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A Study on the Physicochemical Properties, Microstructure and Sensory Characteristics of Fish Flakes

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Abstract: The objective of this project was to determine the chemical composition, color, shear force (N), sensory evaluation and Scanning Electron Microscopy (SEM) of fish flakes prepared with the addition of five different levels (10, 15, 20, 25 and 30%) of Tapioca Starch (TS). Fish flakes were prepared from mixture of stingray meat, spices, TS and dried using oven dryer until the moisture content was reduced to about 25%. No significant difference was found in the fat, Ca and Fe contents among the five treatments. Sensory evaluation shows samples containing 15% of TS more acceptable by the panelists. A color analysis showed that there were significant differences ($p<0.05$) among the samples except for the redness (a) values. The substitution of TS affected to the moisture content and texture of the final product. The shear force values tended to increase by increasing the levels of TS. The SEM photograph showed that increasing level of TS and heating treatment caused change in the microstructure and affected the shear force value of the end product. The information provided by this study can be utilized by the jerky producers to manufacture jerky from stingray meat as diversified jerky product which is already available in the market.

Key words: Dendeng giling, jerky, tapioca starch, snack food, *Himantura gerrardi*

INTRODUCTION

In recent years, fish has become a favorite foodstuff because of health reasons. This is because it is considered safer and healthier to be consumed when compared with goat meat or chevon, mutton, buffalo meat and chicken. Fish is also one of the main sources of protein in the developing countries.

Elasmobranch is a promising export commodity and its processing stages into food product is not yet optimized in Indonesia. According to White, the co-author of survey studies sharks and rays in Indonesia at the years 2001 until 2006 was explained that Indonesia is a country which has the greatest diverse shark and rays fauna in the world, with the landing more than 100,000 tons per years. Based on taxonomy there are 600 species of elasmobranches, most of them live in the sea, but a few species can be found in the river and estuaries as a permanent resident (Tinker and Deluca, 1973). Elasmobranches are made up of two big groups of fishes, namely stingrays and shark. Stingrays, which are known as pari

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in Malaysia, have a specific body shape with a very broad disc, whip tail and poison (White *et al*., 2006). Stingrays are a good source of protein and are low in fat content. According to Mardiah *et al.* (2008) stingrays contain 79.10% moisture, 0.83% ash, 16.86% crude protein and 0.42% crude fat (wet basis). Stingrays can be processed into many products such as fish cracker, salted fish, smoked fish, fish floss and fish flakes as a way to diversify fish based products. Cracker of stingray meat was very popular as a snack food in Kualatungkal region, Indonesia.

Fish flakes, also well-known as Dendeng giling, is a traditional Indonesian Intermediate-Moisture (IM) meat product containing coconut sugar, salt and spices, prepared by sun drying a mixture of minced beef, salt, garlic, coriander and sodium nitrite (Huang and Nip, 2001; Darmadji *et al*., 1990). These products are processed using hurdle technology such as application of temperature, control of water activity (Aw), addition of preservatives and curing ingredients (Leistner, 1987). Dendeng has a sweet taste due to its high sugar content and together with the strong flavor of the spices and the dried meat gives it a characteristic flavor that differentiates it from other traditional intermediate moisture products (Huang and Nip, 2001). This product is easy to prepare, light weight, rich nutrient content and stable without refrigeration and is also popular among travelers and mountaineers as a snack food (Choi *et al*., 2008). Apart from the commercial production, dendeng can be producing at home as a home industry. The presence of jerky product in the market was able to compete to other product due to the specific characteristic taste.

In the west, there is a product that is quite similar to dendeng giling called Jerky. Jerky is one of the oldest meat products that is preserved by salting and drying (Calicioglu *et al*., 2003; Choi *et al*., 2008; Faith *et al*., 1998; Yang *et al*., 2009) and it is rapidly growing in the American market as a snack food (Konieczny *et al*., 2007; Yoon *et al*., 2005). Other names of products that are similar to dendeng giling are biltong in South Africa, pemmican in North America, *carne* de sol in South America, *charqui* in Brazil, lup cheong, isusou gan, nyoursougan and sou song in China, (Darmadji *et al*., 1990) and *bak kua* in Malaysia. The preparation of fish flakes is similar to dendeng giling except for the addition of tapioca starch. There is no previous research concern to study jerky from fish material (Barrett *et al*., 2000; Calicioglu *et al*., 2003; Carr *et al*., 1997; Choi *et al*., 2008; Ioffe *et al*., 2002; Konieczny *et al*., 2007; Pegg *et al*., 2006; Yang *et al*., 2009; Yoon *et al*., 2005). Numerous jerky products were found made from beef, pork and poultry compared to fish jerky. Meanwhile, fish also have the high potential as raw material to produce jerky. Gopakumar (1998) reported that the utilization of low-value fish can be converted into various value-added products such as fish flakes, hydrolysates and fish soup powder. Oduor-Odote and Kazungu (2008) was found that the low value fish in Kenya can be utilized and have the high potential to make snack food based on the mixture of mince fish and flour.

