Preparations and Properties of Surimi Gels from Tilapia and Red Tilapia

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Received 25 September 2007; accepted 31 January 2008

Abstract

The objective of this study was to investigate the effect of heating conditions on properties of tilapia (*Oreochromis niloticus*) and red tilapia (*O. niloticus* x *O. placidus*) surimi gels. A two-step heating process was used to prepare surimi gels. For the first step of heating, combinations of five heating temperatures (40, 45, 50, 60 and 70 ^{o}C) and four heating times (30, 60, 90 and 120 min) were studied. The gels obtained were later heated at 90 ^{o}C for 30 min in the second step of heating. Surimi gels from both fishes possessed highest gel strength when heated in the first step at 45 ^{o}C for 60 min. The gels heated at 70 ^{o}C possessed lowest gel strength. Under the same heating condition, tilapia surimi gels generally exhibited higher gel strength and water holding capacity than red tilapia surimi gels. The whiteness of the gels with different heating conditions was not significantly different, except that of tilapia surimi gels heated at 70 ^{o}C.

Keywords: Tilapia; Red tilapia; Tabtim fish; Surimi

INTRODUCTION

Surimi is obtained by mincing fish flesh, followed by washing steps in order to remove water-soluble components, mainly sarcoplasmic proteins, blood and enzymes. The washed mince is then pressed to remove excess water and added with cryoprotectant to prevent protein denaturation during freezing and frozen storage. High in protein and low in fat, surimi is white in color while having no fishy odor and possesses good gelling property. Surimi is an intermediate product that is used in the formulation of various food products ranging from traditional products of Japan such as chikuwa, kamaboko and hanpen, to seafood analogs and even pet foods.

Thailand is currently one of the leading exporters of surimi. For the first quarter of 2007, Thailand exported 23,646 metric tons of surimi and other minced fish products, valued at 1,747 million Baht (The 2007 fisheries economics status, 2007). Major fish species used for surimi production in Thailand include threadfin bream (*Nemipterus* spp.), bigeye snapper (*Priacanthus tayenus*) and other marine fishes (Holmes et al., 1992). However, due to the decline in catch of marine fishes worldwide, there has been an attempt to find new resources for surimi industry. Several researchers have reported the production of surimi from fresh-water and brackish-water fishes such as common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), big-head carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idellus*), mud carp (*Cirrhinus molitorella*), Chinese snake-head (*Ophiocephalus argus*) and blunt snout bream (*Megalobrama amblycephala*) (Luo et al., 2001; Wang et al., 2005). Surimi from tilapia has been the subject of interest by various researchers (Ahmad et al., 2005; Gopakumar et al., 1992; Tejada et al., 1995; Viratchakul et al., 2000; Xichang et al., 2005; Yongsawatdigul et al., 2000; Zhou et al., 2006). On the other hand, report on surimi from red tilapia (*Oreochromis niloticus* x *O. placidus*) is very rare.

Red tilapia (*O. niloticus* x *O. placidus*), or Tabtim fish, is a hybrid between the Nile tilapia and black tilapia. This red variety of tilapia was developed by Charoen Pokphand Foods in 1989 (The Tabtim fish, 2007). This red tilapia has quick growth rate, good food conversion and excellent disease resistance. It yields tasty white flesh that has good texture and less soil flavor.

One of the most important determinants of surimi quality is its ability to form gel (Saeki et al., 1995). Surimi from different fish species possesses different gel-forming ability. The objective of this study was to investigate the effect of heating conditions on properties of tilapia (*O.* niloticus) and red tilapia (*O. niloticus* x *O. placidus*) surimi gels.

MATERIALS AND METHODS

Materials

Whole tilapia (*Oreochromis niloticus*) and red tilapia (*O. niloticus* x *O. placidus*) were purchased fresh from local market (Samyan Market, Bangkok) and transported on ice in an insulated container to the laboratory within 1 h.

Immediately after arrival, they were processed into surimi.

The ingredients used in the surimi formulations were sodium chloride, sodium tripolyphosphate, sorbitol and sucrose. All chemicals were of food grade.

