

Quality of Fish Ball from Surimi as Affected by Starch and Sterilizing Conditions

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ABSTRACT

Effects of starch and sterilizing conditions on the quality of surimi protein gel formed in fish ball were investigated by measuring gel strength (GS), water holding capacity (WHC), folding test, whiteness and SDS-PAGE. Before sterilization, addition of 5% tapioca flour (TF), corn flour (CF), wheat flour (WF) or modified starch (MS) to SA grade surimi promoted GS of fish balls better than that without starch but WHC was not significantly different ($p > 0.05$). On the contrary, after sterilization at 112°C and 116°C with the F_0 values of 3 and 6 min, the GS of fish balls with starch decreased at 47-58% more than that without starch which decreased at 11-38% while WHC decreased slightly. Sterilized fish balls without starch had the highest GS at 112°C F_0 of 3 min and the highest WHC at 116°C F_0 of 3 min. Comparing within fish balls with starch, fish ball with MS and WF sterilized at 116°C F_0 3 min had higher GS than the others. However, the sensory scores of texture and overall liking of fish balls with MS heated at 112°C F_0 of 3 min and that without starch at 116°C F_0 of 3 and 6 min were not significantly different ($p > 0.05$). The whiteness slightly decreased after sterilization and all samples were rated AA in the folding tests.

Key words: protein gel, starch, sterilization, thermal processing, canned fish ball.

INTRODUCTION

Texture is an important property of fish jelly products such as kamaboko and fish ball. Starch addition is one of the methods to improve textural properties of fish jelly products. In the protein-starch system, starch participates in gel formation as a dispersed phase whereas protein does so as a continuous phase (Lee *et al.*, 1992). Gelatinization of starch in the protein gel is influenced by heating temperature, degree of swelling and water uptake of the starch granule (Wu *et al.*, 1985a). Starch gelatinization occurs concomitantly with thermal gelation of fish proteins. However, myofibrillar proteins are thermally denatured before the starch is

completely gelatinized (Wu *et al.*, 1985b). Heat processing causes starch granules to absorb water and expand resulting in pressuring effect on the protein gel matrix and a higher gel strength (Lee *et al.*, 1992). However, their expansions are limited by the gel matrix and availability of water for gelatinization competed between starch and protein (Kim and Lee, 1987). Starch increases the gel strength of surimi-starch gels more effectively at low concentration (0-3 %) than at high concentration (6-9 %) (Park, 2000).

According to a commercial sterility of low acid canned food (LACF), it is mandatory to process all LACF to an F_0 value not less than 3 min. In practice, the process is usually higher

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than this minimum F_0 of 3 min owing to some probability of underprocess and spoilage from heat tolerable organisms. Depending upon the product and the climatic conditions of storage, a typical F_0 value used operationally for fish and meat products generally varies in the range of 5-20 min (Bratt, 1995; Pflug and Christensen, 1980). However, during longer heating at high temperature, the gel strength of protein gel decreases due to a loss of total SH plus SS groups occurred by oxidation to cysteic acid or splitting to hydrogen sulfide (Nakai and Li-Chan, 1988; Yamazawa *et al.*, 1979). H_2S originated from the free reacting SH groups of actomyosin is formed, starting at about $80^\circ C$ and exponential increase with a rise in temperature (Hamm and Hofmann, 1965). Shie and Park (1999) reported that the higher heating temperature (at the study range of $75^\circ C$ to $93^\circ C$) and the longer time, the lower was the shear strain and whiteness.

To clarify the influences of starch on textural properties of fish ball at high temperature, the effects of 5% tapioca flour, corn flour, wheat flour or modified starch addition on the quality of fish balls heated at F_0 of 3 and 6 min were studied.

