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ARTICLE

Effects of Bundle Type and Substitution with Spent Laying Hen Surimi on Quality Characteristics of Imitation Crabsticks

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Abstract

The purpose of this study was to evaluate the effects of bundle type (BT) and substitution with spent laying hen (SH) surimi on quality characteristics of imitation crabsticks made from Alaska Pollack (AP) during 6 wk of cold storage. Diagonally bundled samples had poorer gel characteristics and more lipid oxidation when compared with straight bundled ones ($p<0.05$). The color of diagonally bundled imitation crabsticks deteriorated with storage time ($p<0.01$). However, BT did not affect sensory characteristics ($p>0.05$). SH substitution had an effect on most quality characteristics of imitation crabsticks; darker and poorer gel characteristics were observed and its effect on sensory evaluation was seen at the initial storage. Thus, BT and SH substitution can be considered to have a slight effect on eating quality of imitation crabsticks, despite their negative effects on color, gel characteristics, and lipid oxidation.

Keywords Surimi, imitation crabsticks, bundling type, spent laying hen

Introduction

Surimi is a fish paste containing a high concentration of myofibrillar proteins, which is primarily made from Alaska Pollock (AP) and Pacific Whiting, and it is an intermediate product used to make fish ball, fried fish cake, grilled surimi seafood, and various imitation products such as crabstick, shrimps, scallops, and lobsters (Athaillah and Park, 2016; Park *et al*., 2014). Isolated myofibrillar proteins from other animal species could be substitutes by surimi. With this background, some studies tested the use of beef, pork, sheep meat, and chicken for making surimi-based products (Antonomanolaki *et al*., 1999; Kenney *et al*., 1992; Nowasd *et al*., 2000; Park *et al*., 1996). However, red meat from domestic animals required additional processing to remove undesirable components such as connective tissue, collagen, myoglobin, and fat (Park *et al*., 1996). The application of surimi technology to proteins from other species is critical for improving the value and utilization of disliked meat and waste resources (Jin *et al*., 2009). In our previous research, we developed imitation crabsticks using spent laying hen (SH) breast meat, and assessed quality improvements (Hur *et al*., 2011; Jin *et al*., 2009). Up to

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20% substitution of SH for Alaska Pollack surimi did not heavily influence on the quality characteristics of imitation crabsticks (Jin *et al*., 2011).

The quality of imitation crabsticks can differ depending on the manufacturing methods used, such as cutting (stick, flake, chunk, and combo), slitting (filament style and solid style) and bundling (straight and diagonal) (Park and Beliveau, 2014). However, this concern has received little attention. Therefore, based on the results of our previous studies (Jin *et al*., 2011), we aimed to evaluate straight bundle (SB) and diagonal bundle (DB) types of imitation crabsticks containing SH breast meat, and assessed the single and combined effects of bundle type (BT) and SH substitution on quality characteristics such as pH, color, gel characteristics, sensory property, and lipid oxidation of imitation crab sticks during 6 wk of cold storage.

Materials and Methods

Sample preparation

AP surimi was obtained from Hansung Food Co. Ltd. (Korea), and SH surimi was prepared using the pH method described by Hur *et al*. (2011) with modification. In brief, SH breast (*pectorals major* m.) was purchased from a commercial slaughter house and its external fat and skin were removed from the muscle. SH muscles were ground through a 3-mm-diameter orifice using a grinder (M-12S, Hankook Fujee, Korea) and homogenized with a Polytron homogenizer (IKA Labortechnik T25-B, Germany) with six volume of water at 8,000 rpm for 30 s. The homogenates were filtered through a 1-mm-mesh metal screen to remove connective tissue and then adjusted to pH 11.0 using 1 N NaOH. The slurry was centrifuged at 10,000 *g* for 25 min, and the top and bottom layers were discarded. The middle layer was taken, adjusted to pH 5.0 using 1 N HCl, and centrifuged at 10,000 *g* for 25 min. The sediment was obtained and its pH and water content were adjusted to 7.0 and 80%, respectively. The SH surimi was mixed with 5% sorbitol and 0.3% phosphate, packed in a polyethylene bag, frozen at -70°C, and stored at -20°C for two wk.

Imitation crabsticks were prepared using the manufacturing process shown in Fig. 1. Four batches (two for AP and two for SH per each batch) were prepared. SH treatments were carried out by substituting 20% AP surimi with SH surimi, as presented in Table 1. After slitting the baked sample sheet, the sample fiber was processed as either SB or DB type (the latter was done by treating with additional processes such as diagonal cutting, turning, and secondary bundling at 60 degree angle). Imitation crabsticks were vacuum-packed in plastic bags and stored at 0°C for 6 wk. Each of the four batches was collected on