Frozen surimi production

For both fishes, the same procedure for producing frozen surimi was used. The fish was headed, gutted and washed with water. The washed fish was then manually filleted to obtain only white muscle. The fillet was minced using a meat grinder attached to a Kenwood mixer (model A907, Long Beach, CA). The minced fish was mixed with iced water (minced fish : iced water = 1 : 4 by weight) and stirred for 5 min, then held without stirring for 5 min. The temperature of the mince-water mixture was kept at 10 °C or below. After filtered through several layers of cheese cloth, the mince obtained was washed for a second time using the same procedure as the first washing. For third washing, chilled 0.3% sodium chloride solution was used instead of water. After the third wash, excess water was removed from the mince using a hydraulic press. The washed mince was finally mixed with 4% sucrose, 4% sorbitol and 0.3% sodium tripolyphosphate in a Kenwood mixer (model A907, Long Beach, CA) for 5 min. The fresh surimi obtained was packed into low-density polyethylene (LDPE) bag, cryogenically frozen and then stored at -20 °C until needed.

Surimi gel preparation

The frozen surimi was thawed in a 25 °C water bath until its temperature reached about 2 ± 2 °C. The thawed surimi was placed in a Mara food processor (model 2102240, Taipei, Taiwan) and chopped for 2 min. Moisture content of the surimi was adjusted to 78% using ice. With the addition of 2.5% sodium chloride, the surimi mixture was chopped for 2 min to obtain a homogeneous surimi paste. During this mixing process, temperature of the surimi paste was kept at 10 °C or below. The surimi paste was finally put in a cylindrical stainless steel mold (3 cm i. d., 3 cm height). The mold was tightly sealed and placed in a water bath at a designated temperature.

A two-step heating process was used to prepare surimi gel in this study. For the first step of heating, heating temperature and heating time were varied in order to study the effect of heating conditions on properties of surimi gel. Five heating temperatures (40, 45, 50, 60 and 70 °C) and four heating times (30, 60, 90 and 120 min) were studied using a 5 x 4 factorial design. For the second step of heating, the gel was heated in a 90 °C water bath for 30 min. The fully-set gel was then cooled immediately in an ice bath for 10 min. The gel was then unmolded, placed in an LDPE bag and stored at 4 °C for 12 h before undergone further analyses.

Surimi gel properties

Gel strength

Gel strength was measured by a compression test according to the procedure outlined by Lanier (1992) using a Texture Analyzer (model TA-XT2, Stable Micro Systems, Surrey, UK). Cylindrical surimi gel sample of 3 cm in diameter and 3 cm in height was equilibrated and tested at 25 °C. The gel strength (g·cm) were measured using a P0.25S plunger with a test speed of 1.1 mm/s.

Folding test

Surimi gel quality was also evaluated using a folding test according to Lee (1984). A 3-mm thick slice was folded into four quarters. A gel that can be folded into four without producing any crack was rated as "AA" quality. An "A" quality gel can be folded into two without cracking but a crack(s) occur(s) when folded in four. A "B" quality gel produced a minor crack(s) when folded in two. A "C" quality gel spitted into two pieces when folded in two while a "D" quality gel came apart when just pressed with finger.

Water holding capacity

Water holding capacity, expressed as expressible drip, was evaluated according to the following method. A 5-mm thick surimi gel was weighed. Two pieces of Whatman No. 1 filter paper were placed over the gel piece and three pieces of the filter paper were placed under the gel piece. The gel was then pressed using 10 kg/cm^2 pressure for 2 min and the gel piece was weighed again. Expressible drip was calculated using the following formula:

$$\% \text{ Expressible drip} = [(g\ sample_{before\ press} - g\ sample_{after\ press})/g\ sample_{before\ press}] \times 100.$$

Gel color

Gel color was measured as CIE L^* (lightness), a^* (green-red) and b^* (yellow-marine) using a Chromameter (model CR300, Minolta, Tokyo, Japan). Whiteness was calculated using the following formula:

$$\text{Whiteness} = 100 - [(100-L^*)^2 + (a^*)^2 + (b^*)^2]^{1/2} \quad .$$

Effect of endogenous protease on surimi gels

Crude actomyosin was extracted from the red tilapia surimi according to the method of MacDonald & Lanier (1994). Surimi sample (4 g) was homogenized in 40 ml chilled 0.6 M potassium chloride solution (pH 7.0) for 4 min. Each 20 sec blending was followed by a 20 sec resting in an ice bath to avoid overheating of the sample until reaching a total blending time of 4 min. The extract was centrifuged at 5,000 x g for 30 min at 0 °C. Three volumes of chilled deionized water were added to precipitate actomyosin. To obtain actomyosin, the suspension was centrifuged at 5,000 x g for 20 min at 0 °C. The pellet was dissolved by stirring for 30 min in an equal volume of chilled 1.2 M potassium chloride solution (pH 7.0). Undissolved material was removed from the preparation by centrifugation at 5,000 x g for 20 min at 0 °C.

