KoSFA 1978
Korean J. Food Sci. An.
Vol. 34, No. 2, pp. 192~199(2014)
DOI http://dx.doi.org/10.5851/kosfa.2014.34.2.192

ARTICLE

The Effects of Mechanically Deboned Chicken Hydrolysates on the Characteristics of Imitation Crab Stick

Sang-Keun Jin[3,#], Jin-Won Hwang[3], Sungsil Moon[4,#], Yeung-Joon Choi[5], Gap-Don Kim[6], Eun-Young Jung[1], and Han-Sul Yang[1,2,*]

[1]*Division of Applied Life Science (BK21 Plus Program), Gyeongsang National University, Jinju 660-701, Korea*
[2]*Institute of Agriculture and Life Science, Gyeongsang National University, Jinju 660-701, Korea*
[3]*Department of Animal Resources Technology, Gyeongnam National University of Science & Technology, Jinju 660-758, Korea*
[4]*Sunjin Meat Research Center, Kandong, Seoul 134-060, Korea*
[5]*Department of Seafood Science & Technology, Gyeongsang National University, Tongyeong 650-160, Korea*
[6]*Department of Food Science & Biotechnology, Kyungnam University, Changwon 631-701, Korea*

Abstract

The effects of adding mechanically deboned chicken (MDC) hydrolysates on the quality characteristics of imitation crab stick (ICS) during storage were investigated. ICS was prepared from Alaska Pollack, chicken breast surimi, and protein hydrolysates enzymatically extracted from MDC. ICS samples were divided into 4 groups: without protein hydrolysate (control), added with 0.5% protein hydrolysate (T1), added with 1.0% protein hydrolysate (T2), and added with 1.5% protein hydrolysate (T3). Results showed that crude protein content did not differ significantly among the ICS samples ($p>0.05$). ICS sample added with MDC hydrolysates had higher crude fat and ash content but lower moisture content than the control ($p<0.05$). Lightness was significantly lower in T2 and T3 than in the other groups at 0 and 4 wk of storage. Also, whiteness decreased in the groups contained MDC hydrolysates. Breaking force and jelly strength were higher in samples containing MDC hydrolysates compared to control samples ($p<0.05$). Additionally, saturated fatty acid contents were lower in the groups containing MDC hydrolysates than in control sample groups ($p<0.05$). Polyunsaturated fatty acid (PUFA) and essential fatty acids (EFA) were significantly higher in T2 and T3 than the control samples. In particular, all samples containing MDC hydrolysates had reduced thiobarbituric acid-reactive substances (TBARS) values at 4 wk. Free radical scavenging activity also was increased with addition of MDC hydrolysates.

Key words: imitation crab stick, surimi, mechanically deboned chicken hydrolysates, quality properties

Introduction

The primary ingredient in fish paste or crab sticks is surimi, a stabilized myofibrillar protein prepared from fish protein by mincing and washing of mechanically deboned fish to remove blood, lipids, enzymes, and sarcoplasmic proteins (Vilhelmsson, 1997). Surimi is light in color, bland in odor, low in fat, and extremely functional due to the unique gelling properties of the myofibrillar proteins, which make it a robust functional ingredient in the manufacture of new food products (Lanier, 2000). Numerous studies have been conducted on surimi containing fish meat. In addition, the application of surimi technology in the production of surimi-based products from other species could provide a new approach for increasing its utilization and functional properties.

Animal meat is of much interest in the development of surimi-based products made from beef, pork and chicken (Jung *et al*., 2004; Park *et al*., 1996). Pork meat has been reported to have high myofibrillar protein content allowing increased gel forming capacity in surimi. Also, chicken breast could be used to produce many refined products, such as fish protein with different textures. Therefore, the addition of myofibrillar proteins from spent laying hens to surimi-based ICS holds promise in promoting the utilization of such products.

Protein hydrolysates, rich in low molecular weight peptides (di- and tri-peptides, with minimal free amino acids),

[#]These authors contributed equally to this work.
*Corresponding author: Han-Sul Yang, Division of Applied Life Science, Gyeongsang National University, Jinju 660-701, Korea. Tel: 82-55-772-1948, Fax: 82-55-772-1949, E-mail: hsyang@gnu.ac.kr

are a good dietary source due to their high nutritional value and therapeutic properties (Bhaskar *et al*., 2007). In recent years, research has focused on the generation of bioactive peptides from food sources including meat and meat by-products (Daoud *et al*., 2005; Jang and Lee, 2005; Li *et al*., 2007). Some peptides possess antihypertensive activity through their ability to inhibit Angiotensin I-converting enzyme (Arihara *et al*., 2001; Saiga *et al*., 2003a). Protein hydrolysates of animal muscles, and their by-products, also possess antioxidant activity and improved functional properties (Saiga *et al.,* 2003b; Sakanaka and Tachibana, 2006; Liu *et al*., 2010). Also, enzymatic hydrolysates have been shown to enhance the emulsifying and foaming properties of fish protein (Shahidi *et al*., 1995).

