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ARTICLE

Effect of Substitution of Chicken Breast for Alaska Pollack on Physico-chemical Characteristics and Quality in Surimi-like Materials Contained Different Cryoprotectants

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Abstract

Surimi-like samples were divided into four groups (C, surimi-like material made from Alaska Pollack with all cryoprotectant ingredients; T1, surimi-like material made from chicken breast with sugar and a sorbitol-free cryoprotectant; T2, surimi-like material made from chicken breast with a sugar-free cryoprotectant; T3, surimi-like material made from chicken breast with all cryoprotectant ingredients). Water and protein content were lower in Alaska Pollack surimi-like material (C) than those in chicken breast surimi-like material. Centrifuge loss and cooking loss were higher in C than those in chicken breast surimi-like material. Lipid oxidation (thiobarbituric acid reactive substances) was lower in T3 than others during storage. In a sensory evaluation, overall acceptability was significantly higher in C than those in other samples during storage. As a result, we found that the raw material composition (Alaska Pollack or chicken breast) had a large influence on the physico-chemical characteristics and quality of surimi-like materials, whereas cryoprotectant composition may have less influence on the physico-chemical characteristics and quality of surimi-like materials.

Key words: surimi-like material, physico-chemical characteristics, chicken breast, alaska pollack, cryoprotectant

Introduction

Application of the surimi-like material technology in the production of a surimi-like products from meats such as chicken, pork and beef could provide a new approach towards increasing its value and utilization. Thus, various studies conducted to develop a surimi-like product from chicken (Lesiów and Xiong, 2003; Nowsad *et al*., 2000) sheep (Antonomanolaki *et al*., 1999), beef and pork (Park *et al*. 1996), and beef heart (Wang and Xiong 1999). The application of the surimi technology in the production of a surimi base product from other meat such as chicken, pork and beef could provide a new approach towards increasing its value and utilization (Jin *et al*., 2009). In the mean time, during frozen storage of fish muscle, denaturation and/or aggregation of myofibrillar proteins cause a loss of functional properties (Shenouda, 1980). Niwa (1992) also reported that this process lead to protein aggregation, textual changes, and loss of gelling and water holding functionality in fish. Thus, the addition of cryoprotectants is required in order to retain its functional properties (MacDonald and Lanier, 1994) and to protect the functionality of fish surimi-like material protein during frozen storage. Various cryoprotectants, such as sucrose, sorbitol, and polyphosphates, have been blended with surimi (Okada, 1985). Usually, surimi-like material from muscles other than fish is expected to have similar properties to surimi from fish, however the properties of surimi-like material from other muscles with cryoprotectant are still not always similar as a surimi-like material made from fish. Therefore, the objective of this study was to investigate the effect of substitution of chicken breast for Alaska Pollack on physic-chemical characteristics of surimi-like materials contained different cryoprotectants during freezing storage.

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Materials and Methods

Sample preparation

The surimi-like material samples were divided into 4 groups (C, surimi-like material made from Alaska Pollack with whole ingredient cryoprotectant; T1, made from chicken breast with sugar and sorbitol free cryoprotectant; T2, made from chicken breast with sugar free cryoprotectant; T3, made from chicken breast with whole ingredient cryoprotectant), and specific ingredient composition of the surimi-like material is presented in Table 1. Fresh chicken breast was purchased from a commercial meat market and Alaska Pollack was purchased from Hansung Co (Korea). The external fat tissue and skin was removed from the muscles and the lean muscle was diced into approximately 2 cm cubes, and ground through a 3 mm diameter orifice using a mincer. Minced samples were homogenized by Polytron homogenizer (T25-B, IKA Sdn. Bhd., Malaysia) with distilled water at 15,000 rpm for 30 sec. The slurry was filtered through a 1 mm-mesh metal screen to remove connective tissues. The filtrate was centrifuged (two times) at 10,000 g for 25 min and the supernatant containing fat and water-soluble proteins was discarded. The resulting sediment was mixed with other ingredients and then stuffed into PVDC casings (Ø3 × 15 cm) and cooked in a cooking chamber at 90°C for 40 min. After cooking, the surimi-like material samples were stored at -20°C for experiments.