Crude protease was extracted from the fish flesh as described by Boye & Lanier (1988). Minced fish (100 g) was homogenized in 200 ml chilled 0.2 M sodium phosphate buffer (pH 7.0) for 1 min. The homogenate was held at 4 °C for 45 min and then centrifuged at 12,000 x g for 30 min. The supernatant was filtered through Whatman No. 4 paper to remove floating fat and dialyzed against chilled 0.2 M sodium phosphate buffer (pH 7.0) overnight. The supernatant was then centrifuged at 12,000 x g for 20 min and the resulting supernatant was used as the crude protease source.

Crude protease was then incubated with crude actomyosin in phosphate buffer (pH 6.5) at the temperature that gave the lowest surimi gel strength for 0, 30, 60, 90 and 120 min. A 0.5 g sample was then solubilized with 20 ml of 0.05 M sodium phosphate buffer (pH 7.2) containing 8 M urea, 2% sodium dodecyl sulfate and 10% 2-mercaptoethanol. An aliquot of 10 µl from each solubilized sample was subjected to sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), using 4% stacking polyacrylamide gel and 12.5% separating polyacrylamide gel (Laemmli, 1970).

Statistical analysis

Data were analyzed using Analysis of Variance (ANOVA). A Duncan's New Multiple Range Test was used to determine the differences among sample means at $p = 0.05$.

RESULTS

Table 1 shows the tilapia and red tilapia flesh yields obtained after filleting and mince washing steps. Heating conditions were found to significantly affect ($p \leq 0.05$) gel strength of surimi gels from tilapia and red tilapia (Tables 2 and 3). Surimi gels from both fishes possessed highest gel strength when heated in the first step at 45 °C for 60 min, followed by a second-step heating at 90 °C for 30 min. Inferior gel strength observed at higher heating temperature (70 °C) could be due to action of fish endogenous proteases on the fish protein. This was later confirmed by SDS-PAGE as shown in Figure 1. Tables 4 and 5 show the quality of the tilapia and red tilapia surimi gels as evaluated using a folding test. The folding test results were found to be in good agreement with the gel strength measurement. Water holding capacity of the gels was assessed in terms of expressible drip as indicated in Tables 6 and 7. There was a relationship between water holding capacity and gel strength of the surimi gels. The results of CIE L^*, a^* and b^* and whiteness of surimi gels from tilapia and red tilapia were as shown in Tables 8 and 9. Different heating conditions were found to minimally affect whiteness of the surimi gels.

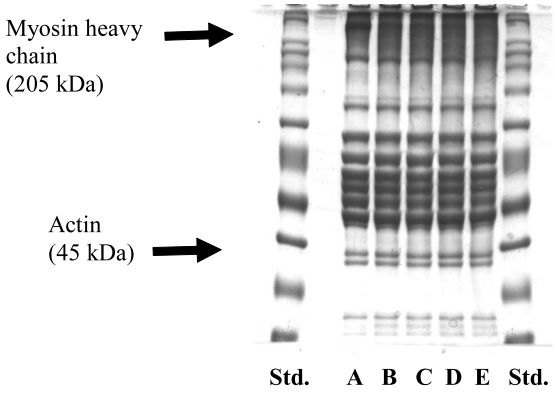

Figure 1. SDS-PAGE patterns of red tilapia heated at 70 °C for 0 to120 min (Std. = protein standard; A = 0 min; B = 30 min; C = 60 min; D = 90 min; E = 120 min).

Table 1. Flesh yield of the tilapia and red tilapia

Type of flesh	Yield (%)	
	Tilapia	Red tilapia
Fish fillet (without skin, white muscle only)	24.46 ± 5.39^{a}	21.25 ± 4.22^{b}
Washed mince	21.32 ± 2.06^{a}	18.72 ± 3.40^{b}

Means within a row which do not share a common superscript letter differ significantly ($p \leq 0.05$).