Mechanically deboned chicken (MDC) is one of the most common raw materials in processed poultry products, which along with other meat by-products, could provide economical bioactive peptides in the form of hydrolysates. Thus, its use in protein hydrolysis could be used to produce value-added surimi-based products. However, there is little information relating to the functional peptides generated in meat-based products such as ICS. Therefore, the aim of the present study was to investigate the effects of MDC protein hydrolysates on the quality and characteristics of ICS during storage at 5°C.

Materials and Methods

Sample preparation and protein hydrolysate

Alaska Pollack was purchased from Han-sung Food Co. Ltd. (Korea) and stored at -20°C until use. Chicken breast meat was obtained from a commercial slaughter house. To make surimi, the external fat, bone, and skin were removed and the lean muscle was cut into approximately 3.0×3.0×2.0 cm^3 cubes and ground through a 3 mm diameter hole using a mincer. Minced samples were homogenized using a Polytron homogenizer (T25-B, IKA Sdn. Bhd., Malaysia) with distilled water at 15,000 rpm for 30 s. The homogenate was filtered through a 1 mm mesh metal screen to remove connective tissue. The filtrate was centrifuged at 10,000 *g* for 25 min and the supernatant containing fat and water-soluble proteins was discarded. The resulting sediment was used for ICS manufacture.

In this study, one- and two-stage hydrolysis was employed. The nerves, skin, and visible fat were removed from the meat, which was then fragmented, ground, and homogenized with distilled water (meat:water ratio, 1:3 w/w). The homogenate was heated to 43°C and the pH was adjusted to 7.0 with 2 N NaOH. The enzyme used for protein hydrolysis was Potarmex (Novonordisk Bioindystrials, Inc., Denmark). Protarmex (5%) was added and the reaction pH was maintained by the addition of 2 N NaOH. The hydrolytic process was terminated by heating the mixture to 85°C for 20 min, ensuring inactivation of the enzyme. The resulting slurry was centrifuged (Union 5KR, Hanil, Korea) at 8,000 rpm for 10 min to remove insoluble fractions. The hydrolysate slurry was then heated to 50°C and the pH was adjusted to 7.0 with 2 N NaOH. Bromelain (1%) was added to the mixture and the reaction pH was maintained by the addition of 2 N NaOH. After heating at 90°C for 15 min to inactivate the enzyme, the hydrolysate was centrifuged at 8,000 rpm for 20 min to remove insoluble fractions. The degree of hydrolysis (DH) was determined using the 20% (w/v) trichloroactic acid (TCA) method, as described in the semi-micro Kjeldahl procedure. DH was defined as the percentage ratio of the total nitrogen in two-stage hydrolysate (A) to the total nitrogen in one-stage hydrolysate (B), and calculated as $[(A-B)/B]\times 100$ (4.64% crude protein and 25.2% DH). The composition of the crab stick is detailed in Table 1, while the flow diagram of its preparation is shown in Fig. 1.

Proximate composition

The proximate composition analysis of ICS including moisture, crude protein, crude fat and crude ash, was performed according to AOAC methods 950.46, 992.15, 985.15, and 920.153 for ICS (AOAC, 2000).

Color

Color (CIE L*, a*, b*) was measured using a Minolta colorimeter (CR-400, Japan), which was standardized using a white plate. Five readings were taken from the surface of the samples. Whiteness was determined using

Table 1. The basic formulation of imitation crab stick

Ingredients (%)	Control	T1	T2	T3
Alaska pollack surimi	30.48	30.48	30.48	30.48
Chicken breast surimi	7.62	7.62	7.62	7.62
MDC[1)] hydrolysates	-	0.50	1.00	1.50
Wheat starch	18.75	18.75	18.75	18.75
Distilled water	36.26	35.76	35.26	34.76
Mixed ingredients[2)]	6.89	6.89	6.89	6.89
Total	100.0	100.0	100.0	100.0

[1)]Mechanically deboned chicken [2)]Mixed ingredients®: salt 1.37, sugar 0.88, crab extract 0.63, gluten 0.32, soy protein isolate 0.53, egg albumen liquid 0.18, carrageenan 0.16, calcium carbonate 0.41, soybean oil 0.53, monosodium L-glutamate 0.44, glycine 0.16, phosphate 0.19, red color DW 0.09, mixed seasoning 1.00