In this research, fish flakes was made from a mixture of stingray meat, different levels of tapioca starch and flavoring ingredients (coriander powder, garlic, onion, salt, palm sugar, tamarind, ginger root and galangal). Because of the lack information of fish jerky make the goal of this study. The objective is to evaluate the physicochemical, microstructure and sensory characteristics of fish flakes which are substituted with tapioca starch.

MATERIALS AND METHODS

Materials

The present study was carried out at the Fish and Meat Processing Laboratory, Food Technology Programme, School of Industrial Technology, Universiti Sains Malaysia, over the period middle of 2007 to end of 2008. Stingrays (*Himantura gerrardi*) were purchased fresh from a local market, Bayan Baru, Penang, Northern part of Malaysia and kept in a cold ice box until arrive at Laboratory. On arrival at the laboratory, the fresh fish was washed immediately and the bones and the skin were separated from the flesh. The fish flesh was then washed until it was free from blood and placed in a plastic bag, sealed and kept in a freezer at -20°C before it was processed. The ratio starch to fish used per each formulation was 20:180, 30:170, 40:160, 50:150 and 60:140 g, respectively. The ingredients used were garlic (2 g), tamarind (10 g), salt (2 g), palm sugar (40 g), ginger (1 g), onion (3 g), coriander (3 g) and galangal root (5 g). All the ingredients were obtained from a local supermarket. The control (without tapioca starch) was not used in this experiment due to that formulation cannot spread into layer and loose when it dried. The thin layers of fish flakes tend to change to floss form when the end of drying. Therefore it is needed tapioca starch to bind the stingray meat to obtain a good texture in final product.

Samples Preparations

The preparations of the fish flakes were carried out using the method of Gopakumar (1998). Each formulation consist of (180 g, 170 g, 160 g, 150 and 140 g) of stingray meat and soaked in 5% of salt solution for 10 min and then steamed at 80°C for 60 min. The cooked stingray meat, other ingredients and tapioca starch were mixed together. The formulation was mixed for 15 min by hand to form dough and then spread into layers in a tray to a thickness of 3 mm using a Dough Sheeter (ESMACH, S.p.A, Italy). The thin layers were steamed (Steamer MSM 2001, Malaysia) at 100°C for 1 h. Fish flakes were obtained by cutting the layers into 12×4 cm rectangles and were dried using an oven dryer (AFOS Mini Kiln, England) at a temperature of 60°C until the moisture content was reduced to about 25% (Fig. 1).

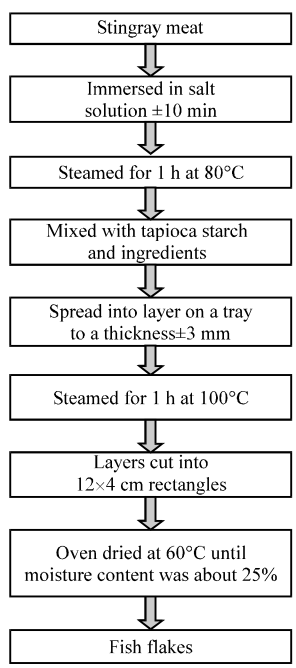

Fig. 1: The diagram of fish flakes manufacturing

Proximate Analysis

The proximate composition of the fish flakes was determined as per AOAC (2000). The moisture content was measured by weighing differences before and after oven drying at 100-105°C for 16 h. The protein content (% N x 6.25) was determined by the Kjeldahl method. Ash content was determined by heating the samples in a furnace at 550°C until a white color of the samples was obtained. Fat content was measured based on the Soxhlet Extraction method utilizing petroleum ether 40-60°C. The analyses were repeated three times and the results are presented as Mean±SD of determinations for the triplicate samples.

Mineral Analysis

In the mineral analysis, the dried sample was used after extracting the fat content. Samples (about 1 g) were digested in a mixture of 65% nitric acid (6 mL) and 30% hydrogen peroxide (1 mL). Na, Mg, Ca, Zn and Fe were measured using a flame atomic absorption spectrophotometer (Perkin Elmer 3110, US). Phosphorus (P) was determined by a spectrophotometer (Shimadzu UV 160 A, Japan) using the ammonium molybdate method (AOAC, 2000). Absorbance values were read at 400 nm and all samples were done in triplicates.

Color and Shear Force Measurement

The surface color of the fish flakes was measured according to the CIE L* a* b* color system using a colorimeter (Minolta Spectrophotometer CM-3500d, Japan). The values, expressed as L* (lightness), a* (redness) and b* (yellowness) units, were obtained from four different areas of the upper surface of each chop. The equipment was standardized with white color calibration tiles and three readings were taken per treatment.

