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Effect of tapioca and potato starch on the physical properties of frozen spanish mackerel *(Scomberomoru guttatus)* fish balls

Tee, E. T. and *Siow, L. F.

School of Science, Monash University Malaysia, Jalan Lagoon Selatan, 46150 Bandar Sunway, Selangor, Malaysia

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Abstract

This study aims to determine the effect of tapioca and potato starch added at 3, 6 or 9%w/w on the physical properties of Spanish mackerel *(Scomberomoru guttatus)* fish balls. Water holding capacity, gel strength and four attributes of texture profile analysis, namely hardness, springiness, cohesiveness and chewiness increased with increasing starch concentration for both fish balls added with tapioca or potato starch after 6th freeze-thaw cycles. Both tapioca or potato starch-added samples showed decrease in drip loss and colour with increasing starch concentration up to 9% (w/w) after 6th freeze-thaw cycles. Drip loss and colour of fish balls made from the two types of starch decreased with increasing starch concentration. Overall, gel strength, drip loss, and color of fish balls added with starch showed no significant changes ($p \geq 0.05$) after 6th freeze-thaw cycle. The results suggested that starch plays an important role in improving freeze-thaw stability of fish balls.

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Introduction

In most Asian countries, especially Southeast Asia, fish is the main protein of the diet (Chung *et al.*, 1994). Other than fresh fish consumption, wide variety of comminuted fish products such as fish ball, fish cake and fish burger are also widely consumed. Basic ingredients for fish ball are fish meat, starch, salt and water. According to Food Regulation (1985), fish ball is defined as fish product prepared from a mixture of fish, with or without the addition of starch, condiments and vegetables, which are shaped into ball (Umordin, 2012). Each ball should contain not less than 50% of fish and may contain permitted flavour enhancer and food conditioner (Umordin, 2012).

Fish paste products, such as fish balls and fish cakes are claimed to be originated from China, using fresh fish as the raw ingredient (Boran and Kose, 2007). Currently, these products have been widely consumed in the Asian region. It is reported that the fish-based industry has been growing tremendously since the early 1980s in countries including Singapore, Malaysia, China and Thailand. Frozen and cuttle fish balls' manufacturers are also aiming at the overseas market such as Australia, Japan and United States (Morrissey and Tan, 2000). In Singapore, it is claimed that 4 million people consumed about 70 tonnes of fish ball/fish cake a day (Park, 2005). Similarly, fish ball consumption in Thailand is relatively high, with approximately 12,000 tonnes of fish ball consumed per year (Park, 2005).

In Malaysia, fish balls are commonly consumed and the production is usually initiated by small family-based enterprises. However, in recent years many factories have invested in modern machinery to increase the production of fish balls, and there are about 27 fish ball manufacturing factories in Malaysia (Huda *et al*., 2010). Fish ball is the second largest processed fish-based production in Malaysia after fish cracker production, where the contribution of fish ball production to the total fish-based products in Malaysia is approximately 15-20%. Fish ball production was reported to increase from 7875 tonnes in 1996 to 16470 tonnes in 2008 (Department of Fisheries, 2010). The increasing consumption and popularity of fish balls in several parts of the world indicates that the market and demand for fish balls are large, most probably due its convenience of preparation and the fact that it can be consumed in many different ways.

Other than fish mince or surimi, starch is one of the major ingredients incorporated into surimi-based products owing to its ability to modify the texture, improve the stability during refrigerated or frozen storage and also for economic reasons (Yang and Park, 1998). The addition of starch was claimed to improve the texture of surimi products by increasing

*Corresponding author.
Email: *siow.lee.fong@monash.edu*
Tel: 60-3-55146034; Fax: 60-3-55146364

the gel strength of the final product. The increased in gel strength is mainly due to pressure exerted upon heating by the swollen starch granules that are embedded in the protein gel matrix (Kim *et al*., 1986; Zhang *et al.*, 2013).

Starch added at 3 to 12% (w/w) is commonly added and the most frequently used starches include wheat, corn, potato and tapioca. Yoon *et al.* (1997) has reported that starch added at lower concentration (<3%) is more effective in increasing the gel strength of surimi than at high concentration (6-9%). Several studies have also shown that potato and corn starch added at 0-6% yield the best performance in terms of gel strength and freeze-thaw stability in Allaska Pollock surimi (Yoon *et al*., 1997; Yang and Park, 1998). Zhang *et al.* (2013) indicated that the addition of corn, potato and tapioca starch at 3% concentration in beef-surimi had the highest gel strength as compared to 6% and 9%. Thus, 3, 6 and 9% starch were used in this study.