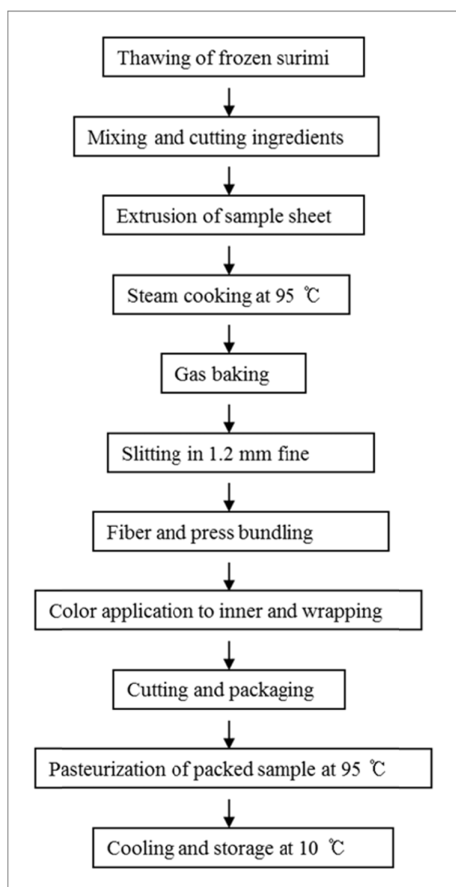

Fig. 1. Manufacturing process of imitation crab stick.

the following formula: L*−3b* (Park *et al*., 1996).

Gel characteristics

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 stored at 20°C prior to determination. The breaking force, deformation, jelly strength, and gel strength were measured using a texture analyzer (EZ-test, Shimadzu, Japan) equipped with a cylindrical plunger (diameter 5 mm, depression speed 80 mm/min).

Fatty acid composition

Lipid extraction was performed as described by Folch *et al*. (1957). Samples (5 g) were homogenized in 30 mL of chloroform-methanol solution (2:1, v/v), after which 10 mL of 0.88% NaCl was added and the mixture incubated for 2 h to allow phase separation. The chloroform-methanol extract was evaporated in a water heating block at 40°C. The lipid extracts were then converted to fatty acid methyl esters using a 14% boron-trifluoride methylation solution. The resultant fatty acid methyl esters were separated and analyzed by gas chromatography (Agilent, 6890N GC system, USA). A fused Supelcoax^{TM} capillary column of 60 m × 0.32 mm × 0.25 μM (Supelco, USA) was used. The gas chromatography oven temperature was 180°C, which increased at a rate of 5°C/min to a final temperature of 240°C. The temperatures of the injector port and the detector were set at 250°C. Fatty acid methyl ester was injected into the split injection port (10:1 split ratio). The flow rate for the N_2 carrier gas was 20 cm/sec.

Lipid oxidation

Lipid oxidation was determined using the thiobarbituric acid reactive substances (TBARS) method (Buege and Aust, 1978). ICS sample (5 g) was weighed into a 50 mL test tube and homogenized for 15 s with 15 mL of deionized distilled water using a Polytron homogenizer at the highest speed (T25basic, IKA, Malaysia). The homogenate (2 mL) was transferred to a disposable test tube (13× 100 mm), and the butylated hydroxyanisole (10%, 50 μL) and thiobarbituric acid/trichloroacetic acid (TBA/TCA) solution (4 mL) were added. Absorbance was determined at 531 nm against a blank containing 2 mL of deionized distilled water and 4 mL of TBA/TCA solution. The TBARS measure was expressed in mg of malondialdehyde (MDA) per kg of sample.

2,2-diphenyl-1-picryhydrazla hydrate (DPPH) radical scavenging activity

The DPPH radical scavenging activity was determined according to the modified method of Brand-Williams *et al*. (1995). A solution of DPPH (6.5 μM) in methanol was prepared daily before measurement. ICS sample (2 mL) was mixed with 3 mL DPPH solution so that the final concentration of DPPH was 0.1 mM. Blank sample contained the same concentrations of methanol and DPPH. The reaction mixture was shaken vigorously and was incubated in the dark for 30 min, after which the absorbance of the solution was measured in triplicate at 517 nm. The radical scavenging activity was calculated using the formula:

$$\text{DPPH inhibition (\%)} = [(A_B - A_A) / A_B] \times 100:$$

A_B = absorption of blank sample,
A_A = absorption a tested sample.

Statistical analysis

This study was designed as a 4×2 factorial experiment based on the parameters of treatment (control, T1, T2,

and T3) and storage time (0 and 4 wk). All experiments were performed in triplicate. Data were analyzed for degree of variation and significance of difference using an analysis of variance (ANOVA) and differences among treatment means were assessed using Duncan's multiple range test. The statistical analysis was performed using SAS program version 8.1 (SAS Institute, 2000). Significance was defined as $p<0.05$.