Chemical composition

Moisture, crude protein, crude fat contents and ash were determined according to the method described by AOAC (1990). Moisture was determined by the oven drying method at 110°C for 24 h; for cooked samples total water content was calculated as (100-(total protein + total lipid + total ash)). Total protein content was determined by the Kjeldhal method. Total lipids were evaluated by the Soxhlet method. Ash was determined as the remnant weight after calcination of a 2 g sample at 550°C for 4 h.

Collagen

The collagen content was determined after 24 h hydrolysis of 300 mg of samples with 25 mL 6 M HCl at 110°C using the modified method cited by Palka (1999). Hydrolysates were clarified with active carbon, neutralized with 10 M and 1 M NaOH, and diluted with distilled water to 250 mL. Hydrolysate (4 mL) and 2 mL of chloramine T solution (1.41 g chloramine T, 10 mL distilled water, 10 mL *n*-propanol and 80 mL citric buffer at pH 6) 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 *p*-DABA, 35 mL $HClO_4$-60% and 65 mL isopropanol) was added. The solutions were shaken and heated at 60°C for 20 min. The samples were cooled for 5 min in tap water and the absorbance was measured at 558 nm. The amount of hydroxyproline was determined from a standard curve. The collagen content was calculated from hydroxyproline content using the coefficient 7.25.

pH

pH was measured using a digital pH meter (Model 420A, Orion, USA). Five grams of sample were cut into small pieces to which 45 mL of distilled water was added and slurry was made using a blender and the pH was recorded.

Centrifuge loss

Five grams of samples were weighed into centrifugation tubes and centrifuged at 5°C at low speed (1,000 g for 15 min). The WHC was determined as liquid loss and expressed as percentage of weight of liquid release. WHC % = (weight before centrifuge – weight after centrifuge)/(weight before centrifuge) × 100.

Cooking loss

The samples were placed in polyethylene bags and cooked in a 100°C water bath until an internal temperature of 75°C was achieved. Cooking loss was calculated from differences in the weight of uncooked and cooked samples, expressed as percentage of initial weight. Cook-

Table 1. Experimental design and composition (%) of cryoprotectants and raw materials

Treatments	Sugar	Sorbitol	Polyphosphate	Raw material	Total
C	4	5	0.3	Alaska Pollack surimi 90.7	100
T1	0	0	0.3	Chicken breast surimi 99.7	100
T2	0	5	0.3	Chickent breast surimi 94.7	100
T3	4	5	0.3	Chicken breast surimi 90.7	100

ing loss % = (weight before cooking – weight after cooking)/(weight before cooking) × 100.

Shear force

Five cylindrical pieces 3.5 cm wide and 3 cm thick were tempered at 20°C prior to measuring. The samples were sheared once through the center using an Instron 3343 (US/MX50, A&D Co., USA) equipped with a Warner Bratzler shearing device (100 mm/min crosshead speed).

Gel strength

The gel strength was determined according to the method described by Phatcharat *et al*. (2006). Gels were equilibrated and evaluated at room temperature. Five cylindrical pieces 3.5 cm wide and 3 cm thick were tempered at 20°C prior to measuring. Breaking force and deformation were measured using a texture analyzer (EZ-test, Shimadzu, Japan) equipped with a cylindrical plunger (diameter 5 mm, depression speed 66 mm min).

Color

Color (CIE L*(lightness), a* (redness), b* (yellowness)) was measured by using a Minolta colorimeter (CR-400, Japan), with measurements standardized with respect to the white calibration plate. Five readings were made from the surface of samples. Whiteness was determined using the following formula: $100 - ((100\text{-}L^*)^2 + a^{*2}b^{*2})^{1/2}$ (Park, 1994).

Myoglobin

The myoglobin content was determined by direct spectrophotometric measurement as described by Chaijan *et al.* (2004). Two grams of chopped sample were weighed into a 50 mL polypropylene centrifuge tube and 20 mL of 40 mM phosphate buffer, pH 6.8 were added. The mixture was homogenized at 13,500 rpm for 10 s, followed by centrifuging at 3000 g for 30 min at 4°C. The supernatant was filtered with Whatman No 1filter paper. The supernatant was added with 0.2 mL of 1% (w/v) sodium dithionite to reduce the myoglobin. The myoglobin content was determined by direct spectrophotometric measurement at 555 nm. Myoglobin content was calculated from the millimolar extinction coefficient of 7.6 and a molecular weight of 16,111 (Gomez-Basauri and Regenstein, 1992). The myoglobin content was expressed as mg/g sample.

