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Effects of Number of Washes and pH Adjustment on Characteristics of Surimi-like Materials from Pork Leg Muscle

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ABSTRACT : The effects of different washing time and pH adjustment of surimi-like materials from pork leg on quality characteristics were investigated. Surimi was made from pork leg by washing two or four times with water, as well as by pH adjustments of 3.0 or 11.0. The control surimi was made by two times washing from Alaska pollock. The content of crude protein was higher in the surimi manufactured from pork leg with pH adjustments. The highest gel strength was found in the control, and the control had greater lightness and whiteness value. The control had higher texture attributes than the other samples, whereas the surimi from pork leg made by a pH 11.0 adjustment had higher texture attributes than the pH 3.0 adjustment. The sensory color was higher in the control compared to other surimi samples, whereas aroma was lower in the control. However, there were no significant differences in overall acceptability among the surimi samples. (**Key Words :** Surimi-like Materials, Washing Time, pH Adjustment, Pork Leg, Alaska Pollock)

INTRODUCTION

Most Korean meat consumers prefer pork belly and boston butt, and as a consequence the Korean pork industry has suffered from a lack of consumption of low-preference pork leg by consumers, thus causing a large stock of pork leg. The aim of this work was to find a use for pork leg by developing an acceptable surimi-like material product made from the pork leg. Research on surimi-like materials from muscle of other species has been conducted (Kang et al., 2007) in an effort to provide healthier alternative meat products (Giese, 1996). Moreover, the consumer's interest in the development of meat using alternative protein sources has been gaining in popularity.

Surimi is a Japanese term that defines a concentrate of myofibrillar proteins obtained after the mincing and water washing of fish flesh (Hastings et al., 1990; Park and Morrissey, 2000). It is light in color, bland in odor, low in fat, high in myofibrillar protein, and extremely functional due to the unique gelling properties of the myofibrillar proteins. Their texture qualities make surimi an ideal functional ingredient for fabricating new meat products (Han-Ching and Leinot, 1993; Lanier, 2000) due to its gel forming capacity to assume almost any desired texture. The success of surimi-based products is mainly due to their low cost and good taste (Park, 1994).

Proteins recovered by the recently developed pH adjustment method (Choi and Park, 2000) are defined as "recovered proteins" to distinguish them from surimi. Compared with surimi produced by aqueous washing, recovering proteins by pH adjustment with acidic and alkaline methods reduces the water soluble protein loss that occurs during washing, resulting in higher yields (Lin and Park, 1996), and reduces the cost of waste treatment (Park et al., 2003). This material can then be used for processing, as it shows better results from the aspect of texture than washing methods (Kristinsson and Hultin, 2003). Studies to devise surimi from animal meats have used beef or pork (Park et al., 1996), chicken breast (Kristinsson and Hultin, 2003; Jin et al., 2008), animal heart (Srinivasan et al., 1996) and mechanically deboned meats (MDM) (Yang and Froning, 1992; Smyth and Óneill, 1997; Lee et al., 1999). Jin et al. (2007) also determined that surimi can be made from pork or chicken meat by washing, and pork hind leg has been reported to have high myofibrillar protein content and could therefore be used as a substitute for fish meat surimi. By appropriately adjusting the ratio of recovered proteins, a range of products have produced different