Shear force was measured by a Warner Bratzler Blade Set with a rectangular slot blade using a TA.XT2 Texture Analyzer (Stable Micro Systems, Surrey, UK) with a load cell of 25 kg. A blade (guillotine-edge) with a thickness of 3.0 mm and a width of 70 mm was used. The samples were fried in hot oil (170°C for ±45 sec) prior to analysis. The 1.5×1.5×0.3 cm rectangular samples were attached to a texture analyzer. Test speeds were set at 2.00 mm sec^{-1}, pre-test speed at 5.00 mm sec^{-1} and post-test speed at 10.00 mm sec^{-1} according to Sigurgisladottir *et al.* (1999) with some slight modifications. Six measurements were performed on each sample.

Scanning Electron Microscopy (SEM) Analysis

The dough and fish flakes samples (±10 g) were put separately in a petri dish then covered with aluminum foil. A small hole was made in the cover to allow air circulation. The samples were kept in a freezer (-20°C) for 24 h; then the frozen samples were freeze dried (LABCONCO, US). By using a knife, the dried pieces of dough and fish flake samples were fractured into sizes of about 1×1×0.3 cm. The samples were then attached to the SEM stub with double-sided cellophane tape. The surface of the samples was coated with ±30 nm of gold (Sputter Coater POLARON SC515). The area was viewed and micrographed by using a Leo Supra 50VP Field Emission SEM apparatus Model Carl-Ziess SMT, Oberkochen (Germany) at an accelerating voltage of 5.00 kV.

Sensory Evaluation

The samples were fried in oil in a fryer (Anvil FFA 3001, South Africa) at a temperature of 170°C and then cooled to room temperature and immediately cut into 1.5×1.5 cm rectangles.

The sensory evaluation of the fish flakes was conducted by 35 panelists that consisted of students from the Food Technology Division at Universiti Sains Malaysia. They evaluated the appearance, color, odor, taste, texture and overall acceptability of the fish flakes. A 7-point hedonic scale was used to indicate the desirability of the products ranging from 1 (dislike very much) to 7 (like very much) (Abdullah, 2000).

Statistical Analysis

Three replicates per formulation were analyzed for each measurement. Three reading were taken for proximate, color, mineral analysis and six reading for shear force values. The data were analyzed by one way analysis of variance as completely randomized with five treatments. The statistical analysis was done using SPSS 11.5 for windows (SPSS, 2002). Duncan's multiple range tests were used to find significant differences among the treatment. A value of $p<0.05$ was used to indicate a significant difference.

RESULTS

Proximate Composition

Table 1 shows the formulation of fish flakes for different levels of Tapioca Starch (TS), the total of fish flesh and TS were 200 g per each formulation. Whereas the amount of spices was used are same in every each formulation. According to these formulations, the highest and least amount of fish flesh is shows in sample 10% and 30% respectively. The highest amount of palm sugar was used for all formulation can be contributed to the color of the end products.

The addition of tapioca starch for different concentration was effected to the moisture content of the samples (Table 2); the protein content range from 34.93±1.27 to 27.66±2.12 was decreased with increase level of tapioca starch. Meanwhile, there was no significant effect to the fat content for all samples. The low score of fat content can extend the shelf life of the product. Increasing levels of tapioca starch significantly decreased ash content for the sample TS 25% and TS 30%. Furthermore, the carbohydrate content was increased significantly ($p<0.05$) with the increased of tapioca starch in the fish flakes formulation.

Table 1: Formulation of fish flakes

Ingredients	10%	15%	20%	25%	30%
Fish flesh (g)	180	170	160	150	140
Tapioca starch (TS) (g)	20	30	40	50	60
Coriander powder (g)	3	3	3	3	3
Garlic (g)	2	2	2	2	2
Onion (g)	3	3	3	3	3
Salt (g)	2	2	2	2	2
Palm sugar (g)	40	40	40	40	40
Tamarind (g)	10	10	10	10	10
Galangal root (g)	5	5	5	5	5
Ginger (g)	1	1	1	1	1

Table 2: Proximate composition of fish flakes

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
TS 10%	25.52 ± 0.04^{c}	34.93 ± 1.27^{b}	1.67 ± 0.03^{c}	6.19 ± 0.03^{d}	31.69 ± 1.26^{a}
TS 15 %	25.21 ± 0.16^{b}	34.59 ± 0.74^{b}	1.51 ± 0.17^{bc}	5.29 ± 0.17^{c}	33.41 ± 0.68^{a}
TS 20%	24.94 ± 0.11^{a}	32.99 ± 1.07^{b}	1.48 ± 0.14^{bc}	4.76 ± 0.04^{b}	35.83 ± 0.81^{b}
TS 25%	25.81 ± 0.05^{d}	29.82 ± 1.32^{a}	1.37 ± 0.19^{ab}	4.51 ± 0.04^{a}	38.48 ± 1.05^{c}
TS 30%	26.34 ± 0.10^{e}	27.66 ± 2.12^{a}	1.19 ± 0.14^{a}	4.48 ± 0.02^{a}	40.32 ± 2.02^{c}