TBARS (thiobarbituric acid reactive substances)

Five grams of samples were weighed into a 50-mL test tube and homogenized with 15 mL of deionized distilled water using the polytron homogenizer for 10 s at the highest speed. One mL of sample homogenate was transferred to a disposable test tube (13 × 100 mm), and butylated hydroxyanisole (50 μL, 10%) and thiobarbituric acid/trichloroacetic acid (TBA/TCA) (2 mL) were added. The mixture was vortexed and then incubated in a boiling water bath for 15 min to develop color. The sample was cooled in a cold water for 10 min, vortexed again, and centrifuged for 15 min at 2,000 g. The absorbance of the resulting supernatant solution was determined at 531nm against a blank containing 1 mL of deionized distilled water and 2 mL of TBA/TCA solution. The amounts of TBARS were expressed as milligrams of malondialdehyde per kilogram of sample.

Sensory evaluation

Sensory evaluation was performed by a panel of 15 semi-trained tasters. Semi-trained taster is a potential consumer, and in the final analysis, the judgement of quality depends on the individual purchaser (Ruiz-Capillas *et al.*, 2003). The panel evaluated each treatment within each replication in triplicate, and the evaluation was performed with the samples at room temperature. Triplicate responses were taken to monitor the inherent texture variability associated with this sample. One slice, 1 cm thick and 1.8 cm in diameter, was cut into six pie-shaped wedges and presented to each panelist. The panelists chose 3 of the most characteristic wedges in order to avoid a sample containing large pieces of connective tissue. The appearance, color, aroma, flavor, juiciness, tenderness and overall acceptability were evaluated using 9-point scale.

Statistical analysis

The data was analyzed using SAS software (SAS Inst. Inc., Cary, NC) by the Duncan's multiple range test to compare the differences among means. Significance was defined at $p<0.05$.

Results and Discussion

Chemical composition

Chemical composition is presented in Table 2. Water and ash content were higher in Alaska Pollack surimi-like material (C) than chicken breast surimi-like material samples. No significant difference in collagen contents were found among the surimi-like material samples. The chemical compositions play an important role in surimi-like material quality. Luo *et al*. (2004) reported that the protein concentration greatly affected the gel properties of

Table 2. Effect of substitution of chicken breast for Alaska Pollack on proximate composition in surimi contained different cryoprotectants

Items	Treatments*			
	C	T1	T2	T3
Water (%)	78.73±0.27^{A†}	76.85±1.57^{B}	76.93±0.51^{B}	77.58±0.13^{AB}
Protein (%)	17.99±0.37^{B}	19.77±0.32^{A}	18.94±0.37^{AB}	18.51±0.25^{B}
Fat (%)	2.63±0.33^{B}	3.20±1.32^{B}	4.00±0.24^{A}	3.71±0.21^{AB}
Ash (%)	0.66±0.01^{A}	0.17±0.06^{B}	0.12±0.04^{B}	0.20±0.04^{B}
Collagen (mg/g)	1.82±0.24$^{1)}$	2.28±0.79	1.49±0.35	1.70±0.03

*Treatments are the same as in Table 1.
† A-C Means±SD with different superscripts in the same row significantly differ at $p<0.05$.
1) Control of collagen (C) data was obtained from Jin *et al*. (2007).

Alaska Pollack and common carp surimi. The lipids in surimi-like material products may bring about an adverse effect on the surimi-like material quality, because the oxidized lipids interact with proteins, causing denaturation, polymerization and changes in functional properties (Smith, 1987). The water content is also a critical factor in surimi products (Uddin *et al*. 2006). In general, high protein, high myofibrillar, low crude fat and adequate water are required to make a high quality surimi-like material. In the present study, protein contents were significantly higher in chicken breast surimi-like material samples (T1 and T2) than Alaska Pollack surimi-like material (C). These differences may be due to raw material contents being higher in T1 and T2. These differences of water and protein contents may influence by the raw material contents, whereas cryoprotectant composition may have less influence on the chemical composition.