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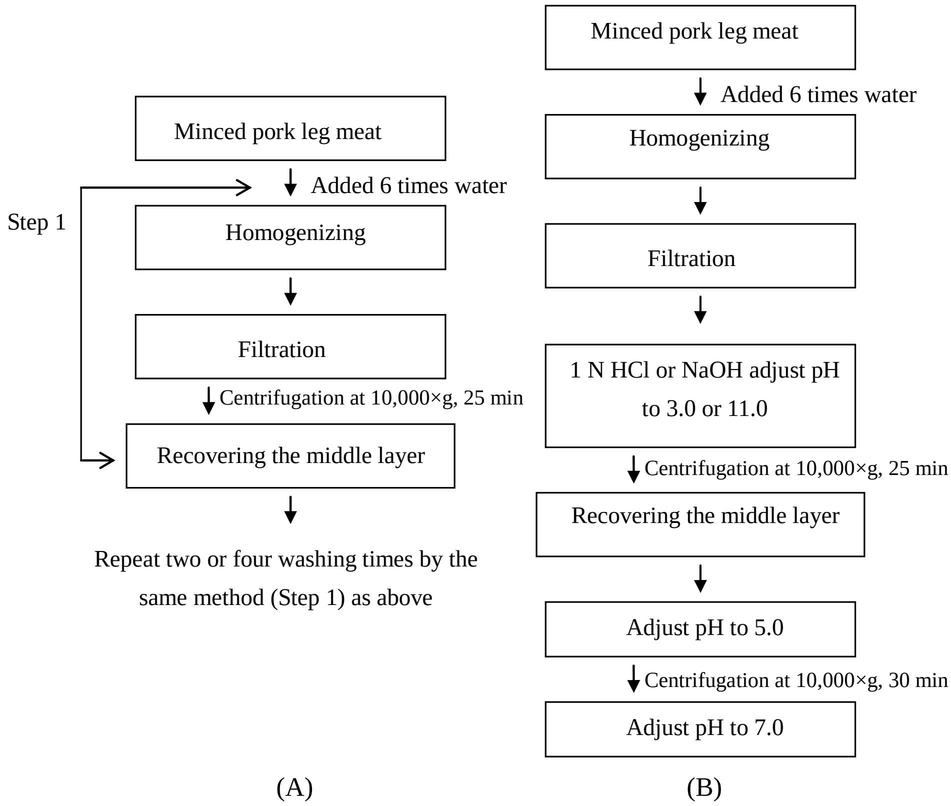

Figure 1. Flow diagram of surimi-like materials from pork leg manufactured by varying washing time (A) and pH adjustment (B).

textures using chicken breast and the hind leg of pork (Jung et al., 2004). However, there is little information on the effects of different washing times and pH adjustments on surimi characteristics.

Therefore, the objective of this study was to investigate the quality characteristics of surimi-like materials from pork leg muscle extracted by different washing times and pH adjustment.

MATERIALS AND METHODS

Processing into surimi

The Alaska pollock was purchased from Han-sung Co. (Seoul, Korea) and twelve left-side pork legs (ham) (pH 5.5-5.8, weight 10-12 kg) were randomly obtained at 48 h post-slaughter from a local pork plant and pork legs were allotted into four treatments. Three replications of four left-side pork legs per replicate were used for each treatment. So, surimi-like treatments were divided into five groups, C: surimi made from Alaska pollock by washing two times, T1: surimi made from pork leg by washing two times, T2: surimi made from pork leg by washing four times, T3: surimi made from pork leg by a pH adjustment of 3.0, and T4: surimi made from pork leg by a pH adjustment of 11.0 (Figure 1).

The external fat tissue, tendon, bone and skin were removed from the muscles, and the lean muscle was cut into approximately 3.0×3.0×2.0 cm^3 cubes and ground through a 3 mm diameter orifice using a mincer (AS-30, Ramon Co., Spain). Five kg mince samples per each treatment were combined with six times the volume of distilled water and homogenized with a maximum 40 liters volume in a Polytron homogenizer (T25-B, IKA Sdn. Bhd., Malaysia) at 8,000 rpm for 30 s. The slurry was filtered through a 1 mm-mesh metal screen to remove the connective tissue, the filtrate centrifuged at 10,000×g for 25 min, followed by discarding the top (the supernatant containing fat and water-soluble proteins) and bottom layers and recovering the middle layer. The process was repeated either two or four times to give the Alaska pollock and pork leg by washing treatments.

Similar to a previous study (Jung et al., 2004) of pH adjustment methods, the minced meat was filtered through a standard sieve (1 mm-mesh metal screen) using 1 N HCl or NaOH solutions. For the extraction of protein, the filtrates were adjusted to acidic or alkaline conditions of pH 3.0 or pH 11.0, and then centrifuged at 10,000×g for 25 min, discarding the top and bottom layers and recovering the middle layer. The recovered portion was adjusted to pH 5 using 1 N NaOH and HCl solutions, incubated for 30 min, and centrifuged at 10,000×g for 25 min to collect the bottom layer, which was then adjusted to pH 7 using 1 N

NaOH. The resulting sediments from both methods were stuffed into PVDC casings (18 mm diameter) and cooked in a chamber at 78°C for 40 min.

Proximate composition

Moisture (AOAC 950.46), crude protein (AOAC 992.15), and crude fat (AOAC 985.15) contents were determined according to AOAC methods (AOAC, 2002). The moisture, protein, and fat parameters of minced surimi samples were determined in triplicate.