TS = Tapioca Starch. *Value is the mean of 3 replicates. Means within a column with different superscript letters are significantly different ($p<0.05$)

Mineral Contents

The addition of tapioca starch was decreased Na, Mg, Ca, Zn, Fe and P contents of fish flakes (Table 3). The data for each mineral in a sample are presented in a unit of mg/100 g sample on a dry basis. Na content had the highest values than other samples which can be attributed to the addition of salt in the formulation. The Na content of fish flakes significantly decreased with the increase of tapioca starch. The Mg content was significantly decrease ($p<0.05$) at the sample TS 25%. In addition, tapioca starch did not significantly affect to the Ca and Fe contents. The Zn content was significantly reduced ($p<0.05$) when tapioca starch was increased to 20%. Meanwhile, the P content decreased significantly ($p<0.05$) with the increased level of tapioca starch.

Color and Shear Force

The results of the color analysis of fish flakes showed that the L*, a* and b* values increased with increasing levels of tapioca starch (Table 4), the increasing color attributes arise mainly from tapioca starch and palm sugar which was used in the formulation. An analysis of variance indicated that the L* (lightness) values were significantly ($p<0.05$) different. Furthermore, redness (a*) values showed a significant difference ($p<0.05$) in sample TS 30%, b* values also showed significant differences ($p<0.05$).

There was a significantly ($p<0.05$) changed the shear force values found among the samples (Table 4), shear force was measured by cutting the samples with a blade. The results showed that increasing level of tapioca starch was increased the shear force values. Shear force value was found higher at 30% substitution of tapioca starch.

Scanning Electron Microscopy (SEM)

As shown in Fig. 2A-C, the SEM of dough samples markedly changed during the processing stage. Figure 2A showed the shape of the starch granules was clear and fish muscle covered most of the starch granules. The distribution of whole, small and large starch granules are dense with the form of the protein matrix. Meanwhile, in Fig. 2B, the starch granules were melted and gelatinization started to occur. A few small gas vacuoles were found inside the samples. The formation of fish muscle network with starch provides a strong interaction. Figure 2C showed that starch and fish muscle was very dense, sticky and firm after steaming and drying.

Table 3: Mineral contents of fish flakes (mg/100 g)

Samples	Na	Mg	Ca	Zn	Fe	P
TS 10%	5416.88 ± 74.34^{d}	116.96 ± 14.96^{c}	45.60 ± 2.99^{c}	1.25 ± 0.05^{c}	6.03 ± 1.49^{b}	44.89 ± 0.57^{e}
TS 15%	4387.41 ± 311.28^{c}	110.01 ± 4.83^{bc}	43.32 ± 1.03^{bc}	1.13 ± 0.10^{b}	4.59 ± 0.49^{ab}	41.39 ± 0.99^{d}
TS 20%	3920.37 ± 274.09^{b}	102.21 ± 4.64^{b}	40.86 ± 3.55^{ab}	0.90 ± 0.04^{a}	4.31 ± 0.86^{ab}	36.69 ± 0.53^{c}
TS 25%	1903.46 ± 74.25^{a}	53.48 ± 1.03^{a}	39.06 ± 0.43^{a}	0.87 ± 0.05^{a}	4.01 ± 0.49^{a}	33.58 ± 1.19^{b}
TS 30%	1746.11 ± 59.49^{a}	50.05 ± 0.59^{a}	37.91 ± 1.43^{a}	0.85 ± 0.03^{a}	3.45 ± 0.86^{a}	31.00 ± 0.44^{a}

TS = Tapioca Starch. *Value is the mean of 3 replicates. Means within a column with different superscript letter(s) are significantly different ($p<0.05$)

Table 4: Color measurement and shear force of fish flakes

Samples	L*	a*	b*	Shear force (N)
TS 10%	25.23 ± 0.08^{a}	4.05 ± 0.02^{a}	6.32 ± 0.07^{b}	103.19 ± 0.56^{a}
TS 15%	25.97 ± 0.08^{b}	3.91 ± 0.12^{a}	6.09 ± 0.06^{a}	117.50 ± 1.09^{b}
TS 20%	26.81 ± 0.11^{c}	5.44 ± 0.16^{b}	7.54 ± 0.16^{c}	115.93 ± 0.25^{b}
TS 25%	28.90 ± 0.08^{d}	5.58 ± 0.07^{b}	7.93 ± 0.05^{d}	128.97 ± 1.25^{c}
TS 30%	29.20 ± 0.10^{e}	6.14 ± 0.03^{c}	8.62 ± 0.09^{e}	135.53 ± 1.27^{c}