Swelling, gelatinization, and retrogradation of starch granules during processing and storage are important to control the rheological properties of food (Nishinari *et al.*, 2000). It was claimed that the gelatinization temperature of starch tends to increase with the presence of additional ingredients. Thus, potato starch for instance, which has low gelatinization temperature is more preferable as the low gelatinization temperature allows better starch granule swelling, thus resulting in high gel strength. Yang and Park (1998) also found that large starch granules produce strong and firm gel. In the study conducted by Zhang *et al.* (2013), the surimi-beef gel added with potato and tapioca starch appeared to have the highest gel strength as compared to sample added with corn starch. Kim and Lee (1987) reported that potato starch showed little tendency of retrogradation in red hake surimi as compared to wheat starch. The Allaska Pollock surimi added with potato and tapioca starch had also been shown to provide a better mouth feel compared to corn starch (Niwa *et al.*, 1990). Tapioca starch was found to improve the water holding capacity and textural properties of products such as low fat pork sausage (Lyons *et al*., 1999). Annor-Frempong *et al.* (1996) reported the use of tapioca flour as the filler in comminuted meat products.

Since studies have demonstrated the potential of both tapioca and potato starch in various fish- and meat-based applications, the objective of this study was to evaluate the quality of fish balls containing different concentration of tapioca starch (TS) or potato starch (PS). Quality changes of the fish balls after various freeze-thaw cycles were also examined as fish balls may go through freeze-thawing process due to temperature fluctuation during transportation and storage. The current study is novel as the physical properties of frozen Spanish mackerel *(Scomberomoru guttatus)* added with TS or PS has not been reported. Spanish mackerel has been commonly used to make fish balls due to the ease of deboning the fish.

Materials and Methods

Chemicals

Tapioca and potato starch, both appear to be in the white powder form, and salt were purchased from a local grocery store. Spanish mackerel fish was purchased from local wet market in SS 15 Subang Jaya. Whatman® qualitative filter paper with 90 mm diameter was purchased from Fisher Scientific Co. (Pittsburgh, Pa., U.S.A.).

Surimi and fish ball preparation

Surimi was prepared from Spanish mackerel weighing approximately 1000 g to 1500 g. They were headed, gutted and washed with water. The meat was manually separated from the skin and bone using a metal spoon. After separation, the meat was washed with chilled filtered water (5ºC) (chilled water: minced meat =1:3) for 3 times (Jin *et al*., 2007). Each washing cycle of 10 minutes was followed by draining using a strainer to remove any residual dark connective tissue, black skin, blood and scale (Jin *et al*., 2007). After the third washing cycle, dewatering process was carried out by pressing the remaining slurry using a 5 kg standard weight for 10 minutes. The dewatered meat (DWM) was blended into surimi paste using a food processor (KENDWOOD Food Processor Model FPM 120, Malaysia) at a low speed.

Fish balls were prepared by mixing the DWM with salt (3%), cold water (18%) and tapioca or potato starch (TS or PS) at 0, 3, 6 and 9% w/w, respectively. The paste was formed into 16 gram per ball using an ice cream scoop, allowed to set in a water bath (Model WNE29, Memmert, Germany) of 40-45ºC for 20 minutes, cooked in 100ºC hot water for 5 minutes, and cooled for 5 minutes in ice chilled water before storing them in a Ziploc bag (Boran and Kose, 2007). Fish balls were divided into two packets where one part of the freshly made fish balls was used for analyses (before freezing) and the remaining samples were stored in -20ºC freezer overnight prior to analysis.

Freeze-thaw study

Freeze-thaw stability study was conducted

according to methods described by Jittinandana *et al.* (2005) with some modifications. One freeze-thaw (FT) cycle consisted of overnight freezing at -20°C and subsequent thawing at room temperature for 1 hour in a container containing tap water. Water in the container was replaced every 10 minutes interval, up to 60 minutes. This protocol represents one FT cycle and this cycle was repeated for 6 times. Samples at 0 FT cycle were unfrozen. Drip loss, gel strength and colour were measured at 0, 1, 3 and 6 FT cycles. The FT cycles were arbitrary chosen in this study.

