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Effect of orange sweet potato *(Ipomoea batatas)* flour on the physical properties of fried extruded fish crackers

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Abstract: The effects of orange sweet potato flour addition to tapioca starch on the expansion, oil absorption, bulk density, water absorption index (WAI), water solubility index (WSI), hardness and colour of fried extruded fish crackers were investigated. The microstructure properties were assessed by Field Emission Scanning Electron Microscope (FESEM) and the sensory properties of fried extruded fish crackers were determined by quantitative descriptive analysis method. The shape and texture of the product were similar to that of normal breakfast cereal. Light brownish and slightly harder texture was obtained with addition of orange sweet potato flour to tapioca starch in the fried extruded fish crackers. The bulk density and water solubility index (WSI) increased with the increase in orange sweet potato flour addition. However, water absorption index (WAI), linear expansion, expansion ratio, volume expansion and oil absorption decreased as the amount of orange sweet potato increased. The microstructure studies revealed that fried extruded fish crackers with high percentage of orange sweet potato flour had small air cells and thick cell wall. The fried extruded fish crackers with 30% fish, 14% orange sweet potato flour and 56% tapioca starch had high crispiness score and accepted by the trained panellists.

Keywords: Sweet potato, flour, fish crackers, extrusion

Introduction

Extrusion cooking which is extensively used in production of pasta, ready-to-eat breakfast cereals and snacks has several advantages over traditional food processing (Harper, 1978). Extrusion cooking provides the opportunity to produce a new variety of innovative snack products. Using single screw extrusion continuous process, the food materials pass through the extruder barrel by the action of flights on the screw. The food will be subjected to shear and heat before being discharged through a die. Release of high pressure as the product emerges cause the product to expand (Chinnaswamy and Hanna, 1990).

Snack foods are cereal or grain-based products which are generally low in protein and often, high in fat content and normally considered as a low value product. A lot of works have been done to improve the nutritive values of the snack products by incorporation of protein sources derived from plant or animal (Bhattacharya *et al.,* 1990; Park *et al.,* 1993; Senthil *et al.,* 2002; Rhee *et al.,* 2004; Anton *et al.,* 2009). The most popular snack food in Southeast Asian countries is a fish cracker which is also known as *keropok* in Malaysia, *kerupuk* in Indonesia, *kaew krab pla* in Thailand and *banh phong tom* in Vietnam (Kyaw *et al.,* 2001). *Keropok* is produced by gelatinisation of fish-starch mixture to form dough, shaped, then sliced, dried and packed. The expanded low density porous product will be obtained upon frying the dried slice in hot oil before consumption (Siaw *et al.,* 1985). Yu (1991) suggested that the extrusion cooking technique might be a promising alternative method for producing fish crackers. Moreover, the extruded fish snack is more accepted by Asian compared to American consumers (Suknark *et al.,* 1998). Rhee *et al*. (2004) claimed that the extrusion technique can reduce the distinct flavour of fish.

Tapioca (*Manihot esculenta*) and sweet potato *(Ipomoea batatas*) are tropical crops grown for edible purposes (Hoover, 2001). Both starches were consumed in various forms like bake, steam, boil and fry. Sweet potato is one of the important commodities for small-scale farmers in Africa, Latin America and Asia. In Asian region, over 90% of this commodity was grown in China with more than 2000 varieties (Tian *et al.,* 1991). In China, sweet potato flour is used as one of the ingredients in the production of noodles. Iwe *et al*. (1998) stated that sweet potato can be used in extruded product due to similarity in X-ray diffraction pattern of sweet potato flour and cereal starch. High percentage of sweet potato in ready-to-eat sweet potato breakfast cereal increases the nutrient

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content and physical properties and also increases the acceptability (Dansby and Bovell-Benjamin, 2003).

Starch serves as a functional ingredient in extruded products which contribute to the expansion. The expansion which in turn relate to the crispiness is important to determine the acceptability of fish cracker (Yu, 1991). There was little information available regarding the addition of sweet potato flour to tapioca starch in the extruded fish crackers. Factors such as raw ingredients, formulation and processing conditions have to be monitored to get high quality of expanded snacks (Wang, 1997). Therefore, the objective of this study is to determine the effect of orange sweet potato flour addition to tapioca starch on the physical properties of fried extruded fish crackers at fish contents of 30% and 40%.