MATERIALS AND METHODS

Raw materials

Frozen threadfin bream SA grade surimi (Apitoon Enterprise Industry Co., Thailand) was cut into 1 kg each, packed in polyethylene bag and kept at $-18^\circ C$ during 4 month period of study. Tapioca flour (TF; New Grade brand), corn flour (CF; Mc Marrgett brand), wheat flour (WF; hard wheat from White Rose brand) and modified starch from acetylated and slight cross-linking tapioca starch (MS; Dutches Internation ltd.) were used.

Fish ball preparation

Frozen surimi was thawed at $4^\circ C$ overnight before using. The formula of fish ball was 100 g surimi, 2.5 g sodium chloride, 0.2 g garlic powder, 0.2 g pepper and ice for adjusting moisture content to 78 %. All ingredients and each of 5% (w/w) TF, CF, WF and MS of surimi were chopped for 10 min in a food processor (MARA KF 1692). One portion of the mixture was then stuffed into a cylindrical case (2.5 cm x 2.5 cm) while another portion was formed into 2.5 cm diameter fish ball. Both samples were heated in a water bath at the setting temperature of $40^\circ C$ for 20 min and subsequently heated at $90^\circ C$ for 20 min. Then they were cooled in ice-water bath for 5 min and kept at $4^\circ C$ overnight prior to sterilizing. The sample which was stuffed in a cylindrical case was removed from case and used as unsterilized sample.

Sterilization of fish ball

Fish ball (75 g) were packed in 307 x 113 can and filled with 115 ml of 2 % NaCl solution. After seaming, the cans were heated in an overpressure retort (FMC 091-3, USA) at $116^\circ C$ for 30 min and $112^\circ C$ for 45 min. F_0 was calculated from heating data collected by data logger (Pressica 2001E) using the general method (Bigelow *et al.*, 1920).

Texture analysis

Fish ball was cut into a cylindrical shape (2.5 x 2.5 cm) before measuring. The penetration test was determined (MFRD, 1987 with a minor modification) with a 5 mm diameter spherical probe at the speed of 1.1 mm/sec using a texture analyzer TA-HD (Stable Micro System, Surrey, UK). The peak force point was called a breaking strength (g) and the distance from the starting point to the peak force point was called a deformation (cm). Gel strength (g. cm) was the multiplication of breaking strength by deformation.

Water holding capacity

Fish ball (cut into cubes of 1.5 x 1.5 x 0.5 cm³) was pressed between filter papers at 10 kg/cm² for 2 min. The moisture remaining in the sample was expressed as the percentage of water holding capacity (Motohiro, 1981 with a minor modification).

Folding test

Six samples from each treatments were conducted by folding a 5-mm thick slice of gel slowly in half, and then in half again to examine the structural failure of gel. The number of folding required to crack the gel was then graded into 5 classes: AA, A, B, C or D. Class AA categorizes good quality and D shows poor quality related to gel cracking due to the folding (MFRD, 1987).

Whiteness measurement

Six samples from each treatments (cut into 0.5 cm thickness x 2.5 cm diameter) were measured for the degree of lightness L*, redness a* and yellowness b* using a Chroma meter CM-3500d (Minolta, Japan). Whiteness was calculated as $100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{0.5}$ (Lanier, 1992).

SDS-PAGE

Fish ball (0.25 g) was solubilized in 10 ml of 8 M urea-2 % SDS-0.05M sodium phosphate buffer (pH 6.8) containing 10 % 2-mercaptoethanol (Merck, AR grade). SDS-PAGE was carried out on the 5% acrylamide continuous gel (Weber and Osborn, 1969). The pattern of protein as polymer, myosin heavy chain (MHC) and actin (AC) was evaluated.

Sensory evaluation

In each of four heating conditions (112 and 116°C with F₀ 3 and 6 min), five samples of sterilized fish balls were ranked (1 = the most texture liking). Then the highest rank from each heating conditions were evaluated for appearance, color, odor, flavor, texture and overall liking by 20 untrained panels using a 9-point hedonic scale.