Myofibrillar protein extraction

The procedure used to extract myofibrillar proteins was similar to that of Kuo and Chu (2003). The myofibrillar proteins were isolated from muscle tissue by homogenizing 4 g of minced sample in a Polytron homogenizer (T25-B, IKA Sdn. Bhd., Malaysia) for 10 s suspended in 10 volumes (v/w) of a 2°C isolating medium containing 100 mM KCl, 20 mM potassium phosphate (pH 7.0), 1 mM EDTA, and 1 mM sodium azide. The homogenate was centrifuged at 1,000×g for 15 min and the supernatant decanted. The sediment was re-suspended and centrifuged at 1,000×g for 15 min, and again the supernatant decanted. The sediment was then re-suspended in the isolating medium (5 volumes, v/w) and passed through a polyethylene sieve, rinsing with isolating medium (5 volumes, v/w) to remove connective tissue and debris. Five more volumes, resulting in 10 volumes (v/w) total of the isolating medium, were used to further facilitate passage of the myofibrillar protein through the sieve. The supernatant was centrifuged at 1,000×g for 15 min and decanted. The sediments were washed three more times by suspension in 5 volumes (v/w) of the isolating medium, and were centrifuged at 1,000×g for 15 min. Finally, the centrifuged myofibrillar proteins were re-suspended in 5 volumes (v/w) of the isolating medium.

Collagen content

Using a modified method cited by Palka (1999), the collagen content of 300 mg of sample was determined after 24 h hydrolysis with 25 ml of 6 M HCl at 100°C. The hydrolysates were clarified with active carbon, neutralized with 10 M and 1 M NaOH, and diluted with distilled water to 250 ml. Four ml of hydrolysate and 2 ml of chloramines T solution (1.41 g of chloramines T, 10 ml of distilled water, 10 ml of *n*-propanol, and 80 ml of citric buffer at pH 6.8) were mixed in a test tube and left for 20 min at room temperature. Next, 2 ml of 4-dimethyl-aminobenzaldehyde (*p*-DABA) solution (10 g of *p*-DABA, 35 ml of $HClO_4$-60%, and 65 ml of isopropanol) was added. The solution was shaken and heated at 60°C for 20 min. The samples were cooled for 5 min in tap water and the absorbance measured at 588 nm. The amount of hydroxyproline was determined from a standard curve. The collagen content was calculated from the hydroxyproline content using the coefficient 7.25.

Yield

The surimi yield was calculated from the difference between the whole muscle weight and the final mass of the surimi: Yield (%) = ((whole muscle weight-surimi weight)/(whole muscle weight))×100.

pH

The pH of surimi samples was measured using a digital pH meter (Model 420A, Orion, USA) that was calibrated daily with standard pH buffers of 4.0 and 7.0 at 25°C.

Water-holding capacity (WHC)

The WHC of surimi samples was determined as described by Hughes et al. (1996). Samples (10 g) were placed in 50 ml centrifuge plastic tubes and heated for 30 min in a water bath (70°C). After heating, the samples were removed, cooled to room temperature, wrapped in cotton cheesecloth, and centrifuged in 10 ml polycarbonate tubes (containing absorbent cotton) for 20 min at 3,000 rpm at 4°C (Union 5KR, Hanil, Korea). The cheesecloth was removed and the sample weights were recorded. WHC (%) = 1-total fluid loss during heating and centrifugation/total water content in the sample×100.

Gel characteristics (breaking force, deformation, and gel strength)

The gel characteristics were determined according to the method described by Phatcharat et al. (2006). Five cylindrical pieces 3.5 cm wide and 3 cm thick were tempered at 20°C prior to measuring. The breaking force, deformation, and gel strength were measured using a texture analyzer (EZ-test, Shimadzu, Tokyo, Japan) equipped with a cylindrical plunger (diameter 5 mm, depression speed 80 mm/min).

Color

Color (CIE L*, a*, b*) was measured using a Minolta colorimeter (CR-400, Tokyo, Japan), with measurements standardized with respect to the white calibration plate. Five readings were made from the surface of the samples. Whiteness was determined using the following formula: L*-3b* (Park et al., 1996).