Results and Discussion

Proximate composition

The results of the proximate composition analysis of ICS containing MDC hydrolysates are shown in Table 2. The carbohydrate content ranged from 19.3% to 20.9%, and there was no significant difference among the ICS samples (data not shown). The ICS also showed no significant difference in crude protein content when compared with the control group. However, all groups containing MDC hydrolysates showed reduced moisture content when compared to control ($p<0.05$). Rawdkuen *et al.* (2004) reported that the expressible moisture of surimi gels decreased when higher an amount of chicken plasma protein was added. Therefore, lower final moisture contents can be reached due to an increase in other chemical compositions. Crude fat content was significantly higher in the MDC hydrolysate containing samples than in the control samples. Also, the ash content was significantly higher in the samples with 1.0% and 1.5% MDC hydrolysates than in the control samples ($p<0.05$). The functional and textural properties of surimi or surimi-based products depend on many factors, including the content of various gelling and non-gelling ingredients (Nowasd *et al.*, 2000). High protein, high myofibrillar protein, low crude fat, and adequate water are required for making high-quality surimi-based products (Jin *et al.*, 2007). Lipids in surimi products may adversely affect quality as oxidized lipids interact with proteins, causing denaturation and alteration of functional properties (Smith, 1987).

Color

The color characteristics of ICS containing MDC hydrolysates are shown in Table 3. The light, red, and yellow values of the MDC hydrolysates were 48.8, 5.0 and 15.6, respectively. Lightness was significantly lower in T2 and T3 than in the other groups at 0 and 4 wk of storage ($p<0.05$). Redness was significantly higher in the groups containing MDC hydrolysates than in the control group at time 0 of storage. It also significantly increased with the storage periods in all treatments ($p<0.05$). Whiteness was lower in T2, but there were no significant differences among the groups. In addition, MDC hydrolysates had no

Table 2. Proximate compositions (%) in imitation crab stick

Items	Treatments[1)]			
	Control	T1	T2	T3
Moisture	69.36 ± 0.06^{A}	68.38 ± 0.05^{B}	67.64 ± 0.10^{C}	67.55 ± 0.06^{C}
Crude protein	9.51 ± 0.29	10.20 ± 0.17	10.39 ± 0.27	9.86 ± 0.01
Crude fat	1.08 ± 0.05^{C}	1.25 ± 0.02^{AB}	1.23 ± 0.09^{B}	1.36 ± 0.06^{A}
Ash	1.54 ± 0.13^{B}	1.84 ± 0.27^{AB}	1.95 ± 0.17^{A}	1.96 ± 0.05^{A}

$^{A-C}$Means with different superscript in the same row significantly differ at $p<0.05$.
[1)]Treatments are the same as in Table 1.

Table 3. Color (CIE value) of imitation crab stick containing MDC hydrolysates during storage

Items	Storage wk	Treatments[1)]			
		Control	T1	T2	T3
Lightness (L*)	0	81.19 ± 0.62^{A}	81.51 ± 0.30^{Aa}	78.72 ± 0.30^{Bb}	81.16 ± 1.02^{A}
	4	80.90 ± 0.20^{A}	80.23 ± 0.22^{ABb}	80.40 ± 0.47^{ABa}	79.72 ± 0.53^{B}
Redness (a*)	0	-1.67 ± 0.03^{Cb}	-1.54 ± 0.19^{BCb}	-1.03 ± 0.06^{Ab}	-1.18 ± 0.27^{ABb}
	4	-0.12 ± 0.06^{Aa}	-0.59 ± 0.13^{Ba}	-0.21 ± 0.01^{Aa}	-0.10 ± 0.06^{Aa}
Yellowness (b*)	0	6.38 ± 0.02	6.80 ± 0.09	6.31 ± 0.31^{b}	6.77 ± 0.29
	4	7.02 ± 0.30	6.77 ± 0.06	7.04 ± 0.23^{a}	6.67 ± 0.38
Whiteness (W)[2)]	0	62.06 ± 0.55^{Aa}	61.11 ± 0.05^{ABa}	59.78 ± 1.06^{B}	60.84 ± 0.61^{AB}
	4	59.83 ± 0.77^{b}	59.93 ± 0.35^{b}	59.28 ± 0.45	59.71 ± 0.61

$^{A-C}$Means with different superscript in the same row significantly differ at $p<0.05$.
$^{a-b}$Means with different superscript in the same column significantly differ at $p<0.05$.
[1)]Treatments are the same as in Table 1.
[2)]$W = L^* - 3b^*$

effect on preservation of the whiteness. Given that whiteness is one of the most important factors in the perceived quality of surimi (Chen, 2002), high quality surimi is obtained when as much as possible of the dark muscle is removed (Ochiai *et al*., 2001). Jin *et al*. (2009) reported that ICS containing MDC surimi were less white and more yellow. Thus, addition of MDC hydrolysates may negatively influence the color of ICS.