Statistical analysis

Treatments were conducted in duplicate. Gel strength, whiteness and water holding capacity data were analyzed by completely block design. Sensory data was analyzed by randomized complete block design. The differences of means were resolved by Duncan's new multiple range test (DMRT).

RESULTS AND DISCUSSION

Various kinds of starch were subjected to fish balls and their properties were evaluated before and after sterilization as follows.

F₀ value

F₀ of sterilized fish balls, namely, control (w/o flour), with 5% TF, CF, WF and MS heated at 112°C 45 min were 6.24±0.03, 6.39±0.18, 6.25±0.08, 6.34±0.05 and 6.29±0.02 min, respectively and at 116°C 30 min were 7.67±0.01, 7.51±0.27, 7.52±0.25, 7.76±0.31 and 7.95±0.43, respectively.

The different additives in samples are one of the factors affecting the rate of heat penetration owing to their unlike chemical or physical properties (Holdsworth, 1997). As monitored by differential sterilizing calorimetry, Belibagi *et al.* (2003) reported that addition of 3 and 7 % potato starch in surimi and heated in the range of 60-110°C changed the thermal properties of the systems attributed to gelatinization of starch and modification of water structure. However from this result, the F₀ of all 5 samples showed no difference in heat penetration patterns (p > 0.05) that might be due to a small amount of flour adding. Therefore, all samples had been sterilized at the same batch and process time used were 112°C 22 min (F₀ 3 min), 112°C 44 min (F₀ 6 min), 116°C 13 min (F₀ 3 min) and 116°C 22 min (F₀ 6 min).

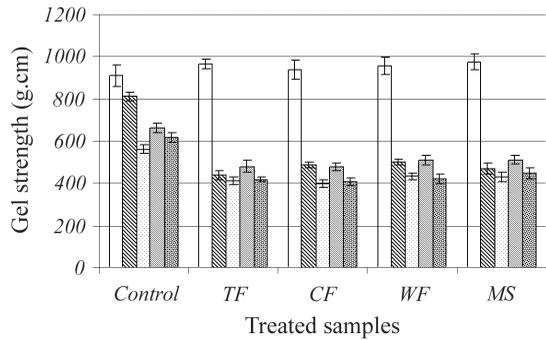
Gel properties

The concentration, modification of starch, granule size as well as the ratio of amylose and amylopectin influence on texture of protein-starch gel. The more amylopectin in starch, the stronger the gel became (Kim and Lee, 1987; Yang and Park, 1998). From this result, all starches improved the GS before sterilizing. GS of TF, CF, WF and MS samples before sterilizing were not different ($p > 0.05$) at the range of 938.91 - 975.69 g.cm which were significantly higher than control (910.13 g.cm) ($p < 0.05$) (Figure 1a). Comparing within samples with starch, the samples ranked from the highest GS were MS, TF, WF and CF, respectively. Modified starch enhances the textural strength of protein gel. TF is high-amylopectin starch which forms adhesive and cohesive gel, whereas WF and CF are high-amylose starches which form somewhat brittle gels (Park, 2000).

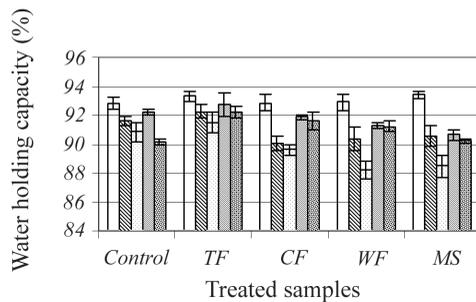
Even though starch can improve the GS of fish ball before sterilizing, it was found that high temperature heating at F_0 of 3 and 6 min decreased the GS of samples with starch by 47 - 58% more than that without starch which decreased by 11 - 38% (Table 1). GS of control at F_0 of 3 min was higher than at F_0 of 6 min and the highest GS was obtained at 112°C F_0 of 3 min. Among samples with starch, GS of MS and WF samples heated at 116°C F_0 of 3 min were higher than the others. The decrease in GS might be owing to a loss of total SH plus SS groups of protein. (Nakai and Li-Chan, 1988) and a loss of starch gelatinized stability.