Materials and Methods

Raw materials

Tapioca starch (*Manihot esculentus*), orange-fleshed sweet potato (*Ipomoea batatas*), red tilapia (*Oreochromis mossambicus*), salt (sodium chloride) and sugar (sucrose) were purchased from local hypermarket in Shah Alam, Selangor, Malaysia. Salt and sugar used were of food grade. Red tilapia with average weight of 150 - 300 g was deheaded, degutted and cleaned. It was then placed in a sealed plastic bag to be stored in freezer at -20°C until used. The cleaned fish was thawed and deboned prior to use.

Preparation of orange sweet potato flour

Orange sweet potatoes (*Ipomoea batatas*) were peeled, washed and sliced. The sliced sweet potatoes were dried in locally fabricated cabinet dryer (Vision Scientific, Selangor, Malaysia) at 55°C overnight. The dried potatoes were ground by using Waring blender (Waring, Torrington, USA). The ground sweet potatoes were sieved through a mesh No. 60 with width size of 0.25 mm (Retsch, Haan, Germany). The fine flour was stored in sealed bottle prior to use.

Production of extruded fish crackers

The minced red tilapia fish was cooked in microwave for 10 minutes and finely chopped in food processor. Cooking of fish reduced the moisture and eliminated the fishy flavour. Then, salt and sugar were added and blended for 2 min. Tapioca starch and orange sweet potato flour were mixed thoroughly in a dough mixer. The moisture content of the mixed powder was determined and should not exceed 35%. The well mixed fish-starches dough was extruded into a locally fabricated single screw extruder (Safeworld, Selangor, Malaysia). The temperature of the compression and the die section were adjusted at 80°C and 90°C, respectively. The screw speed was kept around 115 to 125 rpm. The die-nozzle diameter was 6 mm. The non-expanded snack were cut and then sliced into disc form with thickness of 1 mm and dried at 55°C overnight to reach the moisture content of 10%. The dried extruded fish cracker was kept in sealed plastic container prior to use. The discs were deep fried in vegetable oil at 200°C for 20 seconds and proceed for further analyses. Ten (10) formulations were developed in this study as indicated in Table 1. The 30% and 40% fish contents were chosen because the extruded products gave the best expansion and texture. Higher percentage of fish content did not produce palatable products. Lower percentage of fish did not give fishy taste to extruded products.

Table 1. Formulation of extruded fish crackers

Formulations	Weight of ingredients (g)				
Fish:Tapioca:Sweet Potato	Cooked Fish	Tapioca Starch	Sweet Potato Flour	Salt	Sugar
30:70:00 (0%)*	300	700	0	20	10
30:56:14 (20%)*	300	560	140	20	10
30:49:21 (30%)*	300	490	210	20	10
30:35:35 (50%)*	300	350	350	20	10
30:00:70 (100%)*	300	0	700	20	10
40:60:00 (0%)*	400	600	0	20	10
40:48:12 (20%)*	400	480	120	20	10
40:42:18 (30%)*	400	420	180	20	10
40:30:30 (50%)*	400	300	300	20	10
40:00:60 (100%)*	400	0	600	20	10

(%)* denotes percent orange sweet potato flour addition to tapioca starch

Physical properties of fried extruded fish crackers

Linear expansion

The non-expanded snacks were ruled with five lines across using a fine oil pen. Each line was measured before and after frying in hot oil at 200°C. The percentage linear expansion was calculated according to the method of Yu (1991) as follows:

$$\%\text{ Linear expansion} = \frac{\text{Length after frying} - \text{Length before frying}}{\text{Length before frying}} \times 100$$

Expansion ratio

Randomly 10 pieces of the extrudates were chosen to calculate the expansion ratio by dividing the cross-sectional area of the extrudate by the cross-sectional area of the die-nozzle orifice (6 mm diameter) (Chinnaswamy *et al.,* 1989).