Table 2. Gel strength of tilapia surimi gel as a function of heat treatment

Temperature	Gel strength (g·cm)			
(^{o}C)	30 min	60 min	90 min	120 min
40	$1{,}115.42 \pm 96.62^{bc}$	$1{,}199.54 \pm 99.84^{ab}$	$1{,}100.46 \pm 112.79^{bc}$	$1{,}086.98 \pm 98.93^{c}$
45	$1{,}155.03 \pm 67.88^{b}$	$1{,}262.97 \pm 39.12^{a}$	$1{,}183.90 \pm 105.68^{ab}$	$1{,}146.89 \pm 109.77^{b}$
50	$1{,}056.37 \pm 80.36^{c}$	$1{,}170.50 \pm 54.95^{ab}$	$1{,}094.47 \pm 78.36^{bc}$	999.36 ± 48.39^{c}
60	807.57 ± 38.86^{d}	449.91 ± 22.32^{e}	417.49 ± 57.49^{e}	338.47 ± 59.47^{f}
70	414.18 ± 30.58^{e}	382.67 ± 39.09^{ef}	330.56 ± 34.03^{f}	308.03 ± 47.01^{f}

Means which do not share a common superscript letter differ significantly ($p \leq 0.05$).

Table 3. Gel strength of red tilapia surimi gel as a function of heat treatment

Temperature	Gel strength (g·cm)			
(^{o}C)	30 min	60 min	90 min	120 min
40	547.26 ± 118.27^{b}	546.48 ± 77.12^{b}	585.84 ± 95.49^{b}	600.74 ± 82.56^{b}
45	830.57 ± 20.77^{a}	889.00 ± 47.40^{a}	850.33 ± 26.98^{a}	845.84 ± 59.38^{a}
50	535.07 ± 103.52^{b}	518.07 ± 85.85^{b}	541.74 ± 85.09^{b}	588.02 ± 24.67^{b}
60	544.55 ± 87.98^{b}	217.04 ± 86.10^{c}	296.56 ± 45.34^{c}	254.23 ± 38.35^{c}
70	237.96 ± 65.37^{c}	72.89 ± 7.83^{d}	74.28 ± 8.11^{d}	70.39 ± 7.58^{d}

Means which do not share a common superscript letter differ significantly ($p \leq 0.05$).

Table 4. Results of folding test of tilapia surimi gel as a function of heat treatment

Temperature	Quality as evaluated using a folding test			
(^{o}C)	30 min	60 min	90 min	120 min
40	AA	AA	AA	AA
45	AA	AA	AA	AA
50	AA	AA	AA	AA
60	AA	A	A	A
70	A	A	A	A

AA - No cracks occur even if folded in four

A - No cracks occur if folded in two, but a crack(s) occur(s) if folded in four

Table 5. Results of folding test of red tilapia surimi gel as a function of heat treatment

Temperature	Quality as evaluated using a folding test			
(^{o}C)	30 min	60 min	90 min	120 min
40	AA	AA	AA	AA
45	AA	AA	AA	AA
50	AA	AA	AA	AA
60	AA	B	A	B
70	B	D	D	D

AA - No cracks occur even if folded in four

A - No cracks occur if folded in two, but a crack(s) occur(s) if folded in four

B - A minor crack(s) occur(s) if folded in two

D - Gel comes apart when pressed with finger

Table 6. Expressible drip of tilapia surimi gel as a function of heat treatment

Temperature	% Expressible drip			
(^{o}C)	30 min	60 min	90 min	120 min
40	9.38 ± 0.25^{f}	9.18 ± 0.21^{f}	9.73 ± 0.47^{f}	10.03 ± 0.07^{e}
45	9.25 ± 0.09^{f}	8.46 ± 0.63^{g}	9.02 ± 0.50^{fg}	9.84 ± 0.13^{f}
50	10.90 ± 0.44^{e}	9.13 ± 0.09^{f}	10.00 ± 0.41^{e}	10.21 ± 0.56^{e}
60	10.91 ± 0.52^{e}	13.11 ± 0.87^{d}	14.40 ± 0.82^{bc}	15.04 ± 0.22^{b}
70	15.63 ± 0.07^{ab}	15.75 ± 0.26^{a}	15.91 ± 0.14^{a}	16.02 ± 0.80^{a}

Means which do not share a common superscript letter differ significantly ($p \leq 0.05$).