TS: Tapioca starch. *Value is the mean of 3 replicates for color and six replicate for shear force. Means within a column with different superscript letters are significantly different ($p<0.05$)

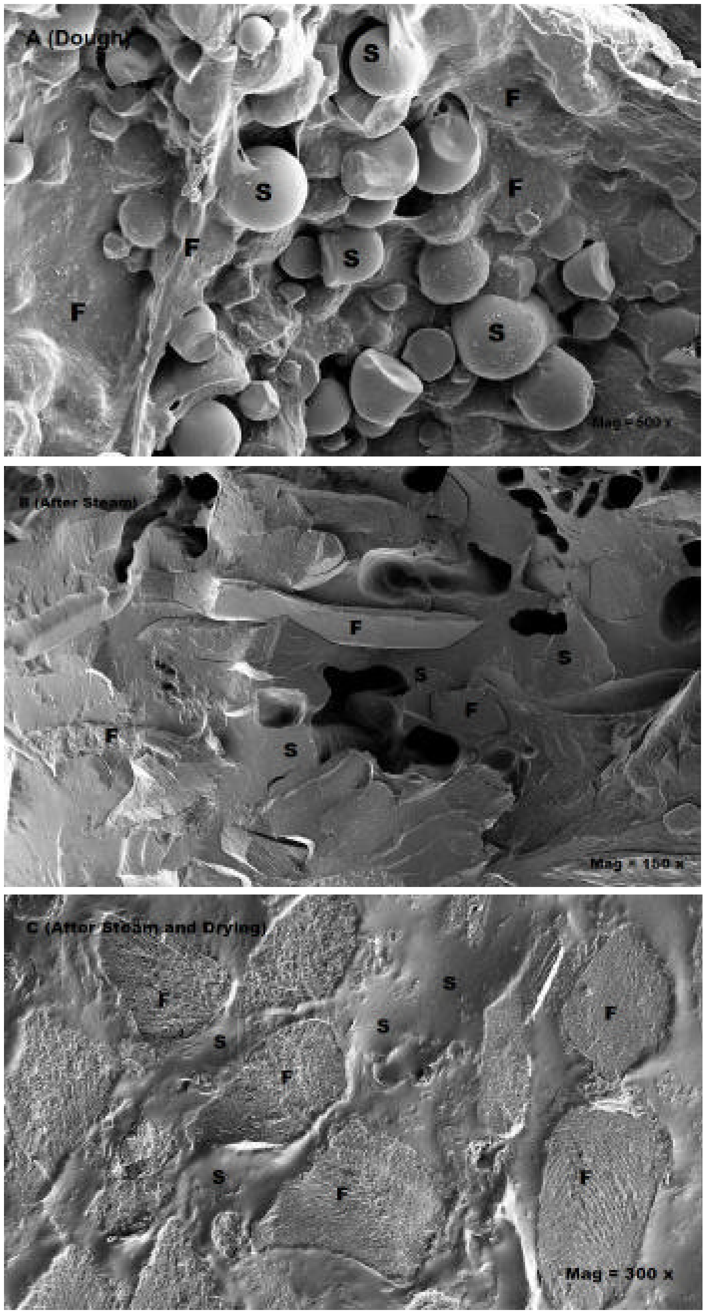

Fig. 2: Effect of thermal processing on the microstructure of fish flakes. F: Fish, S: Starch, A (dough fish flakes, Magnification = 500x), B (fish flakes after steaming, Magnification = 150x), C (fish flakes after steaming and drying, Magnification = 300x)

The microstructure of fish flakes with various levels of tapioca starch during processing stage showed in Fig. 3, the increasing levels of tapioca starch will increase gelatinization and it's had effect on the texture of the fish flakes. Figure 3A showed that there was no starch