Gel characteristics

The gel characteristics of ICS containing MDC hydrolysates are shown in Table 4. The breaking force values increased with storage time for all samples, but were higher in samples containing MDC hydrolysates compared to control (p<0.05). Deformation values were lower in the 0.5% MDC hydrolysate group compared to the control group at wk 0 (p<0.05) and the T3 group had the lowest deformation value at 4 wk. Jelly strength and gel strength significantly increased with storage time for all samples (p<0.05). Jelly strength was greater in samples containing MDC hydrolysates compared to the control samples (p<0.05). Also, the gel strength was greater in the samples containing 1.0 and 1.5% MDC hydrolysates compared to the control samples at wk 0 (p<0.05). Reppond and Babbitt (1997) reported that torsion stress and strain decreased linearly with increased moisture content of surimi, likely a result of lower myofibril protein concentration and decreased cross-link density (Sylvia *et al*., 1994). We found that the addition of MDC hydrolysates increased the breaking force and gel strength values. Thus, it is indicated that the physical strength of ICS may be increased by the addition of MDC hydrolysates.

Fatty acid composition

The fatty acid composition of ICS containing MDC hydrolysates is shown in Table 5. The saturated fatty acid (SFA) content was significantly higher in the control samples compared to the other groups. Monounsaturated fatty acid (MUFA) content was significantly lower in T2 and T3 than the other groups (p<0.05). However, the unsaturated fatty acid (UFA) content was higher in MDC hydrolysate containing samples compared to the control samples (p<0.05). Polyunsaturated fatty acid (PUFA) and essential fatty acids (EFA) were also significantly higher in T2 and T3 than in the other samples. Jin *et al*. (2009) showed that crab sticks containing MDC had a higher linoleic acid level. The increase in the UFA content, thought to have beneficial health properties (Belury, 2002), was positively related to MDC hydrolysate content. According to Kris-Etherton *et al*. (2003), n-3 fatty acids such as linolenic acid (C18:3, PUFA) are beneficial in reducing cardiovascular disease risk. Therefore, supplementation with MDC hydrolysates may have positive effects on health. However, the fatty acid composition can influence adipose tissue firmness; Wood *et al*. (2003) reported that when SFAs increase in animal diets, the fat profile moves towards a more stable composition. This may be partially due to the fact that UFAs are more prone to oxidation than SFAs (Du *et al*., 2001).

Lipid oxidation and DPPH radical scavenging activity

TBARS and DPPH values in ICS containing MDC hydrolysates are shown in Table 6. The TBARS values for all groups increased with storage time (p<0.05). In comparison to the control, all samples containing MDC hydrolysates had reduced TBARS values at 4 wk. Lipid oxidation, measured as TBARS, is a major factor in reducing the quality and acceptability of meat products; those with a high degree of unsaturation and fat content are more

Table 4. Gel characteristics of imitation crab stick containing MDC hydrolysates during storage

Items	Storage wk	Treatments[1)]			
		Control	T1	T2	T3
Breaking force (g)	0	288.00±8.54^{Bb}	363.33±29.30^{Ab}	361.33±32.04^{Ab}	358.00±35.68^{Ab}
	4	436.33±19.01^{Ca}	546.33±5.13^{Aa}	512.00±30.00^{Ba}	463.00±3.61^{Ca}
Deformation (mm)	0	8.57±0.25^{Aa}	7.01±0.06^{Bb}	7.71±0.58^{AB}	7.84±0.80^{ABa}
	4	7.47±0.15^{Ab}	7.17±0.06^{ABa}	6.64±0.52^{BC}	6.37±0.25^{Cb}
Jell strength (g/cm^2)	0	1466.77±43.52^{Bb}	1850.43±149.2^{Ab}	1840.25±163.2^{Ab}	1823.27±181.7^{Ab}
	4	2222.22±96.81^{Ca}	2782.45±26.14^{Aa}	2607.59±152.8^{Ba}	2358.04±18.36^{Ca}
Gel strength (g, cm)	0	246.77±1.45^{Bb}	254.40±19.46^{Bb}	278.45±8.64^{Ab}	278.81±4.11^{A}
	4	326.03±13.67^{Ba}	391.89±2.54^{Aa}	339.07±12.80^{Ba}	295.10±12.19^{C}

$^{A-C}$Means with different superscript in the same row significantly differ at p<0.05.
$^{a-b}$Means with different superscript in the same column significantly differ at p<0.05.
[1)]Treatments are the same as in Table 1.