Physico-chemical characteristics

The physico-chemical characteristics results are presented in Table 3. pH was higher in C sample than chicken breast surimi-like material samples during all storage periods, whereas T3 was lower in pH during all storage periods compared with other surimi-like material samples. Centrifuge loss was higher in C sample compared with chicken breast surimi-like material samples, however, cooking loss was also higher in C sample than chicken breast surimi-like material samples during all storage periods. TBARS was higher in C, whereas T3 had a lower TBARS value than other surimi-like material samples during all storage periods. Honikel (1987) reported that pH has a profound effect on the physical properties such as water holding capacity (WHC), tenderness and color in meat. Usually, high pH, high protein content and low water content are closely related to the high WHC and shear force in meats. In the present study, an increase of pH may cause an increase of centrifuge loss in C samples. pH and centrifuge loss were significantly decreased with storage periods in all surimi-like material sample, whereas centrifuge loss of T2 (made from chicken breast with sugar free cryoprotectant) was not significantly different during storage period. These results indicate the composition of cryoprotectant may influence pH and centrifuge loss in chicken breast surimi-like material samples only. However, cooking loss was increased with storage periods in Alaska Pollack surimi-like material sample (C). As a result of this study, we assumed that many factors may influence the physico-chemical properties in surimi-like material samples. Thus, further studies are needed to confirm these results. On the other hand, TBARS was significantly higher in C sample than chicken breast surimi-like material samples. This may be due to C sample containing more polyunsaturated fatty acid than other samples, because polyunsaturated fatty acids are more susceptible to oxidation than monounsaturated and saturated fatty acids. Ahn *et al*.(1993) reported that the differences in fat content, fatty acid composition and the classes of lipids have significant effects on lipid oxidation only when oxygen has free access to the stored meat products. However, fat content was not significantly higher in C sample, thus, TBARS value may be less influenced by fat content, and more influenced by fatty acids. When comparing TBARS values among the chicken surimi-like material samples, lower TBARS value was found in T3. This may be due to T3 sample contained whole ingredient of cryoprotectant. Sugar, sorbitol and polyphosphate might be prevented lipid oxidation during storage periods.

Shear force and gel strength

The shear force and gel strength results are present in

Table 3. Effect of substitution of chicken breast for Alaska Pollack on physico-chemical characteristics and TBARS in surimi contained different cryoprotectants

Items	Treatments*	Storage periods (months)		
		0	1.5	3
pH[1)]	C[1)]	7.20±0.03^{Aa†}	6.30±0.10^{Ab}	6.21±0.05^{Ab}
	T1	6.47±0.02^{Ba}	5.89±0.22^{Bb}	5.88±0.37^{ABb}
	T2	6.40±0.01^{Ca}	5.85±0.22^{Bab}	5.70±0.52^{ABb}
	T3	6.31±0.02^{Da}	5.37±0.12^{Cb}	5.26±0.10^{Bb}
Centrifuge loss (%)	C[1)]	87.42±0.79^{Aa}	82.56±0.03^{Ab}	81.01±0.98^{Ac}
	T1	74.51±0.82^{Ca}	59.61±2.38^{Cb}	58.86±2.59^{Cb}
	T2	73.21±0.32^{C}	71.14±2.59^{B}	70.07±2.44^{B}
	T3	78.64±0.81^{Ba}	60.32±0.85^{Cb}	59.09±0.55^{Cb}
Cooking loss (%)	C[1)]	12.40±2.04^{Ab}	14.40±2.57^{Ab}	23.33±0.69^{Aa}
	T1	9.64±1.53^{A}	10.68±1.54^{AB}	9.77±0.70^{B}
	T2	6.49±1.27^{B}	6.92±0.69^{B}	5.41±1.97^{C}
	T3	11.26±1.47^{A}	12.16±2.94^{A}	9.16±1.13^{B}
TBARS (mgMA‡/kg)	C	1.54±0.44^{A}	1.67±0.10^{A}	1.77±0.04^{A}
	T1	0.96±0.12^{B}	0.90±0.17^{C}	0.95±0.66^{AB}
	T2	0.64±0.09^{BCb}	1.35±0.06^{Ba}	1.44±0.07^{Aa}
	T3	0.44±0.02^{Cb}	0.49±0.08^{Dab}	0.65±0.12^{Ba}

*Treatments are the same as in Table 1.
† A-D Means±SD with different superscripts in the same column significantly differ at $p<0.05$.
a-c Means±SD with different superscripts in the same row significantly differ at $p<0.05$.
‡Malondealdehyde. 1) Control (C) at 0 d data was obtained from Jin *et al*. (2007).

