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Original Research Article

Effect of Tapioca Starch on Gel Characteristics of Threadfin Bream Surimi

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ABSTRACT

This study investigated the effect of adding tapioca starch (2.5, 5, 7.5, and 10% by weight of surimi) on gel characteristics of threadfin bream surimi (*Nemipterus hexodon*). Surimi gels were analyzed whiteness, gel strength, expressible water, and microstructure by scanning electron microscopy (SEM). Whiteness of samples with tapioca starch was significantly lower, but gel strength was significantly higher than for the control sample ($p \leq 0.05$). Samples with 10% tapioca starch had the highest gel strength value (951 ± 61.86 g.cm). However, sample gel strength with tapioca starch did not significantly differ ($p > 0.05$). Adding tapioca starch lowered expressible water, accompanied by increased gel strength. Expressible water decreased when tapioca starch concentration increased ($p \leq 0.05$). Sample expressible water with 10% tapioca starch was lower by 50% than for the control sample. Surimi gels with tapioca starch has denser and more uniform microstructure than the control sample. As starch concentration increased, gel network microstructure became more compact, and voids within the fiber network reduced in size. These results were concomitant with gel strength and expressible water. Therefore, adding tapioca starch functioned as a filler in the gel matrix. The optimum concentration of tapioca starch to improve the gel characteristics was 7.5% by weight of surimi.

INTRODUCTION

Surimi is a minced fish washed by water to remove most lipid, water-soluble protein, and other impurities, it is stabilized using cryoprotectants to prevent denaturation of the protein (Songkhai and Sompongse, 2019). It can be made into surimi-based products of high price, such as fish ball, fish sausage, kamaboko, and crabstick, which are popular in China, Thailand, Malaysia, and other Southeast Asia countries (Mi *et al.*, 2019). Surimi consists mainly concentrated myofibrillar proteins, which have gel forming ability inducing by heat (Liu *et al.*, 2014).

Many research investigates about improvement of gelation properties and gel network structure by adding various additives.

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Starch is a polysaccharide that the most used additive in the processing of surimi-based products, and as a filler in gel network structure. It has been widely used to increase the gel strength and reduce costs (Li *et al.*, 2022; Luo *et al.*, 2020).

Tapioca starch is a product obtained from cassava root, like a white powder. Tapioca starch is different from other starches by its low level of residual materials (fat, protein, and ash), and lower amylose content (approximately 17-20%) than other amylose-containing starches, and high molecular weights of amylose and amylopectin. It forms a clear and sticky gel by heat. The most used in the food industry requires viscous and clear viscosity (BeMiller and Whistler, 2009).

Therefore, the aim of this study was to investigate the effect of addition tapioca starch (2.5, 5, 7.5, and 10%) on gel characteristics, in terms of whiteness, gel strength, expressible water, and microstructure by scanning electron microscopy (SEM) of threadfin bream surimi (*Nemipterus hexodon*).

MATERIALS AND METHODS

Materials

Frozen threadfin bream surimi (*Nemipterus hexodon*) grade SA were purchased from Pacific Marine Food Products Co., Ltd.; Samut Sakhon province, Thailand and stored at -18 ± 2 °C until use. Tapioca starch (New Grade) was purchased from local supermarket, Bangkok, Thailand.

Preparation of surimi gel

The frozen surimi was partially thawed in a chilled room (4 ± 2 °C) overnight and then cut into small pieces (about 1 cm cubes). The surimi was chopped in a food processor (MCM64060; Bosch; Slovenia) for 30 sec, followed by the addition of sodium chloride (2.5% by surimi weight).

The moisture content of the mixture was adjusted to 80% by the addition of iced water. Then, tapioca starch was added at different concentrations (0, 2.5, 5, 7.5, and 10% by surimi weight). Thereafter, the paste was further chopped in the mixer for 4 min to obtain uniformity. Surimi sol was stuffed into cellulose casing (2.5 cm diameter) and tightly sealed at both ends. The samples were heated at 40 °C for 30 min, followed by 90 °C for 20 min. All gel samples were cooled rapidly in iced water and stored overnight at 4 ± 2 °C prior to analysis.