Table 5. Fatty acid compositions (%) of imitation crab stick containing MDC hydrolysates

Fatty acids	Treatments[1)]			
	Control	T1	T2	T3
Myristic acid (C14:0)	0.78±0.01^{A}	0.72±0.01^{B}	0.66±0.01^{C}	0.63±0.01^{D}
Palmitic acid (C16:0)	16.54±0.12^{A}	16.39±0.05^{B}	16.27±0.05^{B}	16.13±0.01^{C}
Palmitoleic acid (C16:1)	2.06±0.90	1.48±0.01	1.16±0.01	1.20±0.01
Magaric acid (C17:0)	0.38±0.01^{A}	0.35±0.01^{B}	0.34±0.00^{C}	0.34±0.00^{C}
Magaolic acid (C17:1)	0.17±0.00^{A}	0.16±0.00^{B}	0.15±0.00^{C}	0.15±0.00^{C}
Stearic acid (C18:0)	6.23±0.03^{A}	6.08±0.02^{B}	6.18±0.05^{A}	6.08±0.03^{B}
Oleic acid (C18:1)	21.44±0.20^{B}	21.78±0.02^{A}	20.94±0.12^{C}	21.09±0.09^{C}
Linoleic acid (C18:2, n-6)	44.76±0.48^{C}	45.35±0.07^{B}	46.26±0.18^{A}	46.43±0.13^{A}
Linolenic acid (C18:3, n-3)	5.18±0.06^{B}	5.21±0.01^{B}	5.46±0.02^{A}	5.43±0.02^{A}
Arachidic acid (C20:0)	0.40±0.01	0.40±0.00	0.41±0.01	0.40±0.01
Eicosenoic acid (C20:1)	0.42±0.10^{B}	0.51±0.01^{AB}	0.57±0.01^{A}	0.51±0.01^{AB}
Eicosatrienoic acid (C20:4)	1.58±0.02^{A}	1.50±0.01^{C}	1.54±0.02^{B}	1.58±0.01^{A}
SFA[2)]	24.33±0.15^{A}	23.94±0.07^{B}	23.87±0.11^{B}	23.57±0.04^{C}
UFA	75.67±0.15^{C}	76.06±0.07^{B}	76.13±0.11^{B}	76.43±0.04^{A}
MUFA	24.08±0.66^{A}	23.93±0.02^{A}	22.82±0.12^{B}	22.95±0.11^{B}
PUFA	51.52±0.56^{B}	52.06±0.09^{B}	53.26±0.21^{A}	53.43±0.15^{A}
EFA	51.52±0.56^{B}	52.06±0.09^{B}	53.26±0.21^{A}	53.43±0.15^{A}

$^{A-C}$Means with different superscript in the same row significantly differ at $p<0.05$.
[1)]Treatments are the same as in Table 1.
[2)]Saturated fatty acid (SFA), unsaturated fatty acid (UFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), and essential fatty acid (EFA).

Table 6. TBARS and DPPH radical scavenging activity in imitation crab stick containing MDC hydrolysates during storage

Items	Storage wk	Treatments[1)]			
		Control	T1	T2	T3
TBARS (mg/100 g)	0	0.57±0.03^{b}	0.55±0.09^{b}	0.63±0.12^{b}	0.56±0.03^{b}
	4	1.65±0.02^{Aa}	1.52±0.02^{Ba}	1.50±0.07^{Ba}	1.54±0.04^{Ba}
DPPH (%)	0	17.10±0.36^{Ca}	19.00±0.60^{Ba}	19.67±0.67^{Ba}	21.87±0.32^{Aa}
	4	14.97±0.35^{Cb}	16.13±0.61^{Bb}	16.40±0.56^{Bb}	18.00±0.20^{Ab}

$^{A-C}$Means with different superscript in the same row significantly differ at $p<0.05$.
$^{a-b}$Means with different superscript in the same column significantly differ at $p<0.05$.
[1)]Treatments are the same as in Table 1.

susceptible to lipid oxidation (Morrissey *et al*., 1998). However, the TBARS values were not influenced by lipid content or fatty acid composition in the present study. TBARS values were low in the treatment groups, as expected, due to the addition of MDC hydrolysates. Inhibition of the formation of TBARS in beef homogenate by egg-yolk protein hydrolysate was found to be dose-dependent (Sakanaka and Tachibana, 2006). In addition, hydrolysate concentrations ranging from 1 to 2% have previously been shown to retard lipid oxidation in pork patties (Pena-Ramos and Xiong, 2003). In the current study, the TBARS values in ICS varied only minimally from 1.50 to 1.65, suggesting a non-significant effect of hydrosylate addition on this parameter.