Water holding capacity

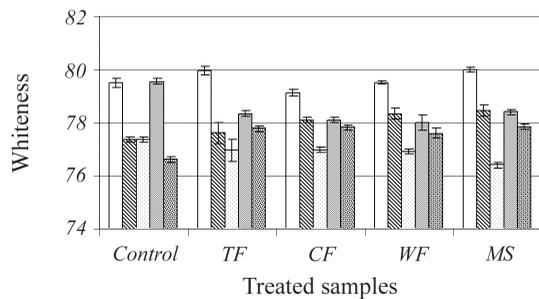
WHC of all samples were not different at the range of 92.79 - 93.40 % ($p > 0.05$) (Figure 1b) and decreased slightly about 1.16 - 5.26 % after sterilizing which was markedly decreased at 112°C F_0 of 6 min (Table 1). Heating at 116°C F_0 of 3 min seemed to maintain WHC better and WHC of TF samples were the highest in all heating conditions.



(1 a)



(1 b)



(1 c)

Figure 1 Gel strength (1a), water holding capacity (1b) and whiteness (1c) of fish ball mixed with 5 % various flour sterilized at various conditions; Control, TF:Tapioca flour, CF:Corn flour, WF:Wheat flour, MS: Modified starch; □ before sterilizing, ▨ 112°C F_0 3 min, ◻ 112°C F_0 6 min, ▩ 116°C F_0 3 min, ▤ 116°C F_0 6 min

Table 1 The decrement of gel strength, water holding capacity and whiteness of sterilized fish ball mixed with 5 % various flour.

Characters	Decreasing ratio (%)			
	112°C F _O 3 min	112°C F _O 6 min	116°C F _O 3 min	116°C F _O 6 min
<i>Gel strength</i>				
Control	10.90	38.37	27.05	32.20
Tapioca flour	54.49	57.52	50.27	56.84
Corn flour	48.10	57.78	49.04	56.71
Wheat flour	47.58	54.72	46.58	56.07
Modified starch	51.80	56.08	47.53	54.22
<i>Water holding capacity</i>				
Control	1.29	2.11	0.64	2.82
Tapioca flour	1.16	1.98	0.68	1.23
Corn flour	3.03	3.52	1.09	1.37
Wheat flour	2.69	5.08	1.72	1.80
Modified starch	3.06	5.26	2.93	3.40
<i>Whiteness</i>				
Control	2.67	2.67	0.0	3.61
Tapioca flour	2.95	3.76	2.04	2.74
Corn flour	1.30	2.73	1.30	1.66
Wheat flour	1.48	3.27	1.91	2.41
Modified starch	1.94	4	1.99	2.70

Folding test

The binding structure of protein gel was determined by a folding test. Although GS of heated samples decreased, all samples both before and after sterilization were rated in AA class indicating good quality. The folding test is suitable for separating high quality from low quality surimi but is not sensitive to differences in quality of surimi which exhibit good to excellent gelling ability (Lanier, 1992).

Whiteness

The color of surimi-starch gels depends on both starch concentration and starch properties. The color of high-amylose starch gels is opaque, whereas high-amylopectin starches make their gels more translucent or transparent (Park, 2000). It was shown that whiteness of all samples were in the range of 79.13-80.00 and the higher values were shown in MS and TF samples while the lowest whiteness presented in CF sample might

be due to a high amylose presence. Whiteness slightly decreased (Figure 1c) about 0.00-4.00 % after sterilization (Table 1) which at 116°C F₀ of 3 min had the highest whiteness owing to taking the least heating time. The higher the processing temperature and the longer the processing time, the higher the b* value which was probably due to the Maillard (browning) reaction between sugars, fish proteins or amines, and water (Shie and Park, 1999). The control-116°C F₀ of 3 min showed the highest whiteness whereas the whiteness within samples with starch were slightly different.