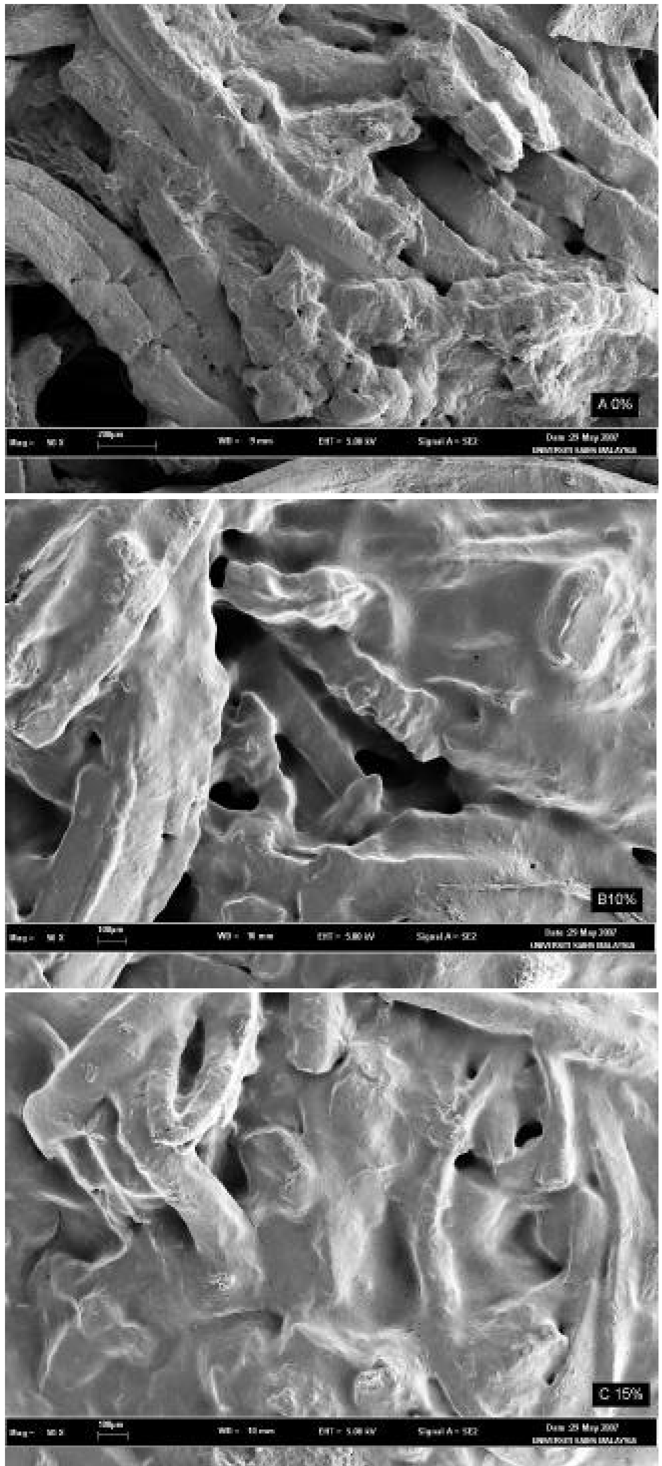

Fig. 3: Continued

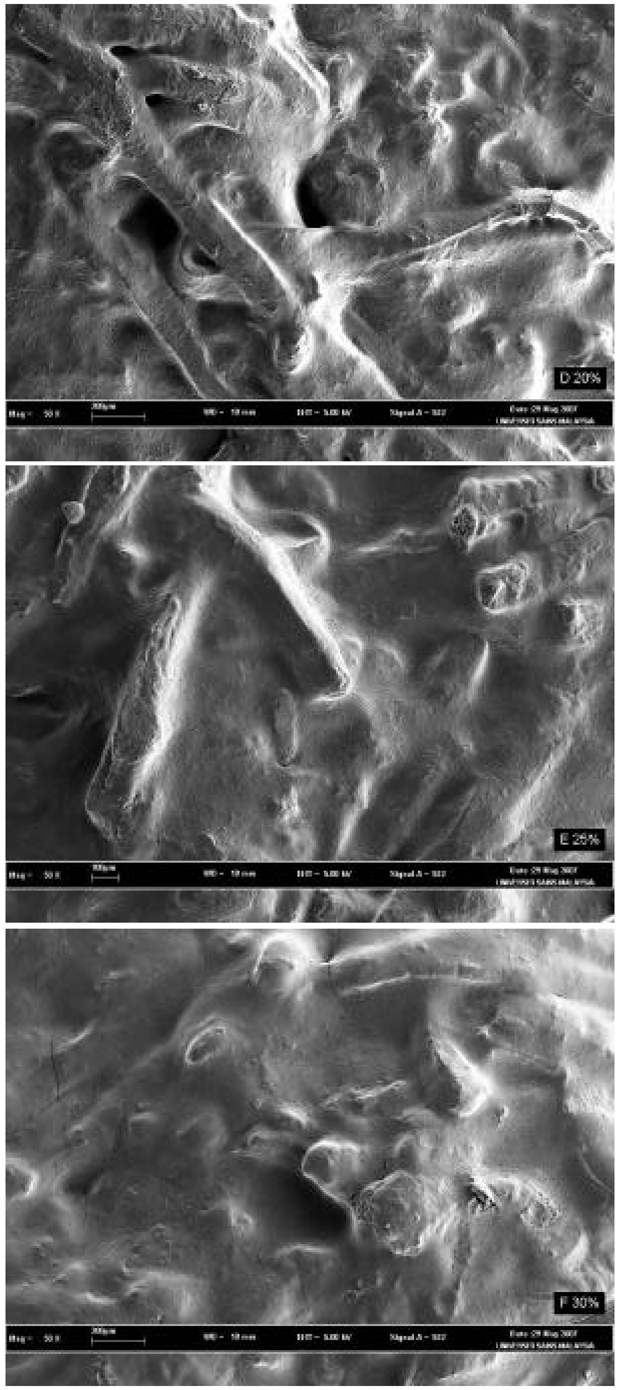

Fig. 3: The effect of the different level of tapioca starch on the sample (Magnification = 50x). sample A (without tapioca starch), B (20 g of tapioca starch), C (30 g of tapioca starch), D (40 g of tapioca starch), E (50 g of tapioca starch) and F (60 g of tapioca starch)

Table 5: Sensory characteristics of fish flakes

Samples	Color	Odor	Taste	Texture	Overall acceptability
TS 10%	4.69±1.41[a]	5.06±1.37[a]	5.31±1.32[ab]	5.23±1.37[b]	5.26±1.27[ab]
TS 15%	4.69±1.23[a]	5.29±1.27[a]	5.63±1.09[b]	5.57±1.17[b]	5.54±1.12[b]
TS 20%	4.57±1.39[a]	5.14±1.03[a]	4.77±1.33[a]	4.54±1.15[a]	4.77±1.06[a]
TS 25%	5.46±0.95[b]	5.46±0.89[a]	4.94±1.26[a]	4.31±1.29[a]	4.94±1.28[ab]
TS 30%	5.51±1.09[b]	5.54±1.40[a]	4.86±1.26[a]	4.26±1.42[a]	4.74±1.40[a]

TS = Tapioca starch. * Value is the mean of 35 replicates. Means within a column with different superscript letters are significantly different ($p<0.05$)

network formation and the longitudinal muscle of the fish was showed clearly. In addition, Fig. 3B to F showed that the high gelatinization was occurred, the starch granules absorb the water and swelling appears during the thermal processing.

Sensory Evaluation

The addition of TS to fish flakes formulation affected to their acceptability and texture attributes. The acceptability of color showed that the higher scores found in the sample TS 25% and TS 30%. As per (Table 5), there exists significant difference among samples containing 10 and 15% of TS compared to other 3 samples. Meanwhile, there had no effect of TS addition on the odor evaluation. In terms of texture and taste evaluation, the addition of TS 20% to 30% gives the lower scores by the panelists and samples were tougher than the other samples. Sensory evaluation revealed that sample TS 15% was preferable by the panelists for overall acceptability.

DISCUSSION

