SW, 2% sodium chloride and 20% water based on muscle weight; F, freezing processing in a -25°C freezer; P, 0.3% sodium tripolyphosphate
[2)]Calculated salt concentration (%, w/w).

was determined following the modification of procedures described by Saffle and Galbreath (1964). A 5 g sample was blended with 50 mL 3% sodium chloride solution at 14,000 rpm for 2 min using homogenizer (AM-7, Nihonseiki Kaisha, Japan). The mixture was centrifuged at 3,000 rpm for 15 min. The protein concentration of supernatant was determined using the biuret method (Gornall *et al*., 1949) and using bovine serum albumin (Sigma Chemical Co., USA).

Cooking loss

All samples stuffed into each centrifugal tube (approximate 50 g) and were cooked in a constant-temperature water bath (75°C, 30 min). The cooked samples were cooled to room temperature for 6 h. 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

2-thiobarbituric acid (TBA) value

Each sample was sealed with polyethylene bangs and stored in 4°C refrigerator for 7 days to evaluate effect of pre-rigor salting on lipid oxidation of duck breast during storage. Lipid oxidation was assessed in triplicate by 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 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 MDA/kg meat.

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

Texture profile analysis (TPA)

TPA was performed at room temperature with a texture analyzer (TA-XT2*i*, Stable Micro Systems, England). Cooked meat samples (2.5 cm in height, 2.0 cm in diameter) 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

All experiments were done at least three times for each treatment and mean values were reported. For pre-rigor treatments, 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., 2008). Duncan's multiple range test ($p<0.05$) was used to determine differences between treatment means. The obtained results of all experiments of post-rigor treatments were statistically processed, and the significance of difference between means (t-test) was determined. Also, the significance of difference between Pre-rigor SW and Post-rigor SW treatments was determined using t-test.

Results and Discussion

The pH value, water holding capacity, and instrumental color

The effects of pre-rigor salting on pH, water holding capacity (WHC), and instrumental color of duck breast muscle are shown in Table 2. pH is one of the main factors that influences the physicochemical characteristics of final products such as WHC, color, and cooking loss. The high pH value over the isoelectric point of muscle protein (about 5.4) produces a wide space between actin and myosin; thus, more water molecules can exist. The 15 min post mortem pH value of pre-rigor duck breast muscle ranged from 6.70 to 6.76 (data not shown). After processing, the pre-rigor salting treatments (pre-rigor S-W, SW, and SWF) had higher pH values than those of the post-rigor treatments (post-rigor SW and SWP), even if the pre-rigor SWP treatment slightly increased the pH value due to added phosphate. Also, the pre-rigor SW

Table 2. The effect of pre-rigor salting on the pH value, water holding capacity, and instrumental color of ground duck breast muscle

Traits	Pre-rigor[1)]			Post-rigor	
	S-W	SW	SWF	SW	SWP
pH	6.33±0.03[3)A]	6.26±0.03[B]	6.24±0.02[B]	5.95±0.02***[4)]	6.20±0.02***
WHC[2)] (%)	94.38±1.15	93.30±1.05	93.38±0.42	91.90±2.44*	93.88±0.68*
CIE L*	40.64±1.33	39.87±1.56	39.66±0.70[B]	43.56±1.57***	43.06±1.40
CIE a*	16.51±1.35	16.12±1.37	16.17±1.61	16.85±1.32	16.83±1.47
CIE b*	2.37±0.31	2.30±0.40	2.87±0.34	2.38±0.36	2.41±0.32

[1)]The ground pre-rigor treatments were salted within post-mortem 30 min, and the ground post-rigor treatments were salted at post-mortem 48 h. S-W, pre-rigor salting (2% sodium chloride) and the addition of 20% water after post-mortem 48 h; SW, 2% sodium chloride and 20% water based on muscle weight; F, freezing processing in a -25°C freezer; P, 0.3% sodium tripolyphosphate.
[2)]WHC : water holding capacity.
[3)]All values are mean±SD of the three replicates.
[4)]Asterisk on post-rigor SW treatment refers to t-test result between pre-rigor SW and post-rigor SW treatments, and asterisk on post-rigor SWP treatment refers to t-test result between post-rigor treatments. *p<0.05; **p<0.01; ***p<0.001.
[A,B]Means sharing different letters within pre-rigor treatments are significantly different (p<0.05).

treatment had significantly higher pH value than post-rigor SW treatment (p<0.001). According to Hamm (1977), glycolytic enzymes result in the lower pH values due to lactic acid formation under anaerobic conditions. Additionally, the inactivity of phosphorylase and phosphofructokinase, which are involved in glycolysis, results from the altered pH values and ionic strength (Dalrymple and Hamm, 1974). Our results agreed with the high pH value of pre-rigor salting muscle; however, the pre-rigor SW and SWF treatments showed lower pH values than those of the pre-rigor S-W treatment (p<0.05).