Volume expansion

Volume expansion was determined by rapeseed volume displacement method. The volume was calculated as a ratio between volume of extrudate before and after frying. The percentage volume expansion was calculated as follows:

$$\%\text{ Volume expansion} = \frac{\text{Volume after frying} - \text{Volume before frying}}{\text{Volume before frying}} \times 100$$

Bulk density

The bulk density was determined by measuring the actual dimensions of the fried extrudates (Ainsworth *et al.,* 2007). Five pieces of fried extrudates were chosen randomly and weighed. The length and diameter of the samples were measured using a vernier caliper. The bulk density was calculated as follows:

$$BD = \frac{4m}{\pi d^2 L}$$

Where BD is bulk density (g/cm^3), m is the mass (g), L is the length (cm), π is 3.142 (const) and d is diameter (cm) of fried extrudate.

Oil absorption

Oil absorption was measured according to Nurul *et al.* (2009) as suggested by Mohamed *et al.* (1989). The extrudates were weighed before and after frying in hot oil. Then, the extrudates were ground and dried overnight in an oven (Memmert, Schwabach, Germany) at 105°C. The percentage of oil absorption was calculated as follows:

$$\%\ \text{Oil absorption} = \frac{\text{Dried sample weight after frying} - \text{Dried sample weight before frying}}{\text{Dried sample weight before frying}} \times 100$$

Water absorption index (WAI) and water solubility index (WSI)

The WAI and WSI were determined according to the method developed for cereals (Anderson *et al.,* 1969). Two gram grounded extrudate was suspended in 30 ml of water and gently stirred for 30 minutes at room temperature (25°C). Then, it was centrifuged at 3000 x g for 15 minutes. The supernatant was decanted into an evaporating dish of known weight and dried in an oven (Memmert, Schwabach, Germany) overnight. The weight of sediment and weight of gel after removing the supernatant were measured. The WAI is the weight of the gel obtained per gram of the dry sample. The WSI is the amount of sediment solid recovered by evaporating the supernatant, expressed as percentages of the dry solids in the sample. The WAI and WSI were calculated as follows:

$$WAI = \frac{\text{Weight of gel}}{\text{Weight of dry sample}} \times 100$$

$$WSI = \frac{\text{Weight of sediment}}{\text{Weight of dried sample}} \times 100$$

Hardness

The hardness of fried extruded fish crackers was measured using a Stable Micro System TA-XT2i (Stable Microsystems Ltd., Surrey, England) fitted with crisp fracture ring (P/0.25S). The area of force-time curve determined the hardness of the fried extruded fish crackers and was analysed using the Texture Exponent software. Ten randomly selected samples were measured and the average taken. The studies were conducted at a pretest speed of 1 mm/s, test speed of 0.5 mm/s, distance of 1 mm and load cell of 50 kg.

Colour

The colour of the grounded fried extruded fish crackers was measured using a chromameter (Minolta CR 300, Osaka, Japan). The lightness (L^*), redness (a^*) and yellowness (b^*) of the samples were recorded. The value taken was an average of five readings. The instrument was calibrated with a white colour standard.

Microstructure properties

The fried extruded fish crackers were fractured and mounted on aluminum stubs using double adhesive tape. The samples were sputter-coated with platinum (BALTEC, SCD 005) and then viewed in a Field Emission Scanning Electron Microscope (FESEM SUPRA™ 40VP, England) at 50x magnifications.

Quantitative descriptive analysis (QDA)

Eleven postgraduate students were selected and trained for the sensory evaluation. The test was carried out in the sensory laboratory at Food Technology Department, Faculty of Applied Sciences, UiTM. Panellists were asked to indicate their opinion by marking on the 15 cm line scaling (Meilgaard *et al.,* 1999). Panellists were required to evaluate the appearance, texture and taste of the samples. The colour, odour and expansion size described the appearance of the samples. The texture properties were determined by its hardness, crispiness and oiliness. Panellists also evaluated the degree of fishy flavour, powdery taste, sweetness and saltiness of samples.

About 15 to 20 pieces of fried extruded fish crackers were put in covered plastic container. The test was conducted in two sessions. Panellists were required to evaluate 5 samples per session. Water was given to the panellists and was asked to rinse their mouth in between tested samples. Panellists were asked to rest for a while in between the two sessions to avoid hectic choice. The sensory evaluation test was done in three replicates. The spider web was used to graphically represent the data.