The average level of the moisture content of fish flakes was 25.56%. Results are similar to Intermediate Moisture (IM) meat product in other studies (Bintoro *et al*., 1987; Choi *et al*., 2008; Darmadji *et al*., 1990; García *et al*., 1997; Huang and Nip, 2001; Kalilou *et al*., 1998; Konieczny *et al*., 2007; Pegg *et al*., 2006). Intermediate Moisture (IM) meat product contain 15 to 50% of moisture and can keep without refrigeration or thermal processing, some can be direct eat raw without rehydration or cooking process (Huang and Nip, 2001). The increasing level of tapioca starch has increased the moisture content of fish flakes. Rai (2006) reported that small amount of starch in a product can bind large quantities of water thus increase the moisture content. This might be attributed to the higher water absorption capacity in the tapioca starch (Rai, 2006). Moisture content also related to the texture and the shelf life of a product (Konieczny *et al*., 2007). Fish flakes were tougher for sample TS 30% compared to TS 10%. As compared to beef, emu and turkey jerky (34.94%, 31.98% and 36.32% respectively) (Carr *et al*., 1997), fish flakes found to be lower in moisture content. The lower moisture content in fish flakes was due to its long drying time. This indicated that fish flakes are more stable stored at room temperature than beef, emu and turkey jerky product. Fish flakes and jerky product have a slightly different in term of materials and formulation. Generally jerky product which is found in the market did not use starch as the texture stabilizer in the formulation.

The increased level of tapioca starch also affected the protein content of fish flakes. The protein content was found lower in sample TS 25% and TS 30% compared to TS 10% to TS 20%. The decrease of protein content can be related to heat treatment during the processing. The results found that protein content of fish flakes sample TS 10% was similar to beef dendeng (Huang and Nip, 2001). However it is quite low compared to beef jerky (Pegg *et al*., 2006), with a range of 43.9 to 44.2%. Protein is an important parameter in determining the quality and texture of muscle fish; small amounts of protein in muscle fish tend to lose water during the cooking process which ruins the texture of the meat (Okland *et al*., 2005). As Calicioglu *et al*. (2003) reported, beef jerky treated with marinades during drying and storage had high protein and low fat content.