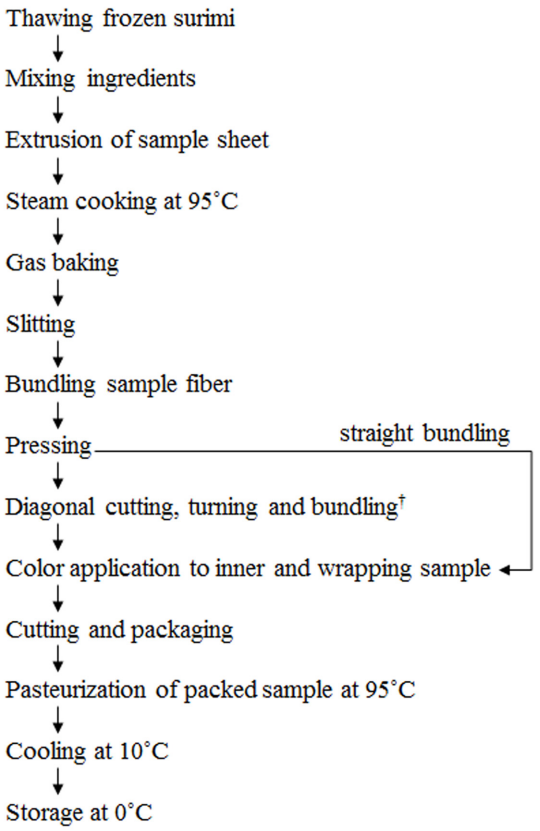

Fig. 1. Manufacturing process of crabsticks. †Diagonal degree was 60°.

Table 1. Formula of imitation crabsticks

Ingredients (g/100g)	Treatments[1)]			
	AP		SH	
	SB	DB	SB	DB
Alaska Pollack surimi	53.53	53.53	42.82	42.82
Chicken breast surimi	-	-	10.71	10.71
Ice	32.12	32.12	32.12	32.12
Wheat starch	2.68	2.68	2.68	2.68
Potato starch	2.68	2.68	2.68	2.68
Salt	1.39	1.39	1.39	1.39
Sugar	1.39	1.39	1.39	1.39
Mixed ingredients[2)]	6.21	6.21	6.21	6.21
Total	100	100	100	100

[1)]AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; DB, diagonal bundle; SB, straight bundle.
[2)]Crab extract 1.18, Carrageenan 0.54, Kelp extract 0.54, Albumen 0.31, Calcium carbonate 0.96, Crab flavor 0.43, Soybean oil 0.32, Phosphate 0.32, Seasoning mix 1.61.

three different days (12 batches total) for analyses.

pH

The pH values were measured in 5.0 g of sample homogenates in 45 mL of distilled water using a pH meter (Model 420A, Orion, USA)

Color

Color values (CIE L* [lightness], a* [redness], and b* [yellowness]) were measured using a Minolta colorimeter (CR-400, Minolta Co., Japan), which was standardized with a white plate (Y = 93.5, x = 0.3132, and y = 0.3198). Whiteness was determined using the following: L* - 3b*, as described by Park (1994).

Gel characteristics

Gel characteristics were determined according to the method described by Phatcharat *et al*. (2006). In brief, samples were equilibrated at room temperature for 20 min, and five cylindrical pieces (3.5 cm wide and 3.0 cm thick) were prepared. Thereafter, the breaking force, deformation, gel strength, and jelly strength were measured using a texture analyzer (EZ-test, Shimadzu, Japan) equipped with a cylindrical plunger (5 mm diameter and 66 mm/min depression speed). Samples for shear force were prepared by using a 1.0-cm-diameter core, and shear force was determined using an Instron Universal Testing Machine (Model 3343, Instron Corp., USA) equipped with a Warner-Bratzler shearing device (100 mm/min crosshead speed).

Fatty acid composition

Lipids from the samples were extracted using a chloroform-methanol (2:1 by volume) solution, as described by Folch *et al*. (1957). Fatty acid methyl esters were prepared from the lipid extracts by saponification with 1.0 N-methanolic NaOH followed by methylation with 14% boron trifluoride in methanol. The separation of fatty acid methyl esters was performed using a gas chromatography machine (6890N, Agilent Technologies Inc., USA) equipped with an SP-2560 column (100 m × 0.25 mm × 0.20 μm, Supelco, USA). Oven temperature was maintained at 140°C and then increased to a final temperature of 240°C at a rate of 4°C/min. The temperatures of the injector and detector were set at 240°C and 250°C, respectively. The flow rate for N_2 carrier gas was 50 mL/min. Each fatty acid was identified by comparing the retention time with the mixture of fatty acid methyl ester standards (FAME Mix CRM47885, Sigma-Aldrich Co., USA). Saturated fatty acid (SFA) was presented as the sum of C10:0, C12:0, C 14:0, C16:0, C17:0, C18:0, and C20:0. Monounsaturated fatty acid (MUFA) was calculated as the sum of the compositions of C16:1n-7, C17:1, C18:1n-9, and C20:1n-9, whereas polyunsaturated fatty acid (PUFA) was calculated as the sum of the compositions of C18:2n-6, C18:3n-3, C20:3n-3, C20:4n-6, and C22:6n-3. Total unsaturated fatty acid (UFA) was calculated as the sum of MUFA and PUFA.