Statistical analysis

The means of collected data were analysed by ANOVA using SAS 9.1 statistical analysis software (SAS Institute Inc, 2002). The differences between the mean values were calculated using Duncan's multiple comparison tests at 95% confidence level ($p<0.05$).

Results and Discussions

Linear expansion

The third generation snacks or half-products which were partially cooked in an extruder barrel were subjected to shear and emerged through a die at temperature below 100°C (Riaz, 2006). The extrudates with less than 12% moisture content expanded into a low density porous product upon deep frying in hot oil (200°C). The degree of linear expansion is the most important quality attributes that describes the cracker products which in turn relates to the crispiness parameter of sensory (Siaw *et al.,* 1985; Yu, 1991).

The effects of orange sweet potato flour addition to tapioca starch at fish contents of 30% and 40% on the linear expansion of fried extruded fish crackers was illustrated in Figure 1. Overall, the mixture of 30 fish: 70 starches mixture had better linear expansion than the mixture with 40 fish: 60 starches. Increased ratio of fish to starch decreased the degree of linear expansion in fish crackers product (Nurul *et al.,* 2009) and higher starch level greatly affect the expansion of final product (Yu and Low, 1992; Sunderland, 1996).

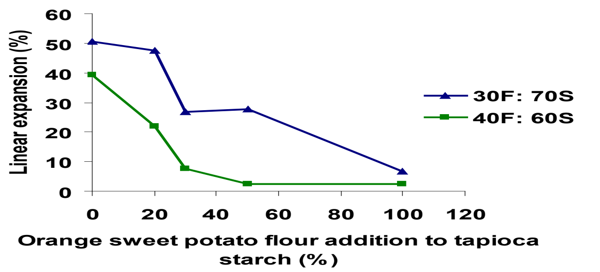


Figure 1. Linear expansion of fried extruded fish crackers. F: fish; S: starch

At fish contents of 30% and 40%, fried extruded fish crackers made up from minced fish with tapioca starch mixture were highly expanded as compared to minced fish with orange sweet potato flour mixture. Among various types of flour used in fish crackers, tapioca starch was greatly affecting the linear expansion of fish crackers (Siaw *et al*., 1980; Yu, 1991; Haryadi, 1994). The increase in the addition of orange sweet potato flour to tapioca starch decreased the expansion of fried extruded fish cracker. However, the fried extruded fish cracker with 20% of orange sweet potato flour had better linear expansion than fried extruded fish cracker with 30% and 50% of orange sweet potato flour at fish contents of 30% and 40%. The result suggested that high expansion on the final product was obtained with low amount of orange sweet potato flour addition.

Expansion ratio

The expansion ratio of fried extruded fish crackers for 30% and 40% fish content with different percentages of orange sweet potato flour addition to tapioca starch in the fish-starches mixture is shown in Table 2. With the addition of orange sweet potato flour, the expansion ratio of fried extruded fish crackers with 40% of fish content was lower than fried extruded fish cracker with 30% of fish content. Moreover, there was no significant difference ($p>0.05$) between the addition of 20%, 30% and 50% orange sweet potato flour in fried extruded fish crackers with fish contents of 40%. Veronica *et al*. (2006) reported that low expansion ratio obtained at higher protein content in maize/soybean puffed snacks. Interaction of starch and protein molecules caused the decrease in the expansion of the extrudates after they passed through the die (Harper and Tribelhorn, 1991). At 30% fish content, the expansion ratio of fried extruded fish crackers with 50% orange sweet potato was lower ($p<0.05$) than fried extruded fish crackers with 20% and 30% orange sweet potato flour. By increasing the bean flour levels from 15% to 45% resulted in a decrease in expansion ratio of corn-starch based extruded snacks (Anton *et al*., 2009).