The post-rigor SW treatment, which showed the lowest pH value, had the poorest WHC. However, no significant differences were observed among the pre-rigor treatments (p>0.05). Many studies have indicated that pre-rigor salting improves WHC, which agreed with our results (Benthal *et al*., 1989). As mentioned above, the improvement in WHC by pre-rigor salting is associated with inhibiting anaerobic glycolysis due to the increase in ionic strength (Hamm, 1977). For this reason, the higher WHC of pre-rigor SW treatment compared to post-rigor SW treatment was obtained (p<0.05).

Pre-rigor salting influenced the lightness (CIE L*) of duck breast muscle; however, no differences in redness (CIE a*) or yellowness (CIE b*) were observed regardless of the rigor state prior to salting. Light reflecting from the water is associated with the lightness of meat; thus, the increased free water on the surface increases the lightness of the meat (Birth, 1978; Offer, 1991). In our results, the lower lightness of the pre-rigor SW treatment resulted from enhanced WHC, in which there was lower moisture on the meat surface, however, pre-rigor salting did not affect the changes in redness and yellowness compared to those in the post-rigor salted samples.

Salt soluble protein solubility and cooking loss

The effects of pre-rigor salting on salt-soluble protein solubility of duck breast muscle are shown in Fig. 1. No

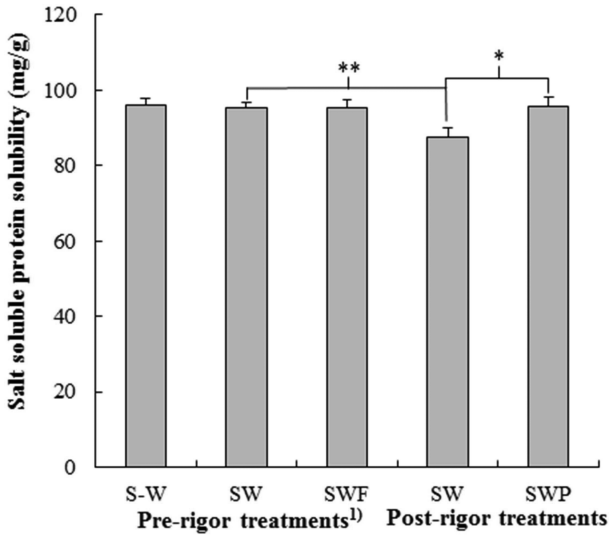

Fig. 1. The effect of pre-rigor salting on the salt soluble protein solubility of ground duck breast muscle. [1)]The ground pre-rigor treatments were salted within post-mortem 30 min, and the ground post-rigor treatments were salted at post-mortem 48 h. S-W, pre-rigor salting (2% sodium chloride) and the addition of 20% water after post-mortem 48 h; SW, 2% sodium chloride and 20% water based on muscle weight; F, freezing processing in a -25°C freezer; P, 0.3% sodium tri-polyphosphate. All values are mean and standard deviation of three replicates. Asterisk on post-rigor SW treatment refers to t-test result between pre-rigor SW and post-rigor SW treatments, and asterisk on post-rigor SWP treatment refers to t-test result between post-rigor treatments. *p<0.05; **p<0.01; ***p <0.001.

significant differences were observed among all pre-rigor treatments, however, the pre-rigor SW treatment showed the higher solubility of salt soluble proteins than post-rigor SW treatment ($p<0.01$). According to Farouk and Swan (1997), the increased protein extractability of pre-rigor muscle is associated with myofibrillar protein solubility, such as actin and myosin, which are soluble in salt. In our results, adding sodium chloride and water to pre-rigor muscle or freezing the samples after pre-rigor salting did not affect salt-soluble protein solubility. According to Reagan *et al*. (1981), the level of added salt into hot-boned beef stored at -10°C after salting did not significantly influence physicochemical properties of weiners. However, the increased storage period of hot-boned beef after pre-rigor salting led to increase cook out and to decrease sensory properties. Thus, further studies will be needed to evaluate effect of freezing period on processing quality on pre-rigor salted duck breast muscle.