2-Thiobarbituric acid-reactive substances (TBARS)

TBARS as a lipid oxidation were analyzed using the method described by Salih *et al*. (1987) with some modification. In brief, 5 g of sample was weighed in a 50-mL test tube and homogenized with 15 mL of distilled water. Thereafter, 2 mL of homogenate were transferred into another test tube and mixed with 100 μL of butylated hydroxyanisole (10% in ethanol) and 4 mL of 0.2 M thiobarbituric acid in 10% trichloroacetic acid. The mixture was incubated in boiling water for 15 min and then cooled in cold water for 10 min. After centrifugation at 2,000 *g*, the absorbance of supernatants was determined at 531 nm against a blank. A standard curve was prepared using a 1,1,3,3-tetraethoxypropane solution, and the TBARS value was presented as milligrams of malondialdehyde per kilogram of sample.

Volatile basic nitrogen (VBN)

VBN analysis was conducted as a protein degradation value using the Pearson (1976) method with modification. In brief, 10 g of ground sample was taken into a beaker and homogenized with 90 mL distilled water. The homogenate was filtered through a Whatman No.1 paper and its volume was adjusted to 100 mL with distilled water. Thereafter, 10 mL of the filtrate and two drips of phenolphthalein indicator were placed in a flask, to which 3.5 mL of 20% NaOH was added. Steam distillate was collected in a flask containing 20 mL of 4% boric acid and two drips of indicator (methyl red/methylene blue, 2:1); this procedure was continued until 250 mL of distillate was collected. Titration was performed using 0.01 N HCl, and the VBN contents were presented in milligrams per 100 g of sample.

Sensory evaluation

Sensory evaluation was performed using 9-point scale by six panelists from Gyeongnam National University of

Science and Technology, Republic of Korea. The panelists were selected based on their frequency of consuming surimi-based products and experience in sensory evaluation of various meat products. One slice (1 cm thick and 5 cm in diameter) was cut into six pie-shaped wedges and presented to each of the panelists, who sat separately in their individual booth and were provided with distilled water and unsalted crackers to cleanse the palate between the samples. The panelists evaluated whiteness, flavor, tenderness, and overall acceptability using a nine point scale, in which 0 represented the least intense for each parameter and 9 represented the most intense for each parameter. Data for sensory evaluation were collected five times for each batch at 0, 2, 4, and 6 wk of cold storage.

Statistical analysis

The data for each measurement were collected from three plastic bags of each treatment and batch at 0, 2, 4 and 6 storage wk. The effects of SH surimi substitution and BT on quality of imitation crabsticks were analyzed using the SAS program (SAS, 2002). Two-way ANOVA (analysis of variance) was adopted to analyze the effects of SH surimi substitution and BT, separately and combined, on pH, color, gel characteristics, sensory evaluation, fatty acid compositions, and TBARS during the 6 wk of cold storage. The storage effect was also examined by ANOVA and *t*-test (fatty acid composition). Duncan's multiple range tests were used to determine the statistical significance among the means at a 95% significant level.

Results and Discussion

pH

The pH values of imitation crabsticks were not affected by SH substitution and BT at storage wk 0 ($p<0.05$), although BT effects were observed at other storage time points ($p<0.01$; Table 2). The pH at storage wk 0 was significantly lowest regardless of treatment ($p<0.05$). However, SH substitution did not affect pH during cold storage ($p>0.05$). The SH surimi was adjusted to pH 7.0, and 20% of AP surimi was substituted with SH surimi for making imitation crabsticks. The pH of SH substitution level did not affect the initial pH of imitation crabsticks. Moreover, phosphate among the additives played a main role in pH adjustment in the imitation crabsticks, as phosphate increases the pH value in the various processed products by binding its negative charges with positively charged groups of myofibrillar proteins (Athaillah and Park, 2016; Offer and Knight, 1988).

Color

All color traits except for redness (CIE a*) were influenced by SH substitution throughout the cold storage ($p<0.01$), whereas BT effect and combined effect of SH and BT were found at 4 or 6 wk of storage ($p<0.05$; Table 3). Redness was slightly increased during storage regardless of treatment ($p<0.05$), whereas whiteness values of all samples were greatly increased ($p<0.0001$) with decreases in yellowness (CIE b*) ($p<0.05$) by 4 wk of storage. Chicken breast muscle has a relatively whiter color when compared with other chicken muscle and muscles from other animal species; this is because chicken breast muscle consists of white muscle fibers (type IIB) that contain low myoglobin content (Kim *et al*., 2008; Ordway and Garry, 2004). In our previous study, the myoglobin content was not different between AP imitation crabsticks and the SH-incorporated ones (Hur *et al*., 2011). Whiteness is one of the important quality traits in surimi-based products, including imitation crabsticks (Chen, 2002; Ochiai *et al*., 2001). Although redness did not differ between AP and SH crab-