Drip loss

Fish ball samples were thawed and left on a stainless steel strainer (0.6-cm diameter holes), covered with aluminum foil and allowed to stand for 30 minutes at room temperature (Jittinandana *et al*., 2005). Thaw loss was calculated as follow:

$$\% \text{ Drip loss} = \frac{\text{Weight before freezing} - \text{weight after thawing}}{\text{Weight before freezing}} \times 100\%$$

Gel strength

Penetration test was used to determine the gel strength following method used by Huda *et al.* (2013). A 5 mm diameter spherical probe was allowed to penetrate at the speed of 1.1 mm/s using a texture analyzer (TA-XT plus, Stable Micro Systems, Surrey, UK). The peak force point is called the breaking strength (g) and the distance from the starting point to the peak force point is called deformation (cm). Gel strength (g·cm) is calculated as the multiplication of breaking strength by deformation.

$$\text{Gel strength} = \text{Breaking force (g)} \times \text{deformation (cm)}$$

Water holding capacity

Water holding capacity (WHC) was measured according to the method established by Nopianti *et al.* (2012) with minor modification. Fish ball was cut into dimension of 2 cm × 1 cm × 1 cm and the weight was measured. The sample was placed between two pieces of filter paper, which were previously weighed. The sliced sample was pressed using standard weight (5 kg) for 2 minutes. The paper was removed and weight again. WHC was calculated using the following equation:

$$\text{WHC (\%)} = \frac{\text{Weight of fish ball before pressing} - \text{weight of fish ball after pressing}}{\text{Weight of fish ball before pressing}} \times 100\%$$

Texture profile analysis (TPA)

Sample preparation for texture profile analysis was according to Nurkhoeriyati *et al.* (2012) where parameters namely hardness, cohesiveness, springiness and chewiness were determined. Compression force was measured using a texture analyzer (TA-XT plus, Stable Micro Systems, Surrey, UK) with a 75-mm compression platen and a 5-kg load cell. The sample was placed under the probe, which moved downward at a constant speed of 3.0 mm/s, a test speed of 1.0 mm/s, a post-test speed of 3.0 mm/s, and a prefixed strain of 60%. After the 1st compression, the probe returned to the initial position and stopped for 2 s before the 2nd compression. Hardness was determined as the maximum force of the first compression force; springiness was determined as the ratio of area under the curve after the first compression to the area under the curve after the second compression. Cohesiveness was determined as the ratio of area after the second compression to the area after the first compression. Chewiness was defined as the energy required to chew a solid sample to a steady state of swallowing (gumminess × springiness).

Color

The color for each fish ball formulation was measured using calorimeter (Hunter Lab, U.S.A.). Colour coordinate values (L^*, a^* and b^*) were recorded and whiteness intensity of samples were determined using the following formula (Ikhlas *et al*., 1996).

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

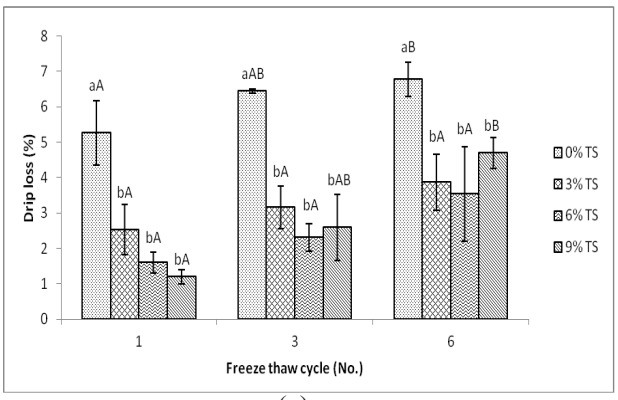
Statistical analysis

All data was measured in triplicates (n = 3) and was reported as mean ± standard deviation. Normality and homogeneity of variance was tested for all the results using Statistics Package for Social Sciences (SSP) version 20.0. Analysis of variance (ANOVA) followed by post-hoc Tukey's test were carried out to determine significant differences ($p < 0.05$) after confirming that the data was normally distributed ($p > 0.05$) and has equal variance ($p > 0.05$). ANOVA and Tukey's test were performed if the transformed data was normal with equal variance. Paired T-test was carried out to compare the significant difference between tapioca and potato starch added fish balls after 1 day frozen storage.