Table 4. Effect of substitution of chicken breast for Alaska Pollack on gel strength in surimi contained different cryoprotectants

Items	Treatments*	Storage periods (mon)		
		0	1.5	3
Shear force (kg/cm^2)	C	3.11±0.02^{C†}	3.07±0.10^{C}	3.06±0.17^{C}
	T1	6.81±0.07^{Ab}	7.03±0.09^{Aa}	6.88±0.03^{Ab}
	T2	6.94±0.09^{A}	7.04±0.09^{A}	6.87±0.17^{A}
	T3	4.34±0.17^{Bb}	4.92±0.22^{Ba}	4.88±0.21^{Ba}
Breaking force (g)	C	234.00±1.00^{A}	234.00±3.61^{A}	241.00±5.00^{A}
	T1	210.00±1.00^{B}	217.33±7.51^{B}	219.67±10.97^{B}
	T2	204.67±1.15^{Cb}	219.67±4.51^{Ba}	227.00±5.29^{ABa}
	T3	206.33±1.15^{Cb}	221.67±4.93^{Ba}	228.33±7.23^{ABa}
Deformation (mm)	C	5.76±0.11^{Aa}	4.94±0.05^{b}	4.85±0.06^{b}
	T1	4.63±0.02^{Ba}	5.17±0.34^{a}	4.99±0.38^{a}
	T2	4.37±0.37^{Bb}	4.95±0.06^{a}	4.74±0.11^{ab}
	T3	4.60±0.02^{Bc}	4.97±0.01^{a}	4.72±0.09^{b}

*Treatments are the same as in Table 1.
† A-C Means±SD with different superscripts in the same column significantly differ at $p<0.05$.
a-b Means±SD with different superscripts in the same row significantly differ at $p<0.05$.

Table 4. Shear force value was significantly lower in C sample compared with chicken breast surimi-like material samples, whereas breaking force was higher in C sample than chicken breast surimi-like material samples during all storage periods. Deformation was higher in C sample than chicken breast surimi-like material samples at 0 d of

storage. Thereafter, no significant difference was found in all samples. In the present study, shear force values were lower in C and T3 samples than other surimi-like material samples. This may be due to raw material (surimi) contents, because raw material contents were lower in C and T3 samples. However, cryoprotectant composition may be less influenced the shear force value.

Color

The color results are presented in Table 5. Lightness (L*) and yellowness (b*) were lower in C sample compared with chicken breast surimi-like material samples. Yellowness (b*) of C sample was not significantly different during all storage periods, however, yellowness (b*) decreased after 15 d of storage in chicken breast surimi-like material samples. Whiteness (W) was significantly higher in T3 sample than those of other samples at 0 day of storage and myoglobin content was not significantly different among the samples during all storage periods. For surimi processing, myoglobin played an essential role in the whiteness (Chen, 2002), whiteness is one of the most important factors in quality of surimi. Ochiai *et al*. (2001) suggested that high-quality surimi with higher whiteness can be obtained when dark muscle is removed as much as possible. Thus, low myoglobin content is better than high myoglobin content for surimi-like material quality. In the present study, lightness (L*) was higher in chicken breast surimi-like material samples but yellowness (b*) also higher in chicken breast samples, moreover no difference was found in myoglobin amount among the surimi-like material samples during all storage periods. Thus, myoglobin content may not influence the color of surimi-like material samples in the present study. As a result of this study, we found that the composition of cryoprotectant also does not have much influence on meat color because mechanical color was not significantly different (yellow-

Table 5. Effect of substitution of chicken breast for Alaska Pollack on color and myoglobin content in surimi contained different cryoprotectants