Table 2. Effect of spent laying hen surimi and bundle type (BT) on pH of imitation crabstick during 6 wk of cold storage

Storage weeks	Treatments[1)]				SE	Level of significance[2)]		
	AP		SH					
	SB	DB	SB	DB		SH	BT	SH×BT
0	7.45	7.43	7.45	7.44	0.03			
2	7.49	7.54	7.53	7.57	0.03		**	
4	7.48	7.55	7.50	7.54	0.02		**	
6	7.49	7.57	7.53	7.56	0.02		**	
SE	0.04	0.02	0.02	0.02				
Storage effect[2)]	*	*	**	**				

Data are means and standard errors (SE).
[1)]AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; DB, diagonal bundle; SB, straight bundle.
[2)]*$p<0.05$, **$p<0.01$.

Table 3. Effect of spent laying hen surimi and bundle type (BT) on color of imitation crab stick during 6 wk of cold storage

Items	Storage weeks	Treatments[1)]				SE	Level of significance[2)]		
		AP		SH					
		SB	DB	SB	DB		SH	BT	SH×BT
CIE L*	0	81.52	82.10	79.49	80.41	0.65	**		
	2	80.15	79.62	78.74	78.70	0.49	**		
	4	79.61[a]	77.97[b]	78.38[b]	77.57[c]	0.27	**	***	*
	6	81.34	79.83	78.97	77.63	0.71	**	**	
	SE	0.58	0.40	0.72	0.43				
	Storage effect[2)]			**	*				
CIE a*	0	2.21	2.14	1.93	2.11	0.15			
	2	3.16	3.06	3.10	3.15	0.09			
	4	3.33	3.24	3.34	3.40	0.12			
	6	3.46	3.39	3.47	3.45	0.08			
	SE	0.09	0.08	0.14	0.13				
	Storage effect[2)]	**	***	**	**				
CIE b*	0	4.59	4.94	6.21	6.07	0.25	***		
	2	3.60	3.56	5.17	4.93	0.20	***		
	4	3.05[c]	3.33[c]	4.63[a]	3.71[b]	0.12	***	*	**
	6	3.42[c]	3.85[b]	4.45[a]	4.43[a]	0.16	***		*
	SE	0.12	0.25	0.19	0.17				
	Storage effect[2)]	***	**	**	*				
Whiteness	0	67.74	67.27	60.85	62.20	0.74	***		
	2	69.35	68.94	63.24	63.92	0.44	***		
	4	79.61[a]	77.97[bc]	78.38[b]	77.57[c]	0.27	**	***	*
	6	81.34	79.83	78.97	77.63	0.71	**	**	
	SE	0.45	0.56	0.55	0.60				
	Storage effect[2)]	***	***	***	***				

Data are means and standard errors (SE).
[a-c]Means with different superscripts in the same row are significantly ($p<0.05$) different in spent laying hen surimi × bundle type interaction.
[1)]AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; DB, diagonal bundle; SB, straight bundle.
[2)]*$p<0.05$, **$p<0.01$, ***$p<0.0001$.

sticks ($p>0.05$), low lightness (CIE L*) and high yellowness resulted in lower whiteness in SH than in AP crabsticks ($p<0.01$). Whiteness was not affected by BT at 2 wk of storage ($p>0.05$); however, DB treatment had offered lower whiteness than SB treatment at 4 ($p<0.0001$) and 6 ($p<0.01$) wk of storage. It seems that additional processes, including diagonal cutting, turning, and bundling at 60 degree angle influenced color changes in imitation crabsticks later in the storage period.

Gel characteristics

Table 4 presents the gel characteristics of the imitation crabsticks. SH substitution decreased breaking force and gel strength, resulting in a decrease in shear force throughout the storage period ($p<0.05$). Shear force was lower in DB than SB regardless of SH substitution ($p<0.01$). BT effects were mainly observed in deformation and jelly strength in addition to shear force. Furthermore, the SH and BT combination also affected these three characteristics. There was a similar trend for deformation and jelly strength: the highest values seen in SB treatment with SH substitution at initial storage ($p<0.01$), whereas the lowest values seen in DB treatment with SH substitution at 2 and 4 wk storage ($p<0.01$) among the treatments. However, the shear force was lowest in DB type imitation crabsticks substituted with SH, as expected, because of the different content and type of myofibrillar proteins, especially the myosin heavy chain between AP and SH. The myosin heavy chain is the main protein for the formation of surimi gel during heating along with a three-phase process of denaturation, unfolding, and polymerization (Chen *et al*., 1992; Kamath *et al*., 1992; Ogawa *et al*., 1993). Therefore, SH was found to deteriorate gel properties of imitation crabsticks. The BT effects on gel characteristics was different than the SH effects. Deformation and jelly strength were higher in SB than in DB at initial storage ($p<0.01$) regardless of SH. For SB treatment, jelly strength increased at mid storage period and decreased later during

Table 4. Effect of spent laying hen surimi and bundle type (BT) on gel characteristics of imitation crab stick during 6 wk pf cold storage