Results and Discussion

Drip loss

Freezing is one of the most common methods used to extend the shelf life of perishable products. Thermal fluctuation during transportation and storage, which results in consequent phase changes of water are the major factors that cause deterioration of frozen food, especially products containing gel



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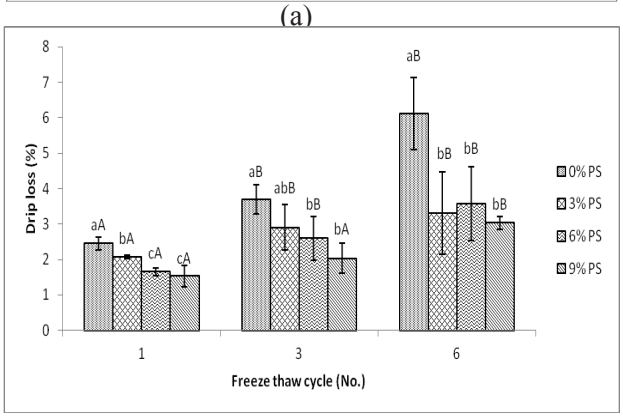

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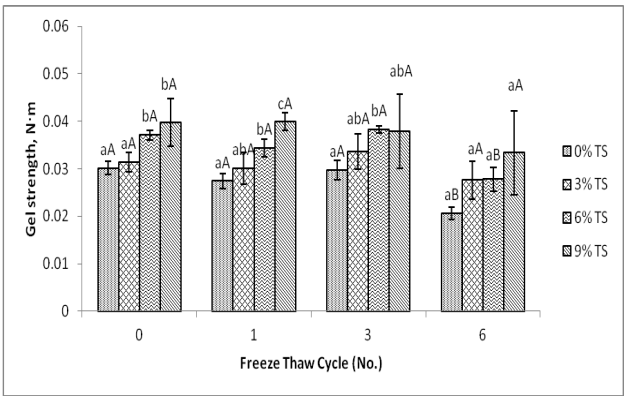
Figure 1. Effect of freeze thaw (FT) cycle (0, 1, 3 and 6) and (a) tapioca starch (TS) and (b) potato starch (PS) concentration (0, 3, 6 and 9%) on the drip loss of fish balls. Data are shown as mean ± standard deviation, n=3.

a,b means significant difference ($p < 0.05$) across starch concentration within each FT cycle

A,B means significant difference ($p < 0.05$) across FT cycle within each starch concentration



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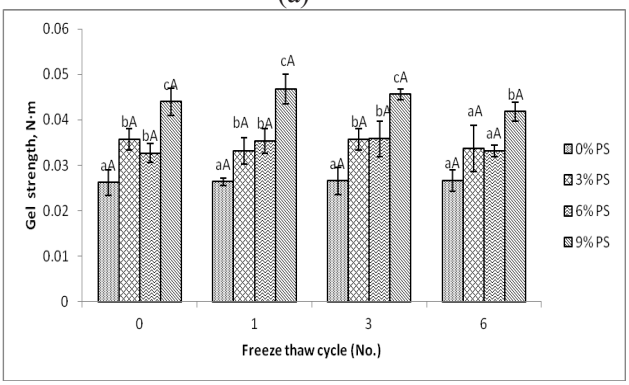

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Figure 2. Effect of freeze thaw (FT) cycle (0, 1, 3 and 6) and (a) tapioca starch (TS) and (b) potato starch (PS) concentration (0, 3, 6 and 9%) on the gel strength (N•m) of fish balls. Data are shown as mean ± standard deviation, n=3.

a,b,c means significant difference ($p < 0.05$) across starch concentration within each FT cycle

A,B means significant difference ($p < 0.05$) across FT cycle within each starch concentration

matrix because frozen storage could result in loss of functional properties, specifically the gelling property (Pongsawatmanit *et al*., 2007).

Drip loss is defined as the amount of fluid lost from food, especially the meat or fish product, via passive exudation as a consequence of the melted ice (Suzuki *et al*., 2005). Based on Figure 1a, it was observed that the effect of freezing on drip loss was more pronounced ($p < 0.05$) in samples without the addition of starch (control) as compared to samples added with 3, 6 or 9% of tapioca starch (TS) throughout six freeze-thaw (FT) cycles. The decrease in drip loss with increasing TS concentration up to six FT cycles indicates that a greater extend of water was retained within the gelatinized starch of the fish balls. It was also found that there was no significant difference ($p \geq 0.05$) in drip loss for samples containing 3%, 6% and 9% TS throughout the six FT cycles (Figure 1).

Throughout the six FT cycles, no significant difference ($p \geq 0.05$) in the drip loss was observed for samples added with 3% and 6% TS, whilst the drip loss of the control samples and samples added with 9% TS at 6th FT cycle was significantly higher ($p < 0.05$) than the drip loss at 1st FT cycle (Figure 1). This finding was supported by Prabpree and Pongsawatmanit (2011), which similarly showed that drip loss of fish sausage added with TS increased with increasing FT cycle. In the current study, six FT cycles did not seem to cause a significant difference in drip loss for samples added with 3% and 6% TS. The reason remains unknown.