The pre-rigor S-W treatment showed the lowest cooking loss among pre-rigor treatments ($p<0.05$). The post-rigor SWP treatment showed a similar cooking loss value compared to that of the pre-rigor SW and SWF treatments. The post-rigor SW treatment showed additional cooking loss of 4.85% in comparison with that of the pre-rigor SW ($p<0.05$). An improvement in cooking loss due to pre-rigor salting was reported due to increased WHC (Hamm, 1977), Offer and Trinick (1983) suggested that adding salt alters net myofibrillar protein charge, resulting in increased water binding capacity. Eventually, pre-rigor salting contributed to increase WHC, resulting in a reduction of released moisture during external impacts and showed that processing quality could be improving using pre-rigor muscle without adding phosphate.

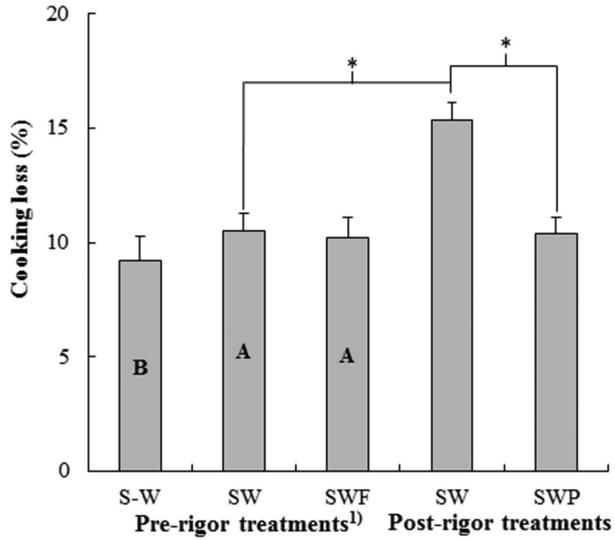

Fig. 2. The effect of pre-rigor salting on the cooking loss of ground duck breast muscle. [1)]The ground pre-rigor treatments were salted within post-mortem 30 min, and the ground post-rigor treatments were salted at post-mortem 48 h. S-W, pre-rigor salting (2% sodium chloride) and the addition of 20% water after post-mortem 48 h; SW, 2% sodium chloride and 20% water based on muscle weight; F, freezing processing in a -25°C freezer; P, 0.3% sodium tri-polyphosphate. All values are mean and standard deviation of three replicates. Asterisk on post-rigor SW treatment refers to t-test result between pre-rigor SW and post-rigor SW treatments, and asterisk on post-rigor SWP treatment refers to t-test result between post-rigor treatments. *$p<0.05$; **$p<0.01$; ***$p<0.001$.

2-Thiobarbituric acid (TBA) value

TBA value is a good indicator of the degree of lipid oxidation. We measured TBA values to evaluate the effect of pre-rigor salting on lipid oxidation of ground duck breast muscle (Table 3). The post-rigor SWP treatment had the lowest TBA value (0.121 mg/kg), whereas the TBA values of other treatments were 0.159-0.177 mg/kg. According to Tims and Watts, (1958), phosphate contributes to decrease lipid oxidation due to the chelating effect of heavy metal ions, which agreed with our results. Adding sodium chloride helps accelerate lipid oxidation due to the released iron ions from heme pigments (Benedict *et al*., 1975); thus, we predicted increased lipid oxidation with pre-rigor salting. However, pre-rigor salting did not influence lipid oxidation of ground duck breast muscle. According to Torres *et al*. (1988), the TBA value of raw pre and post-rigor stored slated muscle during 96 h after salting did not differ; however, significant differences in TBA values were observed between meat cooked pre and post-rigor, indicating that the increased oxidative stability of pre-rigor muscle is associated with the amount of met myoglobin formed and the higher pH value of pre-rigor muscle. Drerup *et al*. (1981) reported that pork sausage prepared with ground salted pre-rigor muscle has a decreased TBA value. Thus, our result suggests that lipid oxidation is not a problem if ground salted pre-rigor duck breast muscle is utilized within a short period; however, further studies are needed to evaluate the extend of lipid oxidation in ground salted pre-rigor duck breast muscle and cooked ground salted duck breast muscle during long-term storage.