Table 7. Expressible drip of red tilapia surimi gel as a function of heat treatment

Temperature (°C)	% Expressible drip			
	30 min	60 min	90 min	120 min
40	12.92 ± 0.08^{c}	12.75 ± 0.23^{c}	12.24 ± 0.19^{c}	12.80 ± 0.16^{c}
45	10.54 ± 0.12^{d}	10.40 ± 0.11^{d}	10.67 ± 0.10^{d}	10.50 ± 1.00^{d}
50	12.92 ± 0.40^{c}	12.99 ± 0.31^{c}	12.74 ± 0.32^{c}	12.00 ± 0.45^{c}
60	12.51 ± 0.26^{c}	16.50 ± 0.29^{b}	16.05 ± 0.75^{b}	16.28 ± 0.98^{b}
70	16.35 ± 1.09^{b}	24.80 ± 2.98^{a}	23.57 ± 3.50^{a}	23.33 ± 3.24^{a}

Means which do not share a common superscript letter differ significantly ($p \leq 0.05$).

Table 8. CIE L*, a*, b* and whiteness of tilapia surimi gel as a function of heat treatment

Temperature (°C)	Time (min)	L*	a*	b*	Whiteness
40	30	78.14 ± 0.40^{b}	-1.95 ± 0.12^{b}	0.58 ± 0.18^{b}	78.05 ± 0.41^{b}
	60	77.12 ± 0.44^{b}	-2.04 ± 0.06^{b}	0.51 ± 0.08^{b}	77.02 ± 0.44^{b}
	90	77.19 ± 0.15^{b}	-1.99 ± 0.09^{b}	0.38 ± 0.02^{b}	77.10 ± 0.15^{b}
	120	79.48 ± 0.39^{b}	-1.98 ± 0.04^{b}	0.45 ± 0.03^{b}	79.38 ± 0.40^{b}
45	30	77.22 ± 0.20^{b}	-1.94 ± 0.09^{b}	0.23 ± 0.02^{b}	77.14 ± 0.20^{b}
	60	77.04 ± 0.86^{b}	-1.97 ± 0.13^{b}	0.21 ± 0.08^{b}	76.95 ± 0.86^{b}
	90	78.38 ± 0.74^{b}	-2.00 ± 0.08^{b}	0.17 ± 0.04^{b}	78.29 ± 0.75^{b}
	120	77.15 ± 0.95^{b}	-2.01 ± 0.05^{b}	0.21 ± 0.07^{b}	77.06 ± 0.95^{b}
50	30	77.20 ± 0.36^{b}	-2.05 ± 0.08^{b}	0.10 ± 0.08^{b}	77.11 ± 0.36^{b}
	60	77.14 ± 0.65^{b}	-2.08 ± 0.05^{b}	0.01 ± 0.02^{b}	77.05 ± 0.65^{b}
	90	77.14 ± 0.25^{b}	-2.11 ± 0.10^{b}	0.02 ± 0.05^{b}	77.04 ± 0.25^{b}
	120	77.35 ± 0.58^{b}	-2.05 ± 0.03^{b}	0.08 ± 0.05^{b}	77.26 ± 0.59^{b}
60	30	79.34 ± 0.87^{b}	-2.14 ± 0.12^{b}	0.08 ± 0.02^{b}	79.23 ± 0.87^{b}
	60	79.74 ± 0.80^{b}	-2.07 ± 0.09^{b}	-0.25 ± 0.09^{b}	79.63 ± 0.80^{b}
	90	80.20 ± 0.48^{b}	-2.00 ± 0.05^{b}	0.09 ± 0.05^{b}	80.10 ± 0.48^{b}
	120	80.20 ± 0.88^{b}	-2.25 ± 0.18^{b}	0.12 ± 0.03^{b}	80.07 ± 0.88^{b}
70	30	84.20 ± 1.58^{a}	-1.15 ± 0.07^{a}	2.73 ± 0.16^{a}	83.92 ± 1.58^{a}
	60	84.98 ± 0.99^{a}	-1.32 ± 0.11^{a}	3.01 ± 0.33^{a}	84.62 ± 1.00^{a}
	90	84.56 ± 1.00^{a}	-1.32 ± 0.08^{a}	2.44 ± 0.38^{a}	84.31 ± 1.00^{a}
	120	86.57 ± 0.67^{a}	-1.32 ± 0.09^{a}	2.50 ± 0.07^{a}	86.28 ± 0.67^{a}

Means within a column which do not share a common superscript letter differ significantly ($p \leq 0.05$).