Similarly, drip loss of control was significantly ($p < 0.05$) higher than all the samples containing potato starch (PS), regardless of the number of FT cycle (Figure 1b). There was no significant ($p \geq 0.05$) difference in drip loss between samples containing 6% and 9% PS at 1st FT cycle. There was a significant difference ($p < 0.05$) between samples added with 6% or 9% PS with the control and sample added with 3% PS. At the 3rd and 6th FT cycle, samples across the PS concentrations did not show a significant ($p \geq 0.05$) difference in drip loss. Within each starch concentration, a significant ($p < 0.05$) increase in drip loss was determined when FT cycle increased

from 1 to 3 for all the PS samples (Figure 1b), except for samples added with 9% PS. However, no further increase ($p \geq 0.05$) in drip loss was observed as FT cycle increased from 3 to 6 for all the PS samples, with an exception for samples added with 9% PS that showed a significant ($p < 0.05$) increase in drip loss as FT cycle increased from 3 to 6. The specific interaction of starch and water in the protein rich matrix remains unclear.

Gel strength

Gelling ability of fish protein is important for the determination of fish ball quality. In this study, it can be seen that gel strength of fish balls containing 6% and 9% of TS were similar and they had significantly higher ($p < 0.05$) gel strength as compared to fish balls without starch (control) and fish balls added with 3% of TS (Figure 2a) at 0 FT cycle (before freezing) and 1st FT cycle. However, the gel strength of fish balls showed no significant difference among all the samples at 6th FT cycle. No significant change ($p \geq 0.05$) in gel strength was observed for all samples across the six FT cycles, with an exception for the control and sample added with 6% starch that showed a significant decrease ($p < 0.05$) in gel strength as FT cycle increased from 3 to 6.

For PS samples, the control showed the lowest ($p < 0.05$) gel strength whilst samples containing 9% PS had the highest gel strength ($p < 0.05$) at 0 FT cycle, (Figure 2b). Samples added with 3% and 6% of PS had similar ($p \geq 0.05$) gel strength but the gel strength was significantly higher than the control and lower than samples containing 9% PS. Similar trend was observed for each FT cycle. No significant change ($p \geq 0.05$) in gel strength was observed within each starch concentration as the number of FT cycle increased.

By comparing the gel strength of TS and PS samples, it was observed that the gel strength of PS samples were slightly higher than TS samples. This might be due to the larger swelling power of PS as compared to TS, owing to the higher phosphorus content of PS as compared to TS (Swinkels, 1985; Panda, 2013). The resultant phosphate cross linkages between phosphate group and amylopectin are harder to break (Swinkels, 1985; Panda, 2013).

Water holding capacity

Water holding capacity (WHC) is defined as the ability of meat products to retain its inherent water during force application and/or processing such as cutting and pressing (Yang and Park, 1998). The WHC of fish balls increased with increasing in TS concentration, in which samples added with 9% TS had similar WHC with samples added with 6% TS. The WHC was significantly higher ($p < 0.05$) than the control and samples added with 3% TS (Figure 3). The control sample appeared to have the lowest ($p < 0.05$) WHC as compared to samples containing TS. For PS-added samples, only samples added with 9% PS was significantly higher ($p < 0.05$) than the control and the other PS-added samples. Starch favours the formation of strong heat-induced structures through the expansion of the starch granules embedded in protein gel matrix. This increased the pressure and water binding in the gel matrix, thus resulting in higher WHC in samples added with starch as compared to the control (Colmenero *et al*., 1996). This phenomenon is supported by the study conducted by Prabpree and Pongsawatmanit (2011) in which the WHC for fish sausage increased with increasing TS concentration from 3.5% to 14%.