Table 2. Physical properties of fried extruded fish crackers

Formulations Fish:Tapioca:Sweet Potato	ER	VE (%)	BD (g/cm^3)	OA (%)	WAI (g/g)	WSI (%)
30:70:00 (0%)*	1.68^{a}	17.09^{a}	0.17^{f}	70.55^{a}	10.48^{a}	12.50^{d}
30:56:14 (20%)*	1.61^{a}	12.22^{b}	0.26^{e,f}	53.30^{b}	8.78^{b}	8.82^{f}
30:49:21 (30%)*	1.65^{a}	6.45^{c}	0.31^{d,e}	51.02^{b}	5.20^{d}	11.63^{e}
30:35:35 (50%)*	1.48^{b}	5.00^{c,d}	0.47^{b,c}	52.02^{b}	5.04^{d}	17.91^{c}
30:00:70 (100%)*	1.23^{d}	3.27^{c,d}	0.96^{a}	17.32^{d}	3.78^{f}	24.93^{a}
40:60:00 (0%)*	1.67^{a}	6.38^{c,d}	0.56^{b}	31.19^{c}	7.26^{c}	6.46^{g}
40:48:12 (20%)*	1.20^{d}	4.38^{c,d}	0.56^{b}	11.97^{e}	4.64^{e}	9.00^{f}
40:42:18 (30%)*	1.20^{d}	5.50^{c,d}	0.58^{b}	7.13^{f}	4.55^{e}	9.39^{f}
40:30:30 (50%)*	1.17^{d}	5.19^{c,d}	0.42^{c,d}	6.29^{f}	3.90^{f}	12.69^{d}
40:00:60 (100%)*	1.31^{c}	2.50^{c,d}	0.99^{a}	12.26^{e}	3.49^{g}	18.90^{b}

$^{a-g}$: means within column with different letters are significantly different ($p<0.05$).
(%)* denotes percent orange sweet potato flour addition to tapioca starch. ER: expansion ratio; VE: volume expansion; BD: bulk density; OA: oil absorption; WAI: water absorption index; WSI: water solubility index.

Volume expansion

Table 2 shows the percentages of volume expansion of fried extruded fish crackers at fish contents of 30% and 40%. At 40% of fish contents, the addition of orange sweet potato flour decreased the volume expansion. However, decreased in volume expansion of fried extruded fish crackers was not significantly different ($p>0.05$) at all formulations. Chinnaswamy and Hanna (1990) reported that high level of protein content decreased the expansion due to the difference in the viscoelastic nature and crosslinking ability. The decreased in volume expansion of fried extruded fish crackers also can be observed with 30% and 50% orange sweet potato flour addition at fish contents of 30% but the values were not significantly different ($p>0.05$) to that fried extruded fish crackers at fish contents of 40%.

Bulk density

At low fish content, the increase in the addition of orange sweet potato flour to tapioca starch increased the bulk density significantly ($p<0.05$) (Table 2). The increase in bulk density of fried extruded fish crackers was not significantly different ($p>0.05$) between the addition of 20% and 30% of orange sweet potato flour at fish contents of 30% and 40%. The density is expected to increase with addition of different percentages of bean flour to corn-starch based extruded (Anton *et al*., 2009) and maize/ pigeonpea flour to cassava flour (Rampersad *et al*., 2003). The researchers also claimed that high protein content resulted in high product density. In general, the bulk density of fried extruded fish cracker at 40% of fish content was high. Badrie and Mellowes (1992) reported that crude protein of soybean flour/cassava extrudates correlated positively ($p<0.01$) with bulk density and negatively ($p>0.01$) with expansion.

Oil absorption

The oil absorption of fried extruded fish cracker with 30% of fish content was significantly higher ($p<0.05$) than fried extruded fish cracker with 40% of fish content (Table 2). The oil absorption was not significantly difference ($p>0.05$) with the addition of 30% and 50% orange sweet potato flour in fried extruded fish cracker with fish contents of 40%. While, at fish contents of 30% there was no significant difference ($p>0.05$) between the addition of 20%, 30% and 50% orange sweet potato flour in oil absorption of fried extruded fish cracker. High oil absorption was observed in fried extruded fish cracker made up from fish with tapioca starch at fish contents of 30% and 40%. This could be due to the highly expanded of the final product as shown in Figure 1.

The greater the expansion, the higher the surface area, hence more oil absorbed on the surface. Suhaila and Norhasyimah (1994) reported that a positive correlation was observed between oil absorption and volume expansion and this could be explained that when expansion occurs, more oil trapped in the surface layer of the bigger air cells.