Texture profile analysis (TPA)

The effect of pre-rigor salting on textural properties of ground duck breast muscle is shown in Table 4. As contrasted with the post-rigor SW treatment, pre-rigor salting

Table 3. The effect of pre-rigor salting on the 2-thiobarbituric acid (TBA) value of ground duck breast muscle after 7 days of manufacturing

Traits	Pre-rigor[1)]			Post-rigor	
	S-W	SW	SWF	SW	SWP
TBA[2)] value (mg/kg)	0.174±0.023[3)]	0.159±0.040	0.165±0.043	0.177±0.030	0.121±0.019***

[1)]The ground pre-rigor treatments were salted within post-mortem 30 min, and the ground post-rigor treatments were salted at post-mortem 48 h. S-W, pre-rigor salting (2% sodium chloride) and the addition of 20% water after post-mortem 48 h; SW, 2% sodium chloride and 20% water based on muscle weight; F, freezing processing in a -25°C freezer; P, 0.3% sodium tripolyphosphate.
[2)]TBA: 2-thiobarbituric acid.
[3)]All values are mean±SD of the three replicates.
[4)]Asterisk on post-rigor SW treatment refers to t-test result between pre-rigor SW and post-rigor SW treatments, and asterisk on post-rigor SWP treatment refers to t-test result between post-rigor treatments. *p<0.05; **p<0.01; ***p<0.001.

Table 4. The effect of pre-rigor salting on the textural properties of ground duck breast muscle

Traits	Pre-rigor[1)]			Post-rigor	
	S-W	SW	SWF	SW	SWP
Hardness (kg)	0.38±0.05[2)]	0.35±0.04	0.34±0.04	0.30±0.03*[3)]	0.37±0.04***
Springiness	0.92±0.03	0.93±0.03	0.91±0.04	0.91±0.05	0.91±0.02
Cohesiveness	0.60±0.05	0.61±0.04	0.59±0.03	0.59±0.05	0.61±0.03
Gumminess (kg)	0.23±0.04	0.21±0.03	0.20±0.03	0.18±0.03*	0.22±0.03***
Chewiness (kg)	0.21±0.04	0.20±0.03	0.18±0.03	0.16±0.02*	0.20±0.03***

[1)]The ground pre-rigor treatments were salted within post-mortem 30 min, and the ground post-rigor treatments were salted at post-mortem 48 h. S-W, pre-rigor salting (2% sodium chloride) and the addition of 20% water after post-mortem 48 h; SW, 2% sodium chloride and 20% water based on muscle weight; F, freezing processing in a -25°C freezer; P, 0.3% sodium tri-polyphosphate.
[2)]All values are mean±SD of the three replicates.
[3)]Asterisk on post-rigor SW treatment refers to t-test result between pre-rigor SW and post-rigor SW treatments, and asterisk on post-rigor SWP treatment refers to t-test result between post-rigor treatments. *p<0.05; **p<0.01; ***p<0.001.
[A,B]Means sharing different letters within pre-rigor treatments are significantly different (p<0.05).

(pre-rigor SW treatment) increased hardness (p<0.05), and the added time of water and freezing did not affect the hardness of cooked ground duck breast muscle. Additionally, no significant differences were observed among the pre-rigor salting treatments (p>0.05). However, none of the treatments showed differences in springiness and cohesiveness. The pre-rigor S-W treatment showed the highest gumminess and chewiness among all treatments, and the pre-rigor SW treatment showed a higher gumminess and chewiness compared to those of the post-rigor SW treatment (p<0.05). Mann *et al*. (1990) reported that recombined precooked beef chuck roasts made from hot boned muscle had high hardness and chewiness values compared to those made from cold boned muscle, and Jones *et al*. (1986) indicated that the increased peak force values of hot boning beef muscle result from improved binding ability, which agreed with our results. Additionally, the textural properties of meat are affected by the gelling ability and myofibrillar protein solubility (Foegeding, 1988). Our results indicated that pre-rigor salting contributed to increase hardness and a simultaneous increase in gumminess and chewiness. We found that the pre-rigor salted duck breast muscle had similar textural properties compared to those of post-rigor duck breast muscle containing phosphate.

In this study, pre-rigor salting of duck breast muscle affected the development of a high pH, resulting in improved WHC and cooking loss. The increase in salt-soluble protein solubility in pre-rigor salting treatments was associated with improved textural properties. In particular, a single addition of sodium chloride to pre-rigor muscle is more efficient method for improving cooking loss.

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