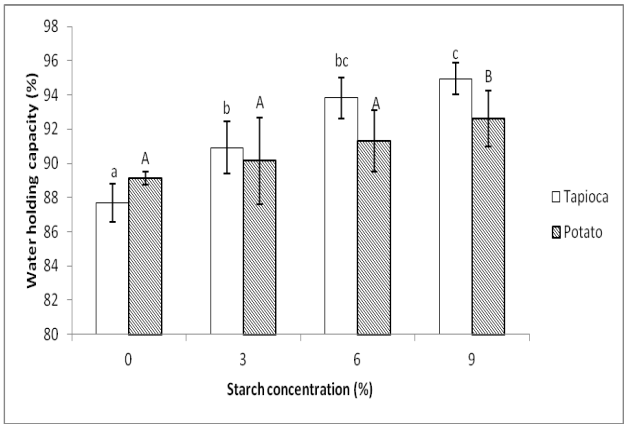
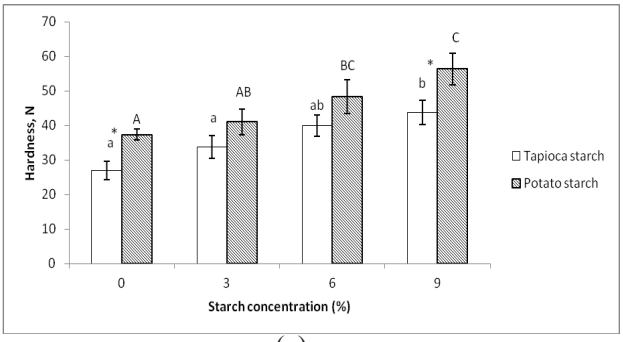


Figure 3. Water holding capacity (%) of the fish balls added with different types of starch (tapioca and potato starch) added at different concentration (3, 6, and 9%). All samples were frozen at -20ºC for 1 day and thawed at room temperature before analysis. Data are shown as mean ± standard deviation, n=3.

a,b,c means significant difference ($p < 0.05$) across the concentration for tapioca starch

A,B means significant difference ($p < 0.05$) across the concentration for potato starch

No significant difference ($p \geq 0.05$) in WHC was observed between samples containing TS and PS, indicating that both starch have similar water binding ability. It was claimed that the amylase/amylopectin ratio is important in determining the WHC of starch, whereby starch with higher amylopectin content tends to have better ability to hold water (Zhang *et al*., 2013). According to Zhang *et al.* (2013), starch retrogradation and ice recrystallization affect the deterioration of the frozen paste during storage and high amylose starches easily undergo retrogradation during frozen storage. In other words, high-amylopectin starch would release the least amount of free water during frozen storage. Since both TS and PS have similar amylase/amylopectin ratio, which



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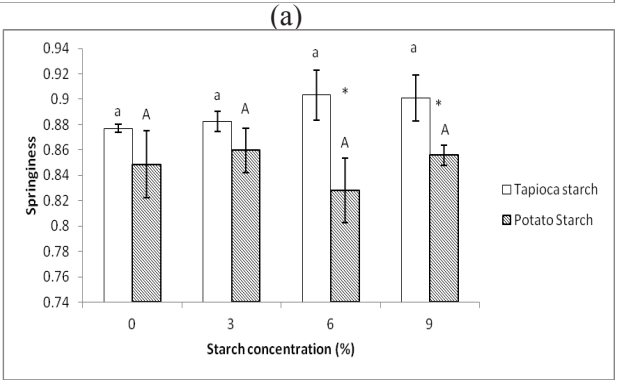

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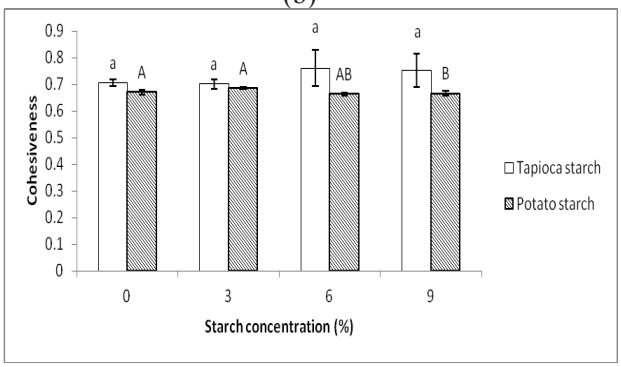

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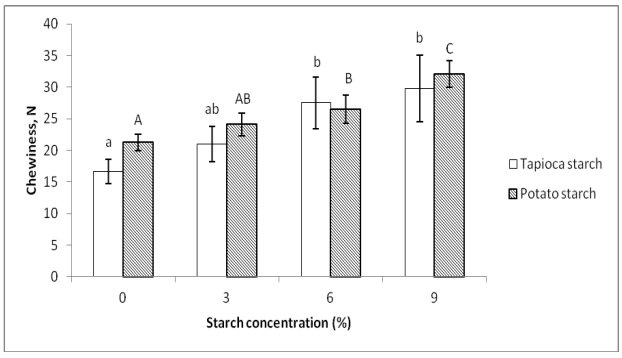


(d)

Figure 4. (a) Hardness (N) (b) Springiness (c) Cohesiveness (d) Chewiness (N) of the fish balls added with different types of starch (tapioca and potato starch) added at different concentration (0, 3, 6, and 9%). All samples were frozen at -20ºC for 1 day and thawed at room temperature before analysis. Data are shown as mean ± standard deviation, n=3.

a,b means significant difference across the concentration for tapioca starch

A,B,C means significant difference across the concentration for potato starch

* means significant difference ($p < 0.05$) between tapioca starch and potato starch at each concentration

is 20:80 and 17:83 for the respective starch (Park, 1995a), no difference was observed for the WHC of the samples containing TS and PS.