SDS-PAGE

Figure 2 shows SDS-PAGE patterns of proteins extracted from fish balls with starch

before and after sterilizing at 116°C F₀ of 3 and 6 min. All solubilized samples were reduced by 2-mercaptoethanol in order to reduce disulfide bond to sulfhydryl group. Prior to sterilizing, the MHC and actin presented the high intensities. After sterilizing, MHC and actin bands decreased at 116°C F₀ of 3 min and almost disappeared in all samples heated at 116°C F₀ of 6 min that agreed with a decrement in gel strength. High temperature caused damage to protein in which the formation of "isopeptides" by reaction of the α-amino group of lysine is probably included (Hofmann, 1977) and formed hydrogen sulfide (Nakai and Li-Chan, 1988; Yamazawa *et al.*, 1979). The decrement of actin band was lower than MHC as same as the results of Hofmann (1977) and Runglerdkriangkrai (1999).

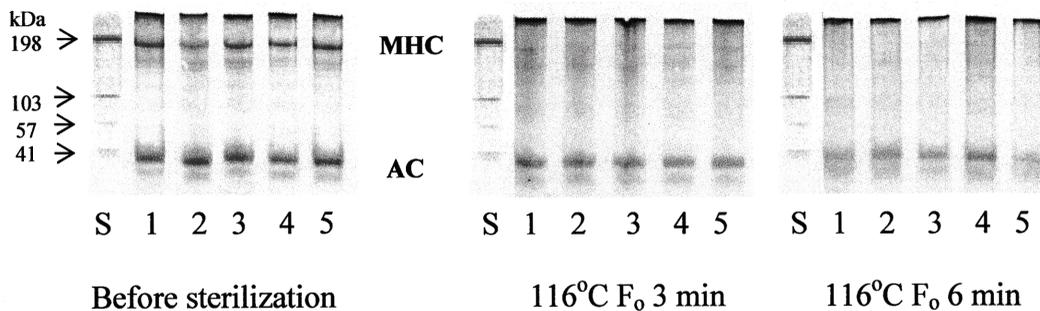


Figure 2 SDS-PAGE with β-mercaptoethanol of fish ball mixed with 5 % various flour sterilized at 116°C F₀ 3 and 6 min; (S) Standard protein (1) Control, (2) Tapioca flour, (3) Corn flour, (4) Wheat flour, (5) Modified starch; MHC (Myosin heavy chain), AC (Actin)

Sensory evaluation

The sensory scores of texture and overall liking of unsterilized fish balls with starch were higher than control sample ($p < 0.05$) while no difference was found in the other attributes (Table 2). After sterilizing and ranking in texture liking (Table 3), only four good samples were taken for hedonic test. Those were MS-112°C/F₀ 3 min, control-112°C/F₀ 6 min, control-116°C/F₀ 3 min and control-116°C/F₀

6 min. It was remarked that the range of GS from those four samples were 470 – 663 g.cm. On the basis of texture and overall liking attributes, taste panels preferred fish balls at MS-112°C/F₀ 3 min and control-116°C/F₀ of 3 and 6 min at moderately liking level ($p > 0.05$). (Table 4) It was noticeable that too long heating time (44 min) at 112°C/F₀ 6 min lowered the preference of taste panels.

Table 2 Hedonic scores of fish ball mixed with 5 % various flour before sterilizing.