Whiteness

Gel samples were cut to a 2.5 mm thickness, and the whiteness was determined using a HunterLab instrument (ColorFlex CX2687; Reston, VA, USA). D65 illuminant was used as the light source. CIE *L**, *a** and *b** values were measured. Whiteness was calculated by the method of Songkhai and Sompongse (2019) using the following equation:

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

Gel strength

Gel strength of the surimi gel samples was measured following the method of Songkhai and Sompongse (2019). The samples were equilibrated at ambient temperature before analysis and cut into lengths of 2.5 cm thickness. The breaking force and deformation (measured in grams and centimeters) of the sample were conducted using a texture analyzer (Model TA-XTplusC; Stable Micro Systems; England) with a spherical probe (5 mm diameter). The gel strength was calculated by multiplying the breaking force by the deformation.

Expressible water content

The expressible water content of the surimi gels was measured following the method of Phisutthigoson and Sompongse (2021). The samples were cut into pieces 0.5 x 1 x 0.5 cm and weighed (W_1) and placed between pieces of Whatman paper (No.4). A standard weight of 5 kg was placed on the top for 2 min then the sample was removed from the paper and weighed again (W_2). The expressible water content was calculated using the following equation:

$$\text{Expressible moisture content (\%)} = (W_1\text{-}W_2/W_1) \times 100$$

Scanning electron microscopy (SEM)

Gel samples were fixed using 2.5% glutaraldehyde in 0.1 M phosphate buffer solution (pH 7.2) overnight at 4 °C. The samples were washed in phosphate buffer solution for two cycles and then in distilled water. The samples were dehydrated in ethanol at serial concentrations of 30, 50, 70, 95, and 100% (v/v). The samples were critical-point dried using a critical point dryer (EM CPD300; Leica; Austria), and dried samples were sputter-coated (SCD 040; Balzers; Germany) with gold. The microstructure of the gels was observed using SEM (JSM – IT500HR; JEOL; Japan) at an acceleration voltage of 15 kV (Sutloet *et al.*, 2019).

Statistical analysis

The experiment was designed using a randomized complete block design. All results were expressed as mean values ± standard deviation. Data were subjected to analysis of variance (ANOVA). Duncan's new multiple range test was used to determine the differences between sample means at $p \leq 0.05$.

RESULTS AND DISCUSSION

Whiteness

As shown in Table 1, the whiteness of surimi gels with tapioca starch was significantly lower than the control sample ($p \leq 0.05$). The sample without tapioca starch had the highest lightness (*L**) value of 70.89 ± 1.20. As the concentration of tapioca starch increased, the lightness of the gel tended to decrease. This might be because the starch granules absorb water and full swollen during heating. As a result, light passes through the swell granules, thereby reducing the *L** value significantly. ($p \leq 0.05$). These results were accord with Luo *et al.* (2020), who reported that the addition of potato starch to hairtail surimi was decreased the whiteness, when increasing the concentration of potato starch.

Gel Strength

The gel strength of control sample and gel with tapioca starch at different concentrations shown in Figure 1A, the sample with tapioca starch had significantly higher gel strength than the control sample ($p \leq 0.05$). The concentration of tapioca starch increased, gel strength increased. The highest value of gel strength was obtained after adding 10% of tapioca starch (951.13 ± 61.86 g.cm). As a result of water absorption and swelling of starch granules during heating (Wu *et al.*, 2018). Starch act as a filler in the three-dimensional protein network structure, increasing the gel strength. This result was agreed with Mi *et al.* (2021a), who found that the addition of corn starch promoted the gel strength of heat-induced myosin gels from hairtail. However, gel strength of samples with 5, 7.5, and 10% of tapioca starch did not significantly differ ($p > 0.05$) due to the limited water content in the system as adjusting the moisture content of all samples to 80%. However, expressible water contents decrease gradually as the concentration of tapioca starch increased.