Texture profile analysis (TPA)

Texture profile analysis was performed in an Instron Universal Testing Machine (Model 3343). Five surimi cores (diameter 2.0 cm; height 2.0 cm; 5 replicates per sample) per replication were axially compressed twice to 70% of their original height. Force versus time curves were

Table 1. Mean values for proximate composition, myofibrillar protein, collagen concentration and yield of surimi-like materials from pork leg manufactured by varying washing time and pH[1]

Treatments[1]	Moisture (%)	Crude protein (%)	Crude fat (%)	Myofibrillar protein (mg/g)	Collagen (mg/g)	Yield (%)
C	74.83±0.64[d]	17.33±0.60[c]	2.40±0.27[a]	5.00±0.03	1.32±0.13[b]	30.33±1.53[d]
T1	77.88±0.20[bc]	14.80±0.27[d]	1.15±0.02[b]	5.03±0.03	1.68±0.13[a]	54.05±2.83[a]
T2	77.01±0.40[c]	14.97±0.23[d]	1.13±0.01[b]	5.01±0.03	1.47±0.09[b]	45.06±4.26[bc]
T3	79.09±0.16[a]	19.42±0.11[a]	1.18±0.01[b]	5.02±0.02	1.27±0.12[b]	47.05±3.82[b]
T4	78.10±0.21[b]	18.26±0.32[b]	1.18±0.01[b]	5.01±0.01	1.31±0.10[b]	40.07±4.15[c]

[a-d] Means in the same column with different superscript letters are significantly different (p<0.05).

Variation of the mean represents standard error.

[1] Data are means of three replicates of four pork legs per replicate.

[2] C: surimi made from Alaska pollock by washing two times, T1: surimi made from pork leg by washing two times, T2: surimi made from pork leg by washing four times, T3: surimi made from pork leg by pH 3.0 adjustment and T4: surimi made from pork leg by pH 11.0 adjustment.

obtained with a 10 kg load cell applied at a crosshead speed of 100 mm/min. The textural attributes of hardness, cohesiveness, springiness, gumminess, and chewiness were then calculated from the curve (Bourne, 1978).

Sensory evaluation

A sensory panel consisting of students, faculty, and staff of the Jinju National University (in Korea) was used to evaluate sensory characteristics of the surimi. Panelists (at least 20 untrained, randomly chosen individuals) were selected based on their frequency of consumption of surimi-like products and their willingness to participate in the test. Cooked surimi samples (2.0×2.0×2.0 cm) from each treatment were placed in covered glass containers and served warm (35°C) to each panelist one at time. Panelists evaluated a total of 5 samples (1 control; surimi made from Alaska pollock by washing two times, and 4 treatments of surimi made from pork leg by different washing time and pH adjustment) every week. The samples were transferred into glass containers (Pyrex with plastic cover) about 30 min before the sensory test started. The panelists evaluated the samples for appearance, color, aroma, juiciness, tenderness and overall acceptability using a 9-point hedonic scale as described by Carr et al. (1999). A score of 1 represented attributes most disliked and a score of 9 represented attributes most liked.

Statistical analysis

Data from three replications were analyzed by one-way analysis of variance (ANOVA) using the Statistical Analysis System (SAS). ANOVA was adapted to a designated mathematical model using SAS 9.1 (SAS Institute, Inc., Cary, NC). A completely randomized design with five treatments was used. If a significant difference was detected, Duncan's multiple range test was employed to determine significance between treatments. Significance level was established at $p<0.05$.

RESULTS AND DISCUSSION

Chemical composition, myofibrillar protein concentration, collagen content, and yield

The chemical composition, myofibrillar protein content, and surimi yield are shown in Table 1. The moisture and protein content varied from 79.09 to 74.83% and 19.42 to 14.80% respectively. The moisture and crude protein content were significantly higher in the pH-adjusted surimi than in the other surimi samples. T3 showed highest moisture and protein content rating among the surimi samples. Higher protein contents were noted from the sodium phosphate and sodium hydroxide adjusted pork leg, which indicated small losses of muscle proteins due to acidic or alkaline conditions (Yang and Froning, 1990). The content of crude fat was significantly higher in the control than the other surimi samples. There was no significant difference in fat content among the pork leg surimi manufactured by different washing times and different pH adjustments. The myofibrillar protein content for all surimi samples was approximately 5.00 mg/g, with no significant differences among them. Collagen content and yield were significantly higher in the pork leg surimi made by two separate washing times (T1) than in the other surimi samples; in particular, the control was significantly lower in yield. Moisture content is a critical factor in surimi products (Uddin et al., 2006). Luo et al. (2004) reported that protein concentration greatly affected the gel properties of Alaska pollack and common crab surimies. The lipids in surimi products may cause an adverse effect on quality, because oxidized lipids interact with proteins causing denaturation, polymerization, and changes in their functional properties (Smith, 1987). Collagen may also play important roles in the textural development of processed foods such as surimi-based products (Mizuta et al., 2007). In general, high myofibrillar protein content, high collagen, low fat, and adequate water are required to make a high quality product (Jin et al., 2007). In this study, the control had a higher lipid