Additives	Means ± Standard deviation					
	Appearance ^{ns}	Color ^{ns}	Odor ^{ns}	Flavor ^{ns}	Texture	Overall liking
Control	7.4±0.9	7.3±1.1	6.4±0.8	6.0±1.1	6.7 ^b ±1.0	5.9 ^b ±1.1
Tapioca flour	7.7±0.8	7.7±1.1	6.8±0.8	5.9±1.1	7.2 ^a ±0.7	6.8 ^a ±1.0
Corn flour	7.5±0.8	7.8±1.1	6.8±1.0	6.0±1.1	7.2 ^a ±0.8	6.8 ^a ±0.8
Wheat flour	7.4±1.0	7.5±1.0	6.7±0.9	6.1±0.9	7.4 ^a ±0.9	6.8 ^a ±0.7
Modified starch	7.6±0.8	7.5±1.0	6.5±0.8	6.1±1.0	7.2 ^a ±0.8	6.8 ^a ±0.9

^{ab} Means in the same column with different superscripts are significantly different ($p < 0.05$).

^{ns} Means of all treatments are not significantly different ($p > 0.05$) by DMRT.

Table 3 Ranking of texture preference scores of fish ball mixed with 5 % various flour after sterilizing at various conditions.

Additives	Means ± Standard deviation			
	112°C, F ₀ 3 min	112°C, F ₀ 6 min	116°C, F ₀ 3 min	116°C, F ₀ 6 min
Control	4.25 ^d ±1.33	1.25 ^a ±0.44	1.25 ^a ±0.44	1.60 ^a ±0.44
Tapioca flour	3.75 ^{bc} ±0.85	3.85 ^c ±1.04	3.75 ^c ±1.11	3.20 ^b ±1.11
Corn flour	3.25 ^c ±1.01	4.25 ^c ±0.91	4.10 ^c ±0.91	4.50 ^c ±0.91
Wheat flour	2.30 ^b ±0.92	2.75 ^b ±1.32	3.10 ^{bc} ±1.11	2.90 ^b ±1.11
Modified starch	1.30 ^a ±0.80	2.90 ^b ±0.91	2.60 ^b ±1.31	2.90 ^b ±1.31

^{ab} Means in the same column with different superscripts are significantly different ($p \leq 0.05$)

Table 4 Hedonic scores of fish ball mixed with 5 % modified starch after sterilizing at various conditions

Characters	Means \pm Standard deviation			
	112°C, F ₀ 3 min (With Modified starch)	112°C, F ₀ 6 min (Without flour)	116°C, F ₀ 3 min (Without flour)	116°C, F ₀ 6 min (Without flour)
Appearance	7.8 ^a \pm 0.8	7.2 ^b \pm 0.7	7.3 ^b \pm 0.8	7.3 ^b \pm 0.9
Color	7.6 ^a \pm 0.8	7.2 ^b \pm 0.5	7.3 ^b \pm 0.5	7.4 ^{ab} \pm 0.6
Odor ^{ns}	6.4 \pm 1.1	6.2 \pm 1.0	6.6 \pm 0.9	6.4 \pm 0.9
Flavor	6.5 ^b \pm 1.2	6.3 ^b \pm 1.1	7.0 ^a \pm 1.1	7.0 ^a \pm 1.1
Texture	7.4 ^a \pm 0.6	6.3 ^b \pm 0.9	7.5 ^a \pm 0.8	7.1 ^a \pm 0.9
Overall liking	7.1 ^a \pm 0.8	6.3 ^b \pm 0.9	7.1 ^a \pm 0.9	7.0 ^a \pm 1.0

^{ab} Means in the same row with different superscripts are significantly different ($p \leq 0.05$).

^{ns} Means of all treatments are not significantly different ($p > 0.05$) by DMRT.

CONCLUSIONS

Addition of 5% TF, CF, WF and MS improved the GS of fish ball before sterilizing but lowered GS after high thermal condition. The optimum condition from this experiment was control-116°C/F₀ 6 min owing to a lower risk in *C. botulinum* toxin, with a high preference score and moderate decrement in GS and WHC. Other additives such as hydrocolloids should be studied further for the improvement of texture of canned fish jelly product.

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