Table 9. CIE L*, a*, b* and whiteness of red tilapia surimi gel as a function of heat treatment

Temperature (°C)	Time (min)	L*	a* ^{ns}	b*	Whiteness
40	30	79.34 ± 0.27^{b}	-2.10 ± 0.29	2.09 ± 0.44^{c}	79.13 ± 0.27^{b}
	60	79.86 ± 0.63^{b}	-2.00 ± 0.12	1.93 ± 0.30^{c}	79.67 ± 0.63^{b}
	90	79.53 ± 2.75^{b}	-2.23 ± 0.11	1.88 ± 0.46^{c}	79.32 ± 2.75^{b}
	120	80.21 ± 0.89^{b}	-2.23 ± 0.11	1.94 ± 0.28^{c}	79.99 ± 0.89^{b}
45	30	79.54 ± 0.64^{b}	-2.11 ± 0.06	2.00 ± 0.05^{c}	79.33 ± 0.64^{b}
	60	79.12 ± 0.75^{b}	-2.22 ± 0.08	1.93 ± 0.09^{c}	78.91 ± 0.75^{b}
	90	79.35 ± 0.13^{b}	-2.05 ± 0.04	1.92 ± 0.03^{c}	79.16 ± 0.13^{b}
	120	79.88 ± 0.25^{b}	-2.30 ± 0.47	1.94 ± 0.05^{c}	79.66 ± 0.26^{b}
50	30	80.21 ± 1.18^{b}	-2.20 ± 0.18	1.74 ± 0.30^{c}	80.01 ± 1.18^{b}
	60	78.86 ± 0.67^{b}	-2.23 ± 0.16	1.76 ± 0.05^{c}	78.67 ± 0.67^{b}
	90	79.33 ± 0.23^{b}	-2.24 ± 0.18	1.76 ± 0.17^{c}	79.13 ± 0.23^{b}
	120	79.56 ± 0.45^{b}	-2.22 ± 0.06	1.76 ± 0.34^{c}	79.36 ± 0.45^{b}
60	30	79.97 ± 0.73^{b}	-2.23 ± 0.13	2.16 ± 0.20^{c}	79.73 ± 0.74^{b}
	60	80.52 ± 0.61^{b}	-2.23 ± 0.08	2.59 ± 0.50^{a}	80.22 ± 0.61^{b}
	90	80.23 ± 0.83^{b}	-2.30 ± 0.10	2.17 ± 0.38^{c}	79.98 ± 0.83^{b}
	120	83.65 ± 1.13^{a}	-2.22 ± 0.12	2.22 ± 0.16^{c}	83.35 ± 1.13^{a}
70	30	81.47 ± 1.15^{b}	-2.20 ± 0.13	2.32 ± 0.31^{b}	81.20 ± 1.15^{b}
	60	80.70 ± 0.47^{b}	-2.18 ± 0.06	2.70 ± 0.27^{a}	80.39 ± 0.47^{b}
	90	80.33 ± 0.87^{b}	-2.20 ± 0.17	2.71 ± 0.30^{a}	80.02 ± 0.88^{b}
	120	80.50 ± 0.98^{b}	-2.20 ± 0.04	2.71 ± 0.87^{a}	80.19 ± 0.98^{b}

Means within a column which do not share a common superscript letter differ significantly ($p \leq 0.05$).

^{ns} Means within a column do not differ significantly ($p > 0.05$).