Table 2. Mean values for physical characteristics of surimi-like materials from pork leg manufactured by varying washing time and pH[1]

Treatments[2]	pH	WHC (%)	Breaking force (g)	Deformation (mm)	Gel strength (g/cm^2)
C	7.54±0.07[a]	83.77±0.38[b]	289.00±1.00[a]	7.96±0.02[a]	2,300.74±14.73[a]
T1	7.35±0.04[bc]	75.49±0.70[e]	213.00±3.61[c]	5.52±0.11[e]	1,175.00±7.08[d]
T2	7.30±0.02[c]	76.69±0.31[d]	212.33±1.53[c]	5.78±0.17[d]	1,227.61±36.08[d]
T3	7.27±0.04[c]	86.73±0.62[a]	259.33±1.53[b]	6.28±0.23[c]	1,628.31±58.10[c]
T4	7.49±0.21[ab]	89.17±0.34[c]	262.67±2.08[b]	6.53±0.02[b]	1,715.49±16.19[b]

[a-e] Means in the same column with different superscript letters are significantly different (p<0.05).
Variation of the mean represents standard error.
[1] Data are means of three replicates of four pork legs per replicate. [2] The same as Table 1.

content compared to the pork leg surimi, but was lower in collagen content and yield. Yield and collagen content were higher in the pork leg surimi made by washing two times (T1), while the protein content was higher in the pork leg surimi made by pH adjustments.

Physical characteristics

The physical characteristics of the different surimies are shown in Table 2. pH and gel characteristics were significantly higher in the control than in the other surimi samples. Comparing pork leg surimi made by different washing times, no significant differences in pH, breaking force and gel strength were observed. The pork leg surimi made by a pH adjustment of 11.0 had significantly higher pH, water holding capacity, deformation and gel strength than the pH 3.0 adjusted surimi samples. The control and T4 had similar pH results, with significantly higher values than the other surimi samples. T3 showed the highest water holding capacity rating among the surimi samples. Kristinsson and Hultin (2003) reported that an increase in gel pH led to dramatic increases in water-holding capacity and water uptake of manufactured washed-chicken breast muscle. Lan et al. (1995) reported that ultimate pH differences in fish and pork muscles have effects on protein extractability, and thus gelation properties might differ among species.

Color

The results for surimi color are shown in Table 3. The control had higher lightness (L*) than the other surimi samples, whereas the pork leg surimi made by pH adjustments had significantly lower lightness. Redness (a*) and yellowness (b*) were significantly higher in the adjusted pH pork leg surimi than other surimi and values of T3 were significantly higher than T4. In relation to the increased lightness, washing decreased redness of mechanically deboned chicken meat (Yang and Froning, 1992). Decreasing redness varied when comparing individual washing solutions and times. Whiteness was higher in the control, whereas the pork leg surimi made by pH adjustments had significantly higher whiteness than the washed pork leg surimi. Whiteness is one of most important factors in surimi quality. The surimi industry has used different whiteness indices to determine functionality of color (Park, 1994). High quality surimi can be obtained with higher whiteness when as much dark muscle as possible is removed (Ochiai et al., 2001). In this study, the control showed highest whiteness and lightness values. On the other hand, when comparisons were made between washing times and pH adjustments, sample color of the pork leg surimi was better in the two- and four-time washed samples. Therefore, color was superior in surimi made by the washing process than the pH processes.

Texture profile analysis

The surimi hardness, cohesiveness, springiness, gumminess and chewiness attributes are shown in Table 4. The control had higher texture attributes than the other surimi samples. The pork leg surimi made by different washing times were not different, whereas T4 had significantly higher texture attributes than T3. Hamann (1988) reported that strain, as an indicator of protein interactions, was strongly affected by protein functionality. Frankfurters manufactured with washed and mechanically separated pork showed little improvement in texture over those made from unwashed, mechanically separated pork

Table 3. Mean values for color of surimi-like materials from pork leg manufactured by varying washing time and pH[1]

Treatments[2]	Lightness (L*)	Redness (a*)	Yellowness (b*)	Whiteness (W)
C	84.22±0.61[a]	2.16±0.13[c]	8.92±0.15[c]	57.46±0.85[a]
T1	81.68±0.60[b]	2.02±0.15[c]	9.20±0.13[c]	54.08±0.94[b]
T2	80.55±1.06[b]	1.96±0.08[c]	8.99±0.05[c]	53.57±0.92[b]
T3	71.95±0.46[c]	6.50±0.43[a]	12.31±0.40[a]	35.02±1.07[d]
T4	72.63±0.45[c]	4.13±1.51[b]	10.16±0.21[b]	42.16±0.39[c]

[a-d] Means in the same column with different superscript letters are significantly different (p<0.05).
Variation of the mean represents standard error.
[1] Data are means of three replicates of four pork legs per replicate. [2] The same as Table 1.