Items	Treatments*	Storage periods (mon)		
		0	1.5	3
L*	C[1)]	$55.93\pm1.28^{B\dagger}$	56.09 ± 0.62^{B}	55.60 ± 0.93^{B}
	T1	48.50 ± 2.14^{Cb}	64.50 ± 3.22^{Aa}	63.46 ± 2.72^{Aa}
	T2	52.05 ± 3.39^{BCb}	66.41 ± 1.32^{Aa}	65.24 ± 1.56^{Aa}
	T3	80.91 ± 1.09^{Aa}	64.76 ± 1.58^{Ab}	63.93 ± 1.60^{Ab}
a*	C[1)]	2.29 ± 0.03^{Ca}	2.17 ± 0.04^{Bb}	2.13 ± 0.05^{Cb}
	T1	5.05 ± 0.32^{B}	8.05 ± 4.21^{AB}	4.71 ± 0.34^{B}
	T2	4.97 ± 0.20^{Bb}	10.40 ± 4.48^{Aa}	11.76 ± 0.44^{Aa}
	T3	7.00 ± 0.23^{Aa}	5.21 ± 0.41^{ABb}	5.10 ± 0.55^{Bb}
b*	C[1)]	1.09 ± 0.15^{B}	1.15 ± 0.06^{B}	1.15 ± 0.04^{B}
	T1	6.37 ± 0.95^{Aa}	4.41 ± 0.70^{Ab}	4.31 ± 0.61^{Ab}
	T2	6.74 ± 1.09^{Aa}	4.73 ± 0.21^{Ab}	4.61 ± 0.11^{Ab}
	T3	7.52 ± 0.44^{Aa}	3.99 ± 0.50^{Ab}	4.03 ± 0.61^{Ab}
W	C[1)]	52.66 ± 0.91^{B}	52.63 ± 0.46	52.16 ± 0.84
	T1	29.46 ± 0.78^{Cb}	51.27 ± 4.27^{a}	50.53 ± 3.21^{a}
	T2	31.83 ± 1.01^{Cb}	52.21 ± 0.81^{a}	51.41 ± 1.23^{a}
	T3	58.34 ± 2.31^{Aa}	52.78 ± 0.10^{b}	51.74 ± 0.28^{b}
Myoglobin (mg/g)	C[1)]	4.84 ± 0.53^{b}	5.99 ± 0.12^{a}	6.22 ± 0.07^{a}
	T1	5.80±0.86	6.14±1.46	6.56±1.36
	T2	7.10±1.03	6.68±0.61	6.99±0.18
	T3	5.03±1.73	5.41±1.21	5.95±0.92

*Treatments are the same as in Table 1.
†A-C Means±SD with different superscripts in the same column significantly differ at $p<0.05$.
a-b Means±SD with different superscripts in the same row significantly differ at $p<0.05$.
1) Control (C) at 0 day data was obtained from Jin *et al*. (2007).

ness) and no consistent trends (yellowness and whiteness) among the chicken breast surimi-like material samples were observed. However, color may be influenced by raw material contents.

Sensory evaluation

The sensory evaluation results are presented in Table 6. In sensory evaluation, appearance and color were higher in C sample than other samples during all storage periods, whereas juiciness and tenderness was significantly lower in C sample than chicken breast surimi-like material samples. Overall acceptability was significantly higher in C sample compared with chicken breast surimi-like material samples during all storage periods. These findings indicate the color was higher in Alaska Pollack surimi-like material sample than chicken breast surimi-like material

Table 6. Effect of substitution of chicken breast for Alaska Pollack on sensory evaluation in surimi contained different cryoprotectants