In all treatment groups, DPPH radical scavenging activity decreased with storage time ($p<0.05$). Scavenging activity was greater in samples containing MDC hydrolysates compared to control samples and was also positively correlated with hydrolysate content. Reactive oxygen species are unstable, and readily react with many other chemical groups and substances in the body (Halliwell and Gutteridge, 1990). Wu *et al*. (2004) found that porcine hemoglobin hydrolysates, prepared by enzyme hydrolysis, had high DPPH radical scavenging activity. Liu *et al*. (2010) also found that the antioxidant activity of porcine plasma protein hydrolysate increased in parallel with DH. We found that DPPH radical scavenging activity in the present study was similar to that reported by Chang *et al*. (2004).

Conclusion

This study was carried out to compare the physicochemical properties of ICS containing different levels of MDC

hydrolysates. Addition of MDC hydrolysates resulted in a higher fat content and lower moisture content compared with control samples. Inclusion of MDC hydrolysates increased both the breaking force and jelly strength, and increased UFA content in a proportional manner. In particular, lipid oxidation was inhibited and free radical scavenging activity increased in the presence of the hydrolysates. This is novel data with regard to MDC hydrolysate peptides in ICS, but further research is needed to characterize the MDC hydrolysate peptides responsible for the antioxidant activity observed.

Acknowledgements

This work was supported by Technology Development Program for Ministry for Food, Agriculture, Forestry and Fisheries and the Priority Research Centers Program through the national research foundation of Korea (FRF) funded by the Ministry of Education, Science and Technology, Republic of Korea. The authors thank the Ministry of Education and Human Resources Development for the financial support of the BK21 Plus program in Korea.

References

1. AOAC. (2000) Official methods of analysis. Association of Official Analytical Chemists. 17th ed. Gaithersburg, MD.
2. Arihara, K., Nakashima, Y., Mukai, T., Ishikawa, S., and Itoh, M. (2001) Peptide inhibitors for angiotensin I-converting enzyme from enzymatic hydrolysates of porcine skeletal muscle proteins. *Meat Sci.* **57**, 319-324.
3. Belury, M. A. (2002) Dietary conjugated linoleic acid in health: Physiological effects and mechanisms of action. *An. Rev. Nutr.* **22**, 505-531.
4. Bhaskar, N., Modi, V. K., Govindaraju, K., Radha, C., and Lalitha, R. G. (2007) Utilization of meat industry by products: protein hydrolysate from sheep visceral mass. *Bioresour. Technol*. **98**, 388-394.
5. Brand-Williams, W., Cuvelier, M. E., and Berest, C. (1995) Use of a free radical method to evaluate antioxidant activity. *LWT-Food Sci. Technol.* **28**, 25-30.
6. Buege, J. A. and Aust, S. D. (1978) Microsomal lipid peroxidation. *Methods Enzymol.* **52**, 302-310.
7. Chang, C. Y., Wu, K. C., and Chiang, S. H. (2010) Antioxidant properties and protein compositions of porcine hemoglobin hydrolysates. *Food Chem.* **100**, 1537-1543.
8. Chen, H. H. (2002) Decoloration and gel-forming ability of horse mackerel mince by air-flotation washing. *J. Food Sci.* **67**, 2970-2975.
9. Daoud, R., Dubios, V., Bors-Dodita, L., Nedjar-Arroume, N., Krier, F., and Chihib, N. E. (2005) New antibacterial peptide derived from bovine hemoglobin. *Peptides* **26**, 713-719.
10. Du, M., Nam, K. C., and Ahn, D. U. (2001) Cholesterol and lipid oxidation products in cooked meat as affected by raw-meat packaging and irradiation and by cooked-meat packaging and storage time. *J. Food Sci.* **66**, 1396-1401.
11. Folch, J., Lees, M., and Sloane-Stanley, G. H. (1957) A simple method for the isolation and purification of total from animal tissues. *J. Biol. Chem.* **226**, 497-509.
12. Halliwell, B. and Gutteridge, J. M. C. (1990) Role of free radicals and catalytic metal ions in human disease: an overview. *Methods Enzymol.* **186**, 1-85.
13. Jang, A. and Lee, M. (2005) Purification and identification of angiotensin converting enzyme inhibitory peptides from beef hydrolysates. *Meat Sci.* **69**, 653-661.
14. 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.
15. Jin, S. K., Kim, I. S., Kim, S. J., Jeong, K. J., Choi, Y. J., and Hur, S. J. (2007) Effect of muscle type and washing times on physic-chemical characteristics and qualities of surimi. *J. Food Eng.* **81**, 618-623.
16. Jung, C. H., Kim, J. S., Jin, S. K., Kim, I. S., Jung, K. J., and Choi, Y. J. (2004) Gelation properties and industrial application of functional protein from fish muscle-2. Properties of functional protein gel from fish, chicken breast and pork leg and optimum formulation. *J. Food Sci. Nutr.* **33**, 1676-1684.
17. Kris-Etherton, P. M., Harris, W. S., and Appel, L. J. (2003) Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. *Arterioscler. Thromb. Vasc. Biol.* **23**, e20-e30.
18. Lanier, T. C. (2000) Surimi gelation chemistry. In: Surimi and surimi seafood. Park, J. W. (ed) Marcel Dekker. New York. pp. 237-265.
19. Li, B., Chen, F., Xang, X., Ji, B., and Wu, Y. (2007) Isolation and identification of antioxidative peptides from porcine collagen hydrolysate by conseutive chromatography and electrospray ionization-mass spectrometry. *Food Chem.* **102**, 1135-1143.
20. Liu, Q., Kong, B., Xiong, Y. L., and Xia, X. (2010) Antioxidant activity and functional properties of porcine plasma protein hydrolysate as influenced by the degree of hydrolysis. *Food Chem.* **118**, 403-410.
21. Morrissey, P. A., Sheehy, P. J. A., Galvin, K., and Kerry, J. P. (1998) Lipid stability in meat and meat products. *Meat Sci.* **49**, 73-86.
22. Nowasd, A. A. A. K. M., Kanoh, S., and Niwa, E. (2000) Thermal gelation characteristics of breast and thigh muscles of spend hen and broiler and their surimi. *Meat Sci.* **54**, 169-175.
23. 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.
24. Park, S., Brewer, M. S., Novakofski, J., Bechtel, P. J., and McKeith, F. K. (1996) Process and characteristics for a surimi-like material made from beef or pork. *J. Food Sci.* **61**, 422-427.
25. Pena-Ramos, E. A. and Xiong, Y. L. (2003) Whey and soy protein hydrolysates inhibit lipid oxidation in cooked pork pat-