Water absorption index (WAI)

As the amount of orange sweet potato flour increased, WAI of extruded fish cracker snacks decreased (Table 2). The addition of 30-50% of orange sweet potato flour to tapioca starch resulted no significant different ($p>0.05$) in terms of WAI for cracker with 30% fish content. In addition, WAI was not significantly different ($p>0.05$) with addition of 20% and 30% orange sweet potato flour for crackers with 40% fish content. The decrease in WAI was observed in soy protein-high amylose corn starch extrudates (Zhu *et al.,* 2010). The researchers stated that, increasing soy protein concentrate reduced the starch content, thus less starch is available to be gelatinised during extrusion and subsequently absorb water.

Water solubility index (WSI)

Table 2 shows that WSI of extruded fish cracker snacks increased with increasing addition of orange sweet potato flour to tapioca starch. The WSI of extruded fish cracker snacks was significantly different ($p<0.05$) with the addition 20%, 30%, 50% and 100% of orange sweet potato flour for formulation containing 30% of fish content. There was no significantly difference ($p>0.05$) between partial addition of 20% and 30% of orange sweet potato flour to tapioca starch in extruded fish cracker snacks at 40% fish content. The WSI was used as an indicator to measure the degradation of starch during extrusion (Zhu *et al.,* 2010).

Hardness

The effect of orange sweet potato flour addition to tapioca starch on the hardness of extruded fish cracker snacks at different fish ratios was illustrated in Figure 2. The increase in the addition of orange sweet potato flour to tapioca starch increased the hardness of extruded fish cracker snacks at fish contents of 30% and 40%. The extruded fish cracker snacks containing 40% fish was harder than extruded fish cracker snacks with 30% fish content. High fish content increased hardness of fish crackers (Nurul *et al.,* 2009). The high hardness values indicated high resistance of product and require high force to break. Park *et al*. (1993) reported that high-fat product with defatted soy flour and corn starch was hard and highly resists shearing force.

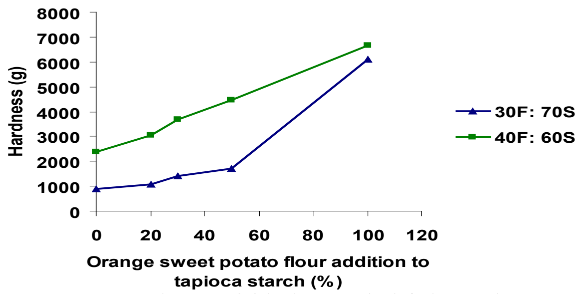


Figure 2. Hardness of fried extruded fish crackers. F: fish; S: starch

Colour

Table 3 shows the effect of orange sweet potato flour addition on the colour of extruded fish cracker snacks. The L^* a^* b^* values varied significantly

($p<0.05$) with addition of orange sweet potato flour. L^* values decreased with increase in orange sweet potato flour addition to tapioca starch at both fish ratios. L^* values correspond to whiteness or lightness and decrease in L^* values possibly due to orange colour of the sweet potato. The increase in the orange sweet potato flour addition to tapioca starch increased a^* values which correspond to redness. The b^* values which represents yellowness were the least affected with the addition of 20%, 30% or 50% orange sweet potato flour to tapioca starch at fish contents of 30 and 40. Higher b^* values comparatively indicate the samples more yellowish.

Table 3. Colour of the fried extruded fish crackers

Formulations Fish:Tapioca:Sweet potato	L^*	a^*	b^*
30:70:00 (0%)*	62.34 ± 1.11^a	-0.23 ± 0.06^g	12.24 ± 1.09^g
30:56:14 (20%)*	58.79 ± 1.49^b	5.14 ± 0.59^f	32.13 ± 0.65^a
30:49:21 (30%)*	55.62 ± 1.68^c	9.13 ± 0.13^e	32.24 ± 1.16^a
30:35:35 (50%)*	38.06 ± 2.05^g	16.34 ± 0.48^a	$31.14 \pm 1.71^{a,b,c}$
30:00:70 (100%)*	27.44 ± 0.36^i	15.90 ± 0.43^a	19.50 ± 0.68^f
40:60:00 (0%)*	63.41 ± 2.20^a	4.65 ± 0.36^f	25.89 ± 1.32^d
40:48:12 (20%)*	51.62 ± 0.79^d	11.90 ± 0.20^d	$31.96 \pm 0.24^{a,b}$
40:42:18 (30%)*	48.12 ± 2.01^e	12.56 ± 0.39^c	$30.64 \pm 1.21^{b,c}$
40:30:30 (50%)*	42.40 ± 0.94^f	14.98 ± 0.51^b	30.45 ± 0.59^c
40:00:60 (100%)*	30.54 ± 1.17^h	16.08 ± 0.53^a	22.22 ± 0.84^e