DISCUSSION

Tilapia was shown to have slightly higher yields ($p \leq 0.05$) obtained after filleting and mince washing steps as compared to red tilapia (Table 1). Effect of heating conditions on properties of surimi gels was investigated. From the ANOVA, it was found that heating temperature, heating time, and the interaction between heating temperature and heating time, had an effect on gel strength of the surimi gels ($p \leq 0.05$). For tilapia surimi, the gels heated in the first step at 45 °C for 60 min exhibited highest gel strength. However, this was not significantly different from the gels heated at 40 °C for 60 min, 45 °C for 90 min and 50 °C for 60 min. The finding was similar to that reported by Viratchakul et al. (2000). The gels heated at 70 °C possessed the lowest gel strength. An et al. (1994) and Park et al. (1997) stated that fish endogenous proteases have highest activity when the temperature is in the range of 60 to 70 °C. Proteases from different fish species were reported to have different optimum temperature for their activity. For example, alkaline proteases of white croaker, Atlantic menhaden and Pacific whiting exhibited highest activity at 60, 60 and 55 °C, respectively (Boye & Lanier, 1988; Chang-Lee et al., 1989; Makinodan et al., 1985). The protease activity greatly affected the degradation of myosin heavy chain (MHC) of the fish protein, which, in turn, had an effect on surimi gel quality.

For red tilapia surimi, the gels heated at 45 °C for either 30, 60, 90 or 120 min possessed highest gel strength. Similar to the tilapia surimi gels, the red tilapia surimi gels heated at 70 °C exhibited the lowest gel strength. This may be due to the fact that both fishes were closely related and were grown in tropical climate, thus possessing similar optimum temperature for protease activity. Under the same heating conditions, surimi gel from red tilapia generally exhibited lower gel strength than that from tilapia.

Myosin heavy chain (MHC) plays a crucial role in heat-induced gelation of surimi. The effect of endogenous fish protease on MHC of the fish protein was also investigated in this study using SDS-PAGE. Red tilapia surimi was chosen because it had shown pronounced gel quality deterioration at higher heating temperature (70 °C). The red tilapia crude protease was mixed with crude actomysin extracted from the red tilapia surimi and the mixture was then incubated at 70 °C. The SDS-PAGE patterns of the red tilapia surimi were shown in Figure 1. It was found that as the incubation time increased, the intensity of MHC band decreased. This MHC degradation as a result of protease activity highly supported the inferior gel quality obtained when heated at 70 °C.

As evaluated using a folding test, tilapia surimi gels heated at either 40, 45 or 50 °C were rated as AA quality while those heated at 60 or 70 °C were of A quality (Table 4). The same trend was also observed in red tilapia surimi gels (Table 5), except that the red tilapia surimi gels heated at higher temperatures (60 and 70 °C) exhibited inferior quality. It could be seen that folding test can be used as a tool to differentiate between high quality and low quality surimi gels. However, it was not as sensitive as objective methods (Tables 2 and 3) in discriminating gels with similar quality. The lack of sensitivity of folding test was also reported by Reppond et al. (1987).

Water holding capacity of the gels was assessed in terms of expressible drip (Tables 6 and 7). For both tilapia and red tilapia surimi gels, the samples heated at 45 °C for 60 min exhibited lowest expressible drip, or highest water holding capacity. There was a relationship between water holding capacity and gel strength of the surimi gels. Surimi gels with higher gel strength generally possessed higher water holding capacity. The gels heated at 70 °C, exhibited highest expressible drip, or lowest water holding capacity. Chang-Lee et al. (1989) reported a relationship between expressible drip and protease activity. It was found that as the protease activity increased, the expressible drip also increased.

The whiteness of the tilapia gels was in the range of 76.95 to 86.28 (Table 8) while that of the red tilapia surimi gels was in the range of 78.67 to 83.35 (Table 9). The whiteness of the gels heated using different heating conditions was not significantly different ($p > 0.05$), except that of tilapia surimi gels heated at 70 °C. This can be due to the fact that only white muscle of the fish was used in the surimi production. Moreover, there were also washing steps which eliminate the majority of blood and fat, resulting in a gel product with opaque white color (Pacheco-Aguilar et al., 1989).

CONCLUSION

This study showed that tilapia (*Oreochromis niloticus*) and red tilapia (*O. niloticus* x *O. placidus*) can be used as raw material for surimi production. Heating condition significantly affected gel strength and water holding capacity of the surimi gel. Tilapia and red tilapia surimi gels exhibited similar response to heat treatments. Surimi gels from both fishes possessed highest gel strength when using the first-step heating at 45 °C for 60 min, followed by a second-step heating at 90 °C for 30 min. Tilapia surimi gels generally possessed higher gel strength and water holding capacity than red tilapia surimi gels.

ACKNOWLEDGEMENTS

The support to this work was attributed to the research project entitled 'Development for Agro-Industry and Food Industry Project' funded by the Bureau of the Budget of the Prime Minister's Office, Thailand.

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