ties. *Meat Sci.* **64**, 259-263.

26. 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.
27. Rawdkuen, S., Benjakul, S., Visessanguan, W., and Lanier, T. C. (2004) Chicken plasma protein: Proteinase inhibitory activity and its effect on surimi gel properties. *Food Res. Int.* **37**, 156-165.
28. Reppond, K. D. and Babbitt, J. K. (1993) Protease inhibitors affect physical properties of arrowtooth flounder and walleye Pollock surimi. *J. Food Sci.* **58**, 96-98.
29. SAS Institute. (2000) User's Guide: Version 8.2. SAS Institute Inc., Cary, NC, USA.
30. Saiga, A., Okumura, T., Makihara, T., Katsuta, S., Shinizu, T., Yamada, R., and Nishimura. T. (2003a) Angiotensin I-converting enzyme inhibitory peptides in a hydrolyzed chicken breast muscle extract. *J. Agric. Food Chem.* **51**, 1741-1745.
31. Saiga, A., Tananbe, S., and Nishimura, T. (2003b) Antioxidnat activity of peptides obtained from porcine myofibrillar proteins by protease treatment. *J. Agric. Food Chem*. **51**, 3661-3667.
32. Sakanaka, S. and Tachibana, Y. (2006) Active oxygen scavenging activity of egg-yolk protein hydrolysates and their effects on lipid oxidation in beef and tuna homogenates. *Food Chem.* **95**, 243-249.
33. Shahidi, F., Han, X., and Synowiecki, J. (1995) Production and characteristics of protein hydrolysates from capelin (Mallotus villosus). *Food Chem.* **53**, 285-293.
34. Smith, D. M. (1987) Functional and biochemical change in deboned turkey due to frozen storage and lipid oxidation. *J. Food Sci.* **52**, 22-27.
35. Sylvia, S. F., Claus, J. R., Mariott, N. G., and Eigel, W. N. (1994) Low-fat, high-moisture frankfurters: Effects of temperature and water during extended mixing. *J. Food Sci.* **59**, 937-940.
36. Vilhelmsson, O. (1997) The state of enzyme biotechnology in the fish processing industry. *Trends Food Sci. Technol.* **8**, 266-270.
37. Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., Kasapidou, E., Sheard, P. R., and Enser, M. (2003) Effect of fatty acids on meat quality: a review. *Meat Sci.* **66**, 21-32.
38. Wu, K. C., Lin, Z. Y., Chiang, S. H., and Chang, C. Y. (2004) Antioxidant properties of porcine blood proton before and after enzymatic hydrolysis. *J. Biomass Energ. Soc. China.* **23**, 79-85.

(Received 2013.12.27/Revised 2014.3.6/Accepted 2014.3.6)