Expressible water content

The expressible water content of control gel and surimi gels was added with tapioca starch at different concentrations shown in Figure 1B, surimi gel with tapioca starch had significantly lower expressible water content than the control sample ($p \leq 0.05$). The sample with 10% tapioca starch had the lowest expressible water content (7.10 ± 1.19%). As the concentration of tapioca starch increased, the expressible water content tended to decrease. A decrease of the expressible water content was associated with an increase in the gel strength (Figure 1A). Liu *et al.* (2020) also reported that the addition of starches reduced the expressible water content of golden pompano (*Trachinotus blochii*) surimi. During heating, the three-dimensional protein network structure was formed, and entrapped some water in their structures. At the same time, the starch granules absorbed water and swollen, then fulfilling the three-dimensional protein network structure. As the concentration of tapioca starch increased, consequently, the starch can absorb more water in the gel system, therefore, expressible water content decrease.

Table 1. Color parameters (*L* a* b**) and whiteness of surimi gels added with different concentrations of tapioca starch.

Concentrations of Tapioca starch (% by surimi weight)	Color Parameters			Whiteness
	*L**	*a**	*b**	
0 (Control)	$70.89^{a} \pm 1.20$	$-1.53^{a} \pm 0.14$	$6.47^{c} \pm 0.80$	$70.14^{a} \pm 1.32$
2.5	$70.59^{a} \pm 1.16$	$-1.61^{a} \pm 0.15$	$6.51^{c} \pm 0.69$	$69.83^{a} \pm 1.24$
5	$69.61^{b} \pm 1.19$	$-1.74^{b} \pm 0.26$	$6.72^{bc} \pm 0.93$	$68.81^{b} \pm 1.32$
7.5	$68.94^{c} \pm 1.09$	$-1.88^{c} \pm 0.19$	$6.89^{b} \pm 1.12$	$68.12^{c} \pm 1.20$
10	$68.60^{c} \pm 1.04$	$-1.69^{b} \pm 0.05$	$7.35^{a} \pm 1.30$	$67.69^{c} \pm 1.17$

Mean ± SD (n = 3; $^{a\text{-}c}$ Different superscripts in the same column indicate significant differences ($p \leq 0.05$)

Microstructure (Scanning electron microscopy: SEM)

The microstructure of control gel and gels with tapioca starch at 5, 7.5, and 10% shown in Figure 2. The control sample had many void and irregular network. While surimi gels with tapioca starch had a denser and more uniform microstructure than the control**.** As starch concentration increased, gel network microstructure became more compact, and reduced size of voids within the network. These results might due to more entrapped water of the swollen starch granules within three-dimensional protein network. Eventually, expressible water was decreased, meanwhile gel strength was increased. These results agreed with the report by Mi *et al.* (2021b), who studied the addition of starch and/or gums possibly constructed the compact gel network of silver carp surimi.