The different level of tapioca starch did not significantly affect the fat content of fish flakes. Starch is not a good source of fat content. Rai (2006) found that tapioca starch had low lipid content. Substitution of tapioca starch in a product did not affect the fat content of the end product. Astawan (2004) reported that products from elasmobranches had low fat levels; shark fillet has 0.3% fat content. The fat content in a product related to the shelf life of product. The same agreements with Winarno (1984), fat easily binds oxygen in the air and rancidity will occur in the product thus lowering its quality. Fat content also can be change during the frozen storage (Keyvan *et al*., 2008).

Increased levels (25 and 30%) of TS has resulted in significant reduction in ash content of the fish flakes. The results are similar with Choi *et al*. (2008) reported that semi-dried jerky contain ash content with a range of 4.83 to 5.60%.

The carbohydrate content tends to increase with increased level of tapioca starch. The carbohydrate content of sample was found higher compared to emu and beef jerky (Pegg *et al*., 2006).

The Na content of the fish flakes ranged from 1746.11±59.49 to 5416.88±74.34 mg/100 g. The result was found higher than emu jerky reported by Pegg *et al.* (2006). The Mg content of fish flakes sample TS were 10 to 20% also higher than emu jerky (Pegg *et al*., 2006). Furthermore, Ca and Fe content of fish flakes did not significantly ($p>0.05$) affected by the addition of tapioca starch. Ca and Fe content ranged from 37.91±1.43 to 45.60±2.99 mg/100 g and 3.45±0.86 to 6.03±1.49 mg/100 g, respectively. The Ca content was found higher compared to emu jerky (Pegg *et al*., 2006), which had a value of 28 mg/100 g. Meanwhile Fe was found lower than emu jerky (Pegg *et al*., 2006). Fe is an important mineral for preventing anaemia among women of reproductive age and Ca is crucial in relation to osteoporosis among aged people (Sakurai *et al*., 2008). The Zn and P content of fish flakes was significantly reduce ($p<0.05$) with increased the level of tapioca starch. Results were found lower than emu jerky (Pegg *et al*., 2006).

The increased levels of tapioca starch in the formulation of fish flakes affected the lightness values. The range was found 25.23±0.08 to 29.20±0.10. Huang *et al*. (2005) found that increasing the amount of rice bran in meatball gave a lighter color. Serdaroğlu *et al*. (2005) reported that meatball treated with Lentil Flour (LF) also give the lighter color. The color of the fish and meat product can change markedly when it is dried. Konieczny *et al*. (2007) explained that meat samples heated over a longer time give the darker color. In the other hand, the yellow-brown color of fish flakes is the obvious indicator to explain the Maillard reaction after processing (Louka *et al*., 2004). The L values of fish flakes were found slightly lower compared to beef jerky (30.66±0.43 to 52.15±0.35) (Konieczny *et al*., 2007).

The addition of tapioca starch affected to texture of fish flakes. Li and Yeh (2002) reported that the binary mixtures of protein and starch components are capable of forming gel network which had an effect on the texture of product. The shear force values ranged from 103.19±0.56 to 135.53±1.27. This indicated that starch is responsible for textural properties of the product. The shear forces of frankfurters also increase with increased level of tapioca starch in the formulation (Hughes *et al*., 1998).

The microstructure of fish flakes changed considerably while heating and drying. Xie *et al*. (2006) reported that the corn starch granules were swollen and gelatinized by the heating treatment. High temperatures caused a high rate of gelatinization, product become sticky and tough (Kim *et al*., 2003; Kyaw *et al*., 2001). During the fermentation, Kim *et al*. (2003) was found the SEM for the surface of dough bread samples is uniform with gluten matrix covering the starch granules. Kyaw *et al*. (2001) also found that fish filaments will bind starch granules in a ratio of fish to starch of 10:90 during the processing.

The sensory analysis is a scientific measurement for interpretation of a product which is become acceptable by the panelists. According to overall acceptability, the addition of 15% tapioca starch was preferred by the panelists compared to other samples. Konieczny *et al*. (2007) also used the sensory evaluation to study the acceptability of jerky as a snack food in young people, primarily students.

CONCLUSIONS

In conclusion, this project provides general information to produce fish flakes which is a new product as fish jerky. The addition of TS aims to obtain a good texture, due to the fact that there exist difficulty in slicing the stingray meat alone, as compared to the beef jerky. In terms of chemical composition, some of the parameters decreased and the others did not affect the fish flakes with substitution of TS. The different levels of TS affected the moisture content and shear force of fish flakes. The addition of TS and processing stage did not showed significant decrease in nutritional values of fish flakes. Sensory evaluation revealed that results clearly shows there was significant different for samples containing 10 and 15% of TS.

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