Items	Treatments†	Storage periods (months)		
		0	1.5	3
Appearance*	C	$6.90\pm0.32^{A‡}$	6.20 ± 1.14^{A}	6.10 ± 0.94^{A}
	T1	5.00 ± 0.82^{B}	5.00 ± 0.82^{B}	4.80 ± 0.79^{B}
	T2	5.20 ± 0.79^{B}	5.60 ± 0.97^{AB}	5.20 ± 0.79^{B}
	T3	5.60 ± 0.97^{B}	5.00 ± 0.94^{B}	4.80 ± 0.79^{B}
Color	C	7.50 ± 0.71^{Aa}	6.70 ± 1.06^{Ab}	6.10 ± 0.84^{Ab}
	T1	5.20 ± 0.79^{C}	5.20 ± 0.79^{B}	5.20 ± 0.79^{B}
	T2	5.50 ± 0.85^{BCab}	5.90 ± 0.88^{ABa}	5.00 ± 0.82^{Bb}
	T3	6.20 ± 0.92^{Ba}	5.60 ± 0.84^{Bab}	5.10 ± 0.57^{Bb}
Aroma	C	5.70 ± 0.95^{A}	5.50 ± 1.27	4.90 ± 0.82
	T1	4.40 ± 0.52^{B}	5.30 ± 1.70	4.50 ± 0.71
	T2	4.50 ± 0.71^{Bb}	5.60 ± 0.52^{a}	5.20 ± 0.79^{a}
	T3	4.50 ± 0.71^{B}	5.00 ± 0.82	4.80 ± 0.79
Flavor	C	4.30 ± 1.06	4.30 ± 1.06^{B}	4.20 ± 0.97
	T1	4.20 ± 0.42	4.80 ± 1.03^{AB}	4.50 ± 0.71
	T2	4.50 ± 0.53	4.80 ± 1.03^{AB}	4.60 ± 0.70
	T3	4.30 ± 0.48^{b}	5.60 ± 0.97^{Aa}	4.90 ± 0.74^{b}
Juiciness	C	3.90 ± 0.57^{B}	4.50 ± 1.08^{B}	4.20 ± 1.14^{B}
	T1	5.60 ± 0.70^{A}	5.60 ± 0.70^{A}	5.00 ± 0.94^{A}
	T2	5.50 ± 0.53^{A}	5.60 ± 0.52^{A}	5.40 ± 0.52^{A}
	T3	5.40 ± 0.52^{A}	5.20 ± 1.14^{AB}	5.10 ± 0.88^{A}
Tenderness	C	4.20 ± 0.79^{B}	4.70 ± 1.06^{B}	4.30 ± 0.84^{B}
	T1	5.80 ± 0.79^{A}	5.80 ± 0.79^{A}	5.20 ± 0.92^{A}
	T2	5.60 ± 0.97^{A}	5.50 ± 0.97^{AB}	4.80 ± 0.92^{AB}
	T3	5.40 ± 0.70^{A}	5.40 ± 0.84^{AB}	5.00 ± 0.82^{AB}
Overall acceptability	C	6.70 ± 0.48^{Aa}	6.10 ± 1.10^{Aab}	5.90 ± 0.92^{Ab}
	T1	5.20 ± 0.79^{B}	5.20 ± 0.79^{AB}	5.00 ± 0.94^{B}
	T2	4.80 ± 0.63^{B}	5.00 ± 0.94^{B}	4.70 ± 0.67^{B}
	T3	5.20 ± 0.63^{Bab}	5.80 ± 0.92^{ABa}	4.90 ± 0.57^{Bb}

*Appearance (9 = very good and 1 = very bad), color (9 = very good and 1 = very bad), aroma (9 = very intense and 1 = very weak±), flavor (9 = very good and 1 = very bad), juiciness (9 = very juiciness and 1 = very dry), tenderness (9 = very tender and 1 = very though), overall acceptability (9 = very good and 1 = very bad).

†Treatments are the same as in Table 1.

‡A-C Means±SD with different superscripts in the same row significantly differ at $p<0.05$.

a-b Means±SD with different superscripts in the same column significantly differ at $p<0.05$.

samples although mechanical color showed no consistent trends among the samples, whereas tenderness was higher in chicken breast surimi-like material samples than Alaska Pollack surimi-like material sample. Sensory evaluation scores were not much different among the chicken breast surimi-like material samples. These results indicate the raw material contents and the composition of cryoprotectant may have less influence on the sensory evaluation score between chicken breast surimi-like material samples although other qualities were influenced by raw material contents and the composition of cryoprotectant. As a result of this study, we found that chicken breast surimi-like material samples were higher in protein, juiciness and tenderness compared with Alaska Pollack surimi-like material sample (C), whereas C sample showed higher pH, WHC and breaking force. Thus, we conclude that the raw materials composition (Alaska Pollack or chicken breast) may have large influence on the physico-chemical characteristics and quality of surimi-like materials, whereas cryoprotectant compositions may have less influence on the physico-chemical characteristics and quality of surimi-like materials. Thus, further studies are needed for the improvement of surimi-like material made from chicken breast qualities.

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