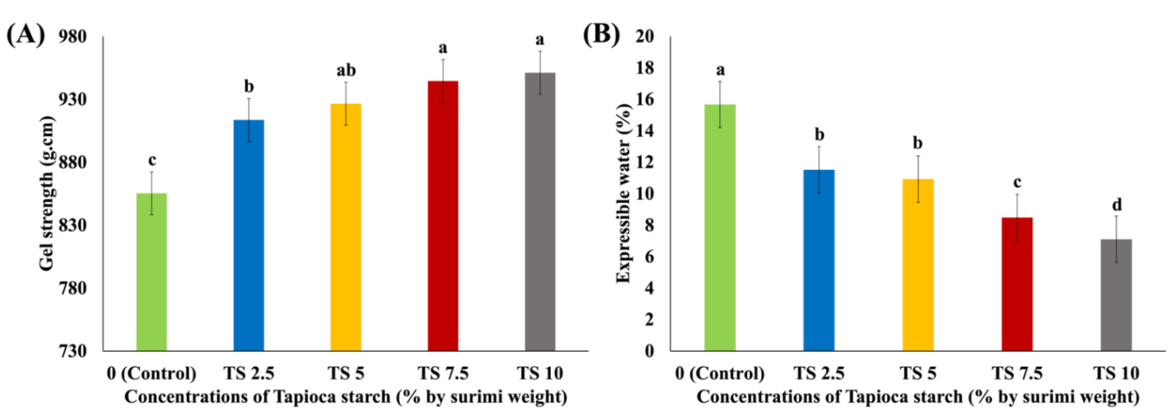

Figure 1. (A) Gel strength and (B) expressible water content of surimi gels added with different concentrations of tapioca starch. Different letters on each bar indicate significant differences ($p \leq 0.05$).

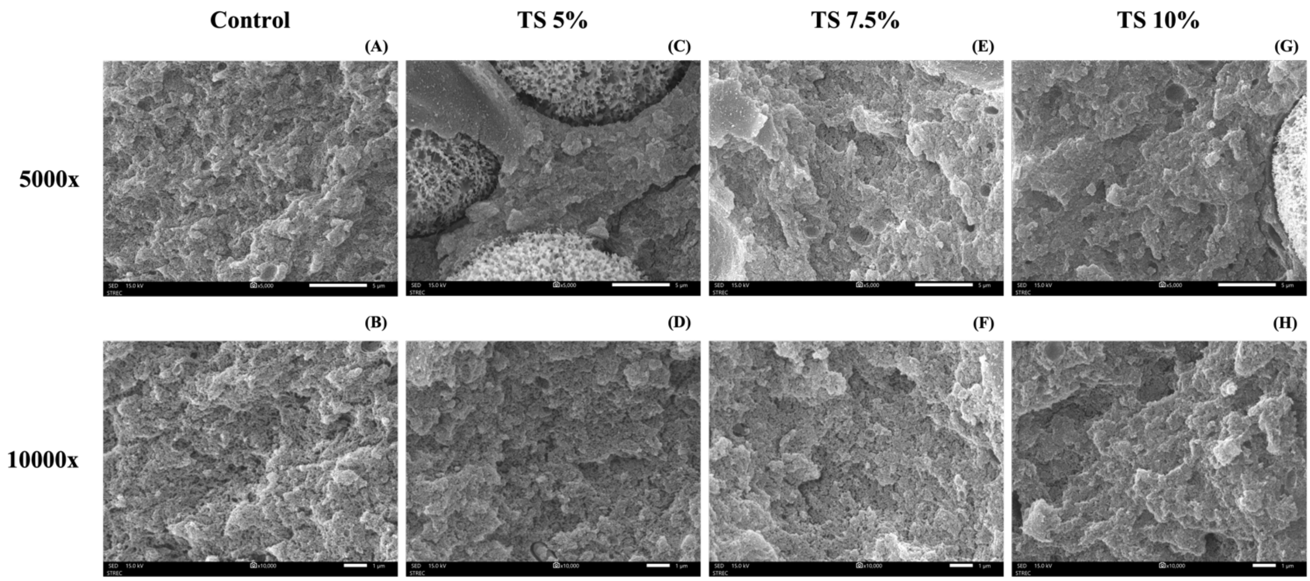

Figure 2. Microstructure (magnification: 5000x and 10,000x) of surimi gels added with different concentrations of tapioca starch: (A) and (B) without starch; (C) and (D) 5% tapioca starch; (E) and (F) 7.5% tapioca starch; (G) and (H) 10% tapioca starch**.**

CONCLUSIONS

The addition of tapioca starch was able to improve the gel properties of threadfin bream surimi (*Nemipterus hexodon*). Increasing of tapioca starch concentration, resulting in reduction of L^* value, led to lower whiteness than control sample ($p \leq 0.05$). During heating process, starch granules absorbed water and swollen. Starch acted as a filler in the protein network structure. Therefore, gel strength of the sample with tapioca starch was higher, while expressible water content was lower than that of the control. The microstructure by SEM shown denser network structure with smaller voids. The optimum concentration of tapioca starch to improve the gel characteristics was 7.5% by weight of surimi.

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