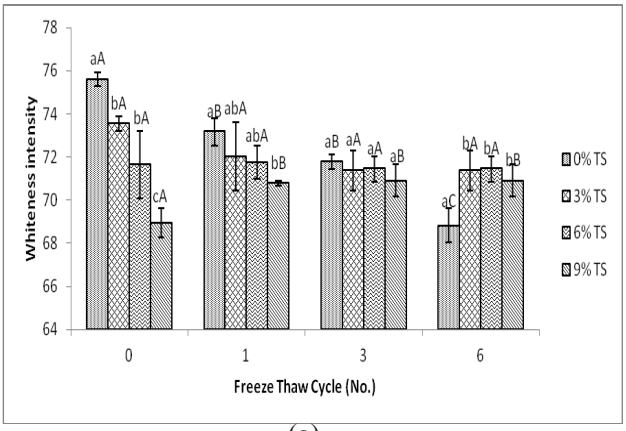
Texture profile analysis

Hardness is defined as force necessary to attain a given deformation (Szczesniak, 1963). The hardness of samples added with 3% and 6% TS were not significantly ($p \geq 0.05$) different from the control and sample with 9% TS (Figure 4a). The hardness of fish balls added with 9% TS appeared to be significantly ($p < 0.05$) higher than the control. The significant ($p < 0.05$) increase in hardness is due to the composite reinforcing effect of starch in the surimi gels, whereby the absorption of the embedded water in protein gel matrix by starch granules will tend to push the matrix as they swell during cooking, thus resulting in a more compact and firmer product as protein matrix loses moisture (Kim and Lee, 1987).

The hardness of PS-added samples was similar to the trend observed in TS samples (Figure 4a); with the exception that the hardness of samples added with 6% and 9% PS appeared to be significantly ($p < 0.05$) higher than the control. The PS-added sample appeared to be significantly harder ($p < 0.05$) as compared to TS-added samples at 9% concentration. This phenomenon could be due to the larger granules size of PS as compared to TS, thus resulting in greater swelling in PS granules and hence more water is absorbed from the protein matrix, giving rise to a firmer texture.

Springiness is defined as the rate of a product to return to its original position after deformation of force was exerted (Szczesniak, 1963). There was no significant difference ($p \geq 0.05$) in the springiness for both TS and PS samples across the starch concentrations (Figure 4b). When comparing the springiness between TS- and PS- added samples, it was observed that springiness of samples containing 6% and 9% PS was significantly ($p < 0.05$) lower than TS-added samples with the same concentration. The reason remains not clear.

Cohesiveness is determined from the area of work during the second compression divided by the area of work during the first compression (Szczesniak, 1963). This parameter indicates the ability of the product to withstand a second deformation relative to how it behaved under the first deformation. In this study, no significant difference ($p \geq 0.05$; Figure 4c) was observed for the cohesiveness in TS-added samples as TS concentration increased from 0 to 9%. For PS-added samples, the cohesiveness of samples containing 9% was significantly ($p < 0.05$) lower than the control and samples added with 3%



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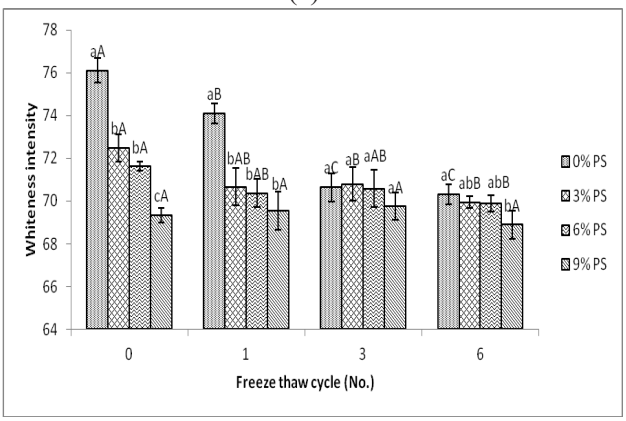

(b)

Figure 5. Effect of freeze thaw (FT) cycle (0, 1, 3 and 6) and (a) tapioca starch (TS) (b) potato starch (PS) concentration (0, 3, 6 and 9%) on the whiteness intensity of fish balls. Data are shown as mean ± standard deviation, n=3.

a,b means significant difference ($p < 0.05$) across starch concentration within each FT cycle

A,B means significant difference ($p < 0.05$) across FT cycle within each starch concentration

PS. The cohesiveness of 6% or 9% PS-added were significantly ($p < 0.05$) lower than TS samples.