Items	Storage weeks	Treatments[1]				SE	Level of significance[2]		
		AP		SH					
		SB	DB	SB	DB		SH	BT	SH×BT
Breaking force (g)	0	127.33	129.67	95.67	88.33	11.65	**		
	2	154.67	143.00	118.67	108.33	6.18	***	*	
	4	170.67	166.33	140.67	136.33	4.11	***		
	6	191.33	189.67	165.67	167.00	7.05	**		
	SE	7.12	10.15	3.77	7.96				
	Storage effect[2]	***	***	***	***				
Deformation (mm)	0	4.63^{b}	5.43^{b}	9.90^{a}	3.70^{c}	0.44	**	***	***
	2	9.20^{a}	9.53^{a}	9.47^{a}	4.90^{b}	0.49	***	**	***
	4	7.43^{b}	9.87^{a}	6.53^{bc}	4.77^{c}	0.56	***		**
	6	5.87	9.13	5.93	9.73	1.15		**	
	SE	0.95	0.42	0.71	0.56				
	Storage effect[2]	**	**	**	*				
Gel strength (g/cm^2)	0	648.50	660.37	487.20	449.87	59.33	**		
	2	787.70	728.30	604.37	551.73	31.49	***	*	
	4	869.20	847.13	716.40	694.33	20.96	***		
	6	974.47	965.97	843.73	850.57	35.92	**		
	SE	36.24	51.72	19.20	40.54				
	Storage effect[2]	***	***	***	***				
Jelly strength (g×mm)	0	593.53^{b}	706.70^{b}	945.37^{a}	324.17^{c}	49.25		**	**
	2	1418.30^{a}	1361.37^{a}	1123.50^{b}	520.77^{c}	43.69	***	**	**
	4	1262.67^{b}	1635.70^{a}	916.73^{c}	650.80^{d}	52.73	***		**
	6	1111.07	1721.50	983.97	1618.90	107.71		**	
	SE	93.02	57.86	63.38	39.12				
	Storage effect	*	*	*	***				
Shear force (kg/cm^2)	0	1.10^{a}	0.78^{b}	1.02^{a}	0.61^{c}	0.04	*	***	**
	2	1.10^{a}	0.95^{b}	0.83^{c}	0.70^{d}	0.02	***	***	*
	4	1.14	1.00	0.79	0.68	0.02	***	***	
	6	1.23	1.10	0.89	0.82	0.04	***	**	
	SE	0.04	0.02	0.02	0.03				
	Storage effect[2]	*	*	**	***				

Data are means and standard errors (SE).
[a-d]Means with different superscripts in the same row are significantly (p<0.05) different in spent laying hen surimi × bundle type interaction.
[1]AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; DB, diagonal bundle; SB, straight bundle.
[2]*p<0.05, **p<0.01, ***p<0.0001.

the storage (p<0.05). On the contrary, for DB treatment, this characteristics increased with the storage period (p< 0.05). During the 6 wk of cold storage, most traits of gel characteristics increased regardless of treatment. However, shear force decreased in SB type with SH substitution with increase in the storage time (p<0.01). As mentioned above, high deformation and jelly strength at initial storage decreased due to the combination of SH and BT and, consequently, resulted in a shear force decreasing with storage time.

TBARS, fatty acid composition, and VBN

For lipid oxidation during cold storage, TBARS and fatty acid composition were investigated and the results are shown in Fig. 2 and Table 5, respectively. For lipid oxidation SH effects were noted at all storage wk (p< 0.0001), whereas BT effects were observed only at 6 wk of storage (p<0.0001). The TBARS values of imitation crabsticks increased during the 6 wk of cold storage (p< 0.05). AP, when compared with SH, had higher PUFA content at initial storage (p<0.01). The PUFA composition of AP (68.40% and 69.50%) decreased to 60.67% and 58.93% (p<0.01) and that of SH also decreased like AP, although the initial composition was lower than that of AP. However, the TBARS values were lower in SH than in AP throughout the cold storage. Our previous report (Jin