Table 4. Mean values for textural attributes of surimi-like materials from pork leg manufactured by varying washing time and pH[1]

Treatments[2]	Hardness (kg)	Cohesiveness	Springiness (mm)	Gumminess (kg)	Chewiness (kg×mm)
C	0.75±0.09[a]	78.79±0.80[a]	26.42±1.10[a]	38.00±1.97[a]	332.68±6.11[a]
T1	0.18±0.01[d]	49.13±0.91[b]	13.07±0.50[b]	8.81±0.52[d]	114.96±4.44[c]
T2	0.19±0.01[d]	48.87±0.50[b]	13.05±0.43[b]	9.76±0.48[d]	116.79±0.98[c]
T3	0.39±0.01[c]	45.93±2.20[c]	12.05±0.19[b]	18.94±1.03[c]	228.03±9.93[b]
T4	0.49±0.04[b]	48.35±1.30[b]	11.78±1.13[b]	22.60±3.12[b]	243.38±38.37[b]

[a-d] Means in the same column with different superscript letters are significantly different ($p<0.05$).
Variation of the mean represents standard error.
[1] Data are means of three replicates of four pork legs per replicate. [2] The same as Table 1.

Table 5. Mean values for sensory evaluation of surimi-like materials from pork leg manufactured by varying washing time and pH[1]

Treatments[2]	Color	Aroma	Juiciness	Tenderness	Overall acceptability
C	6.98±0.49[a]	4.89±0.33[b]	5.56±0.88	6.11±0.60	6.32±0.44
T1	5.56±0.43[b]	5.82±0.57[ab]	5.10±0.50	5.33±0.87	5.79±0.33
T2	5.88±0.57[b]	4.49±0.50[b]	5.33±0.71	5.78±0.67	6.00±0.50
T3	5.77±0.67[b]	5.52±0.57[ab]	5.56±0.97	5.44±1.13	5.85±0.78
T4	5.89±0.58[b]	6.25±0.41[a]	6.11±0.60	5.67±1.12	6.08±0.78

[a, b] Means in the same column with different superscript letters are significantly different ($p<0.05$).
Variation of the mean represents standard error.
[1] Data are means of three replicates of four pork legs per replicate. [2] The same as Table 1.

(Wimmer et al., 1993). Jin et al. (2007) reported that the texture attributes of surimi can be improved by increasing the pH adjustment. The pork leg surimi made by an adjusted pH of 11.0 had significantly higher hardness, gumminess, and chewiness than the two- and four-time washed pork leg surimi samples.

Sensory evaluation

The surimi sensory evaluation results are shown in Table 5. Sensory evaluations were performed to assess the effects of the washing time and pH adjustment on pork leg surimi quality characteristics of color, aroma, juiciness, tenderness and overall acceptability. The control had a higher color score than the other surimi samples, whereas aroma score was lower in the control and the four-washing time surimi sample, although the control had a good color attribute from sensory evaluation. However, there were no differences in juiciness, tenderness and overall acceptability among the surimi samples. In particular, all surimi samples achieved the same score for overall acceptability. This suggests that there are minimal taste differences between washed or pH-adjusted pork leg surimies compared to original surimi such as Alaska pollock.

CONCLUSION

This study was carried out to compare the physicochemical and sensory characteristics of pork leg surimi manufactured by different washing times and pH adjustments. We found that the control, Alaska pollock surimi, was higher in fat content, pH, lightness, and whiteness compared to the pork leg surimi, and also had greater breaking force, deformation, gel strength, and texture attributes. On the other hand, the pork leg surimi made by pH adjustments showed higher protein content, pH, WHC, breaking force, deformation, gel strength, and texture attributes than the pork leg surimi samples made by different washing times. The control had a higher sensory color score than the other surimi samples, whereas the aroma score was lower in the control and the four-washing time surimi sample. However, there was no difference in overall acceptability among the surimi samples. Therefore, we suggest that surimi can be made from pork leg with pH adjustments, despite slightly reduced qualities compared to surimi made from Alaska pollock.

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