Chewiness is known as the energy required to masticate a solid food to a state ready for swallowing and it is calculated by multiplying hardness with cohesiveness and springiness. The control appeared to have significantly ($p < 0.05$) lower chewiness as compared to samples containing 6% or 9% of TS (Figure 4d). Sample with 3% TS had intermediate chewiness, where it did not show a significant difference ($p \geq 0.05$) from neither control nor samples with 6% and 9% TS. The increase in chewiness as TS content increased could be due to the increase in hardness as TS concentration increased since the formula used to calculate chewiness is known as the multiplication of hardness with cohesiveness and springiness. The similar trend was observed for PS samples, with the exception that the chewiness of samples 9% PS-added samples appeared to be significantly ($p < 0.05$) higher than 3% PS-added samples. No significant ($p \geq 0.05$) difference in chewiness was observed between TS- and PS-added samples.

Colour

Colour is known to be an important attribute for a food product as it usually affects consumer acceptance for a product. Whiteness intensity is important for fish based products such as fish balls as whiter fish balls are perceived to be fresh and have better quality. Based on Figure 5a and b, at 0 FT cycle, the whiteness intensity of fish balls decreased significantly ($p < 0.05$) as starch concentration increased, where fish balls containing 9% starch appeared to be the darkest as compared to the control samples and fish balls added with 3% or 6% of TS or PS samples. Addition of starch decreases the whiteness intensity of fish balls because as starch granules are swollen due to water absorption, more light will be allowed to pass through these swollen granules, thus forming translucent gels that result in the decrease of the lightness, L^* value, of the fish ball samples containing starch (Yang and Park, 1998).

Freeze-thaw treatments affected the colour of fish balls, making them darker as freeze-thaw cycles increased from 0 to 6th FT cycle, specifically for fish balls without the addition of starch (control) ($p < 0.05$) (Figure 5a and 5b). Although fish balls added with TS and PS appeared to be darker than the control before freezing (FT cycle 0), the whiteness intensity of TS- and PS-added fish balls did not show a significant change ($p \geq 0.05$) throughout 1st, 3rd and 6th FT cycles. The decrease in whiteness intensity for control samples might be due to reduced of moisture content as a consequence of freezing (Park, 1995b). This phenomenon was supported by several studies which showed decreased in lightness (L^*) values for trout fillets (No and Storebakken, 1991) and pike eel surimi (Hsu, 1990) during frozen storage. The consistency of colour for TS- and PS-added fish balls throughout the six FT cycles could be supported by the lower drip loss of TS- and PS-added fish balls as compared to the control throughout six FT cycles (Figure 1a and b), in which more moisture was retained in the sample as compared to the control, thus preserving the color of fish ball.

When comparing the whiteness intensity of TS- and PS-added samples, PS-added samples appeared to be slightly darker than TS-added samples. This might be due to the size of PS granules that is twice the size of TS granules. The former is approximately 40 μm whlist the later is is approximately 20 μm (Tester et al., 2004). The larger granule size allows more light to pass through, thereby increasing the translucency

of the gel and resulting in lower whiteness intensity for PS-added fish ball as compared to TS-added fish ball.

Conclusions

In conclusion, the drip loss of control is more pronounce than samples added with TS and PS across starch concentrations, within each FT cycle. The gel strength of fish balls increases in the presence of starch and had the highest gel strength when TS and PS was added at 9%. The WHC increased as starch concentration increased and no significant difference was observed between TS- and PS-added samples. Generally, the hardness and chewiness of fish balls increase with the addition of starch whilst springiness and cohesiveness remain unchanged in the presence of starch. Samples added with starch appeared to be darker than the control. The colour of the starch-added samples did not change after six freeze-thaw cycles. These findings indicated that both TS and PS could improve the physical properties of frozen fish balls. Consumer acceptance of fish balls containing different starch concentrations could be further investigated.

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