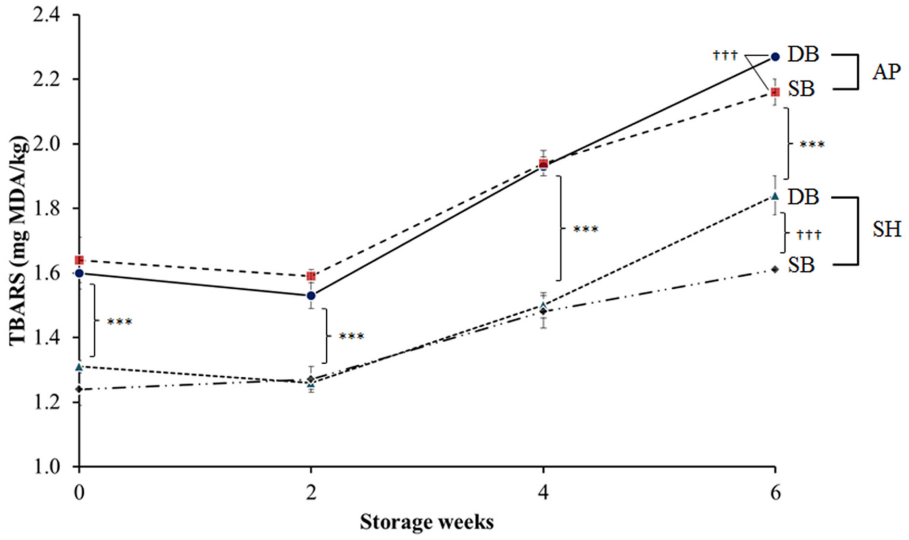

Fig. 2. Changes of TBARS of imitation crabsticks during 6 wk of cold storage. AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; BT, bundle type; DB, diagonal bundle; SB, straight bundle. *** indicates significant differences between AP and SH at each week of cold storage at $p<0.0001$ level. ††† indicates significant differences between DB and SB at 6 wk of cold storage at $p<0.0001$ level. The storage effects were found in all treatments ($p<0.0001$).

Table 5. Changes of fatty acid compositions (%) of imitation crabsticks during 6 wk of cold storage

Items[1)]	Storage weeks	Treatments[2)]				SE	Level of significance[3)]		
		AP		SH					
		SB	DB	SB	DB		SH	BT	SH×BT
SFA	0	13.80	13.90	15.17	15.10	0.64	*		
	6	18.13	18.13	20.57	20.57	0.70	**		
	SE	1.11	0.51	0.72	0.35				
	Storage effect[3)]	**	**	***	**				
UFA	0	86.63	86.07	84.83	84.90	1.17	*		
	6	81.87[a]	79.50[b]	79.43[b]	78.50[c]	0.40	**	**	*
	SE	1.60	0.28	0.67	0.60				
	Storage effect[3)]	**	*	**	***				
MUFA	0	19.23	16.57	18.63	17.57	0.59		**	
	6	21.17[b]	20.60[c]	23.27[a]	23.37[a]	0.15	***	*	**
	SE	0.73	0.21	0.35	0.19				
	Storage effect[3)]		**	***	***				
PUFA	0	68.40	69.50	66.20	67.30	0.58	**		
	6	60.67	58.93	56.13	55.13	0.38	***	**	
	SE	0.87	0.16	0.38	0.51				
	Storage effect[3)]	***	**	***	***				

Data are means and standard errors.
[a-c]Means with different superscripts in the same row are significantly ($p<0.05$) different in spent laying hen surimi × bundle type interaction.
[1)]SFA, sum of saturated fatty acids; UFA, sum of unsaturated fatty acids; MUFA, sum of monounsaturated fatty acids; PUFA, sum of polyunsaturated fatty acids. [2)]AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; BH, bundle type; DB, diagonal bundle; SB, straight bundle. [3)]*$p<0.05$, **$p<0.01$, ***$p<0.0001$.

et al., 2009) supports these results, and Ahn *et al*. (1993) also reported that lipid oxidation could be influenced by the differences in fat content and fatty acid composition. Moreover, PUFA is more susceptible to oxidation than MUFA and SFA. Like TBARS at 6 wk of storage, the BT effect on PUFA was observed at 6 wk of storage ($p<0.01$). DB treatment had significantly higher TBARS values ($p<0.0001$) and lower PUFA compositions ($p<0.01$) than SB treatment, although there were no differences at initial storage ($p>0.05$). These results indicate that more storage

Table 6. Effect of spent laying hen surimi and bundle type (BT) on volatile basic nitrogen of imitation crab stick during 6 wk of cold storage

Storage weeks	Treatments[1)]				SE	Level of significance[2)]		
	AP		SH					
	SB	DB	SB	DB		SH	BT	SH×BT
0	45.73[c]	42.33[c]	60.92[a]	51.87[b]	3.59	**	*	*
2	54.37	42.79	65.10	63.23	3.76	***	*	
4	62.86	51.89	74.20	71.40	3.51	***	**	
6	64.41	55.36	76.55	71.60	4.64	**	*	
SE	3.32	4.21	3.16	4.81				
Storage effect[2)]	*	*	**	**				

Data are means and standard errors (SE).
[a-c]Means with different superscripts in the same row are significantly (p<0.05) different in spent laying hen surimi × bundle type interaction.
[1)]AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; DB, diagonal bundle; SB, straight bundle.
[2)]*p<0.05, **p<0.01, ***p<0.0001.