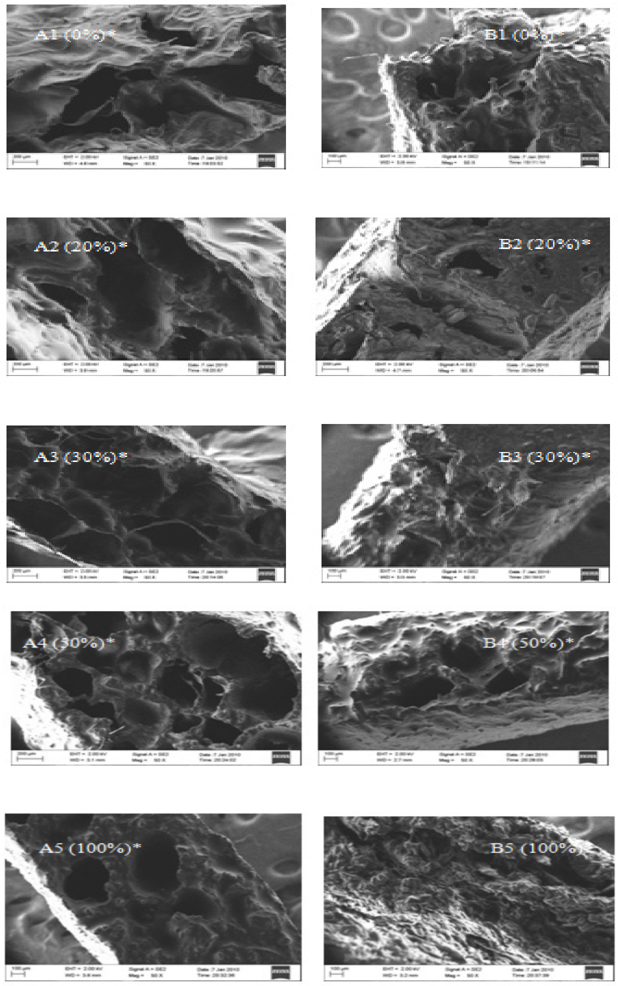
[a-h]: means within column with different letters are significantly different ($p<0.05$).
L^*: lightness; a^*: redness; b^*: yellowness. (%)* denotes percent orange sweet potato flour addition to tapioca starch.

Microstructure properties

Figures 3: A1-A5 and B1-B5 show cross-sectional morphologies of the extruded fish cracker snacks. The internal structures of the snacks were affected by the ratio of fish, tapioca starch and orange sweet potato flour mixture. Large air cells obtained in extruded fish cracker snacks with less fish and high starches content (Fig 3: A1-A5). Smaller air cells observed with increase in fish content (Fig 3: B1-B5). For crackers with 30% fish, increase in orange sweet potato flour addition to tapioca starch resulted in the thicker cell wall and a more compact cell structure of more spherical cells. Lee *et al.* (2003) reported that popped snacks with meat had smaller air cell than those with grain and claimed that starch content affected the production of air cells. The researchers also suggested that the degree of popping snacks were influenced by popping temperature, starch content and size of starch granules. Higher amount of fish in the extruder feed resulted in formation of unbroken fibres while, less compacted structure was revealed with less protein (Bhattacharya *et al.,* 1990).

Sensory properties

Effect of orange sweet potato flour addition to tapioca starch in extruded fish cracker snacks were evaluated based on their appearance, texture and



Figures 3. Field Emission Scanning Electron Microscope (50x) of fried extruded fish crackers. **A1-A5**: 30:70 fish-starches mixture; **B1-B5**: 40:60 fish-starches mixture. (%)*denotes percent orange sweet potato flour addition to tapioca starch

taste. There were significant differences ($p<0.05$) in terms of the appearance and texture of extruded fish cracker snacks at fish contents of 30% and 40% as illustrated in Figure 4(A) and Figure 4(B), respectively. However, there were no significant differences in terms of tastes ($p>0.05$) as shown in Table 4.