Table 7. Effect of spent laying hen surimi and bundle type (BT) on sensory properties of imitation crab stick during 6 wk of cold storage

Items	Storage weeks	Treatments[1)]				SE	Level of significance[2)]		
		AP		SH					
		SB	DB	SB	DB		SH	BT	SH×BT
Color	0	6.17	6.17	6.67	6.83	0.33	*		
	2	6.83	6.83	6.67	6.83	0.44			
	4	6.33	6.50	6.50	6.50	0.62			
	6	6.83	6.67	6.33	6.67	0.49			
	SE	0.41	0.47	0.67	0.75				
Flavor	0	6.50	6.67	7.00	6.83	0.62			
	2	6.33	6.83	6.17	6.33	0.52			
	4	6.67	6.67	6.83	6.67	0.62			
	6	6.17	6.33	6.33	6.17	0.52			
	SE	0.52	0.54	0.71	0.52				
Tenderness	0	6.17	6.50	7.12	6.83	0.34	**		
	2	6.50	6.33	6.83	6.67	0.55			
	4	6.33	6.33	6.67	6.83	0.58			
	6	6.67	6.33	6.83	6.50	0.64			
	SE	0.52	0.58	0.62	0.41				
Overall acceptability	0	7.00	7.35	6.67	6.67	0.21	***		
	2	6.50	6.33	6.83	6.17	0.34			
	4	6.33	6.33	6.67	6.50	0.60			
	6	6.50	6.17	6.67	6.50	0.51			
	SE	0.54	0.52	0.52	0.23				

Data are means and standard errors (SE).
[1)]AP, Alaska Pollock; SH, replacement of Alaska Pollock with 20% spent laying hen surimi; DB, diagonal bundle; SB, straight bundle.
[2)]*p<0.05, **p<0.01, ***p<0.0001. The storage effect was not found in sensory properties (p>0.05).

time-dependent lipid oxidation could occur in DB type imitation crabsticks than the SB type ones.

VBN results showed a different trend than lipid oxidation (Table 6). SH and BT effects were observed at all storage weeks (p<0.05) and VBN increased with increase in storage time regardless of treatments (p<0.05). At storage week 0, combined effect of SH and BT was found (p<0.05); SB type imitation crabsticks with SH substitution had the highest VBN value, among all the treatments. These results did not agree with our previous study (Hur *et al*., 2011) where we observed no significant differences between imitation crabsticks made from AP and those from AP with SH substitution, regardless of SH preparation methods. Although the VBN value is an important reference index to evaluate freshness of meat as well as meat product (Castro *et al*., 2006; Rodtong *et al*., 2005) and protein degradation can be compared among the treatments with VBN values, the shelf-life of imitation crab-

sticks in the present study should be considered in light of lipid oxidation. The interesting finding of the opposite trends between lipid oxidation and protein degradation indicates that more specific studies are needed on their relationship and on the effects of BT and SH on shelf-life of imitation crabsticks.

Sensory evaluation

SH substitution had effects only on sensory characteristics of color, tenderness, and overall acceptability at storage wk 0 (Table 7). At initial storage, the panels evaluated that imitation crabsticks with SH substitution were darker (high color value) and tougher than AP imitation crabsticks regardless of BT ($p<0.05$). Consequently, overall acceptability was significantly lower in SH than in AP crabsticks ($p<0.0001$). As presented in Tables 3 and 4, SH had poor color (low whiteness) and gel characteristics (low breaking force and gel strength) than AP. However, there were no significant effects of BT and combined SH and BT. Again, although color and gel characteristics of imitation crabsticks changed during cold storage, the storage did not affect sensory evaluation findings. Thus, 20% SH substitution and DB did not largely affect sensory characteristics of imitation crabsticks.

Conclusions

SH substitution had distinct effects on the quality characteristics of imitation crabsticks. SH substitution deteriorated main quality traits such as whiteness, breaking force, and gel strength. BT effects were noted mainly at later storage weeks, and DB negatively affected whiteness and gel characteristics. When SH and BT effects were combined, the DB imitation crabsticks with 20% SH surimi substitution had poor gel characteristics initially and poor color later in the storage period. Lipid oxidation was accelerated in AP owing the high composition of PUFA; however, higher protein degradation was noted in AP crabsticks. DB negatively affects the color, gel characteristics, and lipid oxidation when compared with SB; however, the overall quality characteristics were not unacceptable. In particular, there was no difference in sensory evaluation between DB and SB.

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References

1. Ahn, D. U., Ajuyah, A., Wolef, F. H., and Sim, J. S. (1993) Oxygen availability affects prooxidant catalyzed lipid oxidation of cooked turkey patties. *J. Food Sci.* **58**, 278-291.
2. Antonomanolaki, R. E., Vareltzis, K. P., Georgakis, S. A., and Kaldrymidou, E. (1999) Thermal gellation properties of surimi-like material made from sheep meat. *Meat Sci.* **52**, 429-435.
3. Athaillah, Z. A. and Park, J. W. (2016) Characterization of surimi slurries and their films derived from myofibrillar proteins with different extraction methods. *Food Biosci.* **15**, 118-125.
4. Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., and Larriva, R. M. D. (2006) Total volatile base nitrogen and its use to assess freshness in European sea bass stored in ice. *Food Control* **17**, 245-248.
5. Chen, H. H. (2002) Decoloration and gel-forming ability of horse mackerel mince by air-flotation washing. *J. Food Sci.* **67**, 2970-2975.
6. Chen, J. K., Gill, T. A., and Paulson, A. T. (1992) Cross-linking of myosin heavy chains from cod, herring and silver hake during thermal setting. *J. Food Sci.* **57**, 906-912.
7. Folch, J., Lees, M., and Sloane-Stanley, G. H. (1957) A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.* **226**, 497-509.
8. Hur, S. J., Choi, B. D., Choi, Y. J., Kim, B. G., and Jin, S. K. (2011) Quality characteristics of imitation crab sticks made from Alaska Pollack and spent laying hen meat. *LWT-Food Sci. Technol.* **44**, 1482-1489.
9. Jin, S. K., Hur, I. C., Jeong, J. Y., Choi, Y. J., Choi, B. D., Kim, B. G., and Hur, J. J. (2011) The development of imitation crab sticks by substituting spent laying hen meat for Alaska Pollack. *Poultry Sci.* **90**, 1799-1808.
10. Jin, S. K., Kim, I. S., Choi, Y. J., Kim, B. G., and Hur, S. J. (2009) The development of imitation crab stick containing chicken breast surimi. *LWT-Food Sci. Technol.* **42**, 150-156.
11. Kamath, G. G., Lanier, T. C., Foegeding, E. A., and Hamann, D. D. (1992) Nondisulfide covalent cross-linking of myosin heavy chain in "setting" of Alaska pollock and Atlantic croaker surimi. *J. Food Biochem.* **16**, 151-172.
12. Kenney, P. B., Kastner, C. L., and Kropf, D. H. (1992) Muscle washing and raw material source affect quality and physicochemical properties of low-fat, restructured beef. *J. Food Sci.* **57**, 545-550.
13. Kim, G. D., Jeong, J. Y., Moon, S. H., Hwang, Y. H., Park, G. B., and Joo, S. T. (2008) Effects of muscle fibre type on meat characteristics of chicken and duck breast muscle. *Proceed. 54th Int. Cong. Meat Sci. Technol. Cape Town, South Africa,*

pp. 124.
14. Nowasd, A. A. K. M., Kanoh, S., and Niwa, E. (2000) Thermal gelation characteristics of breast and thigh muscles of spent hen and broiler and their surimi. *Meat Sci.* **54**, 169-175.
15. Ochiai, Y., Ochiai, L., Hashimoto, K., and Watabe, S. (2001) Quantitative estimation of dark muscle content in the mackerel meat paste and its products using antisera against myosin light chains. *J. Food Sci.* **66**, 1301-1305.
16. Offer, G. and Knight, P. (1988) The structural basis of water-holding in meat. Part 1: General principles and water uptake in meat processing. Lawrie, R. A. (ed.), Developments in meat science. Elsevier Applied Science, London, pp. 173-243.
17. Ogawa, M., Ehara, T., Tamiya, T., and Tsuchiya, T. (1993) Thermal stability of fish myosin. *Comp. Biochem. Physiol. B: Comp. Biochem.* **106**, 517-521.
18. Ordway, G. A. and Garry, D. J. (2004) Myoglobin: an essential hemoprotein in striated muscle. *J. Exp. Biol.* **207**, 3441-3446.
19. Park, J. W. (1994) Functional protein additives in surimi gels. *J. Food Sci.* **59**, 525-527.
20. Park, J. W. and Beliveau, J. L. (2014) Manufacture of crabsticks. Park, J. W. (ed), Surimi and surimi seafood, CRC Press, Boca Raton, pp. 245-270.
21. Park, J. W., Nozaki, H., Suzuki, T., and Beliveau, J. L. (2014) Historical review of surimi technology and market developments. Park, J. W. (ed), Surimi and surimi seafood, CRC Press, Boca Raton, pp. 3-24.
22. Park, S., Brewer, M. S., Novakofski, J., Bechtel, P. J., and McKkeith, F. K. (1996) Process and characteristics for a surimi-like material made from beef or pork. *J. Food Sci.* **61**, 422-427.
23. Pearson, D. (1976) The chemical analysis of foods (7th ed.). Chemical Publishing Co., New York, pp. 386.
24. Phatcharat, S., Benjakul, S., and Visessanguan, W. (2006) Effects of washing with oxidizing agents on the gel-forming ability and physicochemical properties of surimi produced from bigeye snapper. *Food Chem.* **98**, 431-439.
25. Rodtong, S., Nawong, S., and Yongsawatdigul, J. (2005) Histamine accumulation and histamine-forming bacteria in Indian anchovy (*Stolephorus indicus*). *Food Microbiol.* **22**, 475-482.
26. Salih, A. M., Smith, D. M., Price, J. F., and Dawson, L. E. (1987) Modified extraction 2-thiobabituric acid method for measuring lipid oxidation in poultry. *Poultry Sci.* **66**, 1483-1488.
27. SAS (2002) SAS for window. Release 9.4, SAS Institute Inc., Cary, NC, USA.