Table 4. The non significance *F* value of taste attributes

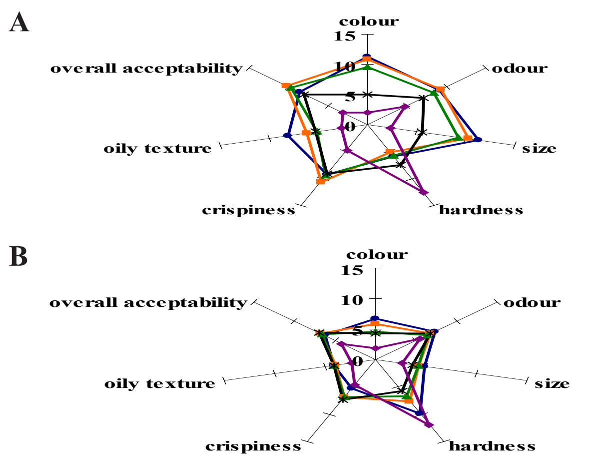
Taste attributes	*F* value	*p*
Fish flavour	1.35	>0.05
Powdery taste	0.40	>0.05
Sweetness	0.40	>0.05
Saltiness	0.97	>0.05

p: probability at 95% confidence level

One-way analysis of variance (ANOVA) revealed that the panellists were unable to detect or perceive the fish flavour note, powdery taste, sweetness and saltiness of extruded fish cracker snacks. This indicates a good sign of acceptance in terms of extruded fish cracker snacks taste. The extruded fish snacks had higher overall acceptance by Asian consumers than by American consumers (Suknark *et* *al*., 1998). Furthermore, the difficulty in differentiate the flavour attributes of corn starch and grounds meat extrudates by the trained sensory panels were also reported (Rhee *et al*., 1999). In addition, Rhee *et al*. (2004) suggested that the extrusion cooking process could decrease or eliminated the fish or distinct flavour when puffed with non-meat ingredients.

The outward spokes in spider web indicate a higher intense value of samples' attributes. Therefore, at 30% fish contents (Figure 4: A) shows extruded fish cracker snacks with 20% orange sweet potato flour addition to tapioca starch had better effects on the colour, odour, size of extrudates, crispiness and overall acceptability than extruded fish cracker snacks with 30% and 50% orange sweet potato flour addition ($p<0.05$). In addition, it also resulted in extruded fish cracker snacks with the softer texture. Increase in the orange sweet potato flour content from 30% to 100% in the fish-starches mixture decreased the scores of sensory attributes except for hardness. The results obtained were similar to instrumentally measured hardness (Figure 2). Tougher texture obtained with high amount of orange sweet potato flour addition.

Extruded fish cracker snacks which contained 40% of fish and starches mixture (Figure 4: B) comparatively had lower scores of sensory attributes compared to extruded fish cracker snacks with 30% fish content (Figure 4: A). Lower expansion and less crispy might contribute to the low overall acceptability of the extruded fish cracker snacks. The acceptability of food products always rely on the food texture and crispiness was highlighted as the importance parameter especially in cracker or snacks product (Roudaut *et al.,* 2002). In addition, Siaw *et al*. (1985) claimed that linear expansion which determines the crispiness had the least degree of tolerance in the acceptability of fish crackers.



Figures 4. Spider webs of fried extruded fish crackers. (A): 30:70 fish-starches mixture; **(B)**: 40:60 fish-starches mixture. Concentration of orange sweet potato flour addition to tapioca starch: (●) 0%; (■) 20%; (▲) 30%; (✱) 50%; (◆) 100%

Conclusion

Orange sweet potato flour is a promising ingredient in extruded fish cracker snacks. Partial addition of 20% orange sweet potato flour to tapioca starch in extruded fish cracker snacks produced high expansion, low bulk density and soft textured product. The colour of the product was light brownish. This formulation also resulted in crackers with big air cells and thin cell walls. The product had high crispiness score and was highly accepted by the trained panellists.

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