International Food Research Journal 16: 159-165 (2009)

The effect of different ratios of Dory fish to tapioca flour on the linear expansion, oil absorption, colour and hardness of fish crackers

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Abstract: The objective of this study was to examine the effect of different ratios of fish to tapioca flour on the linear expansion, oil absorption, colour, and crispiness of fish crackers. Four different ratios of fish to tapioca flour were used in the formulation of the fish crackers. The results showed that protein and fat content increased with the increase in the ratio of the fish. On the other hand, linear expansion and oil absorption decreased with an increase in the ratio of the fish. Hardness also increased with the increase in the ratio of the fish. The colour measurement showed that the lightness value decreased with an increase in the ratio of fish and this decrease is seen more clearly with the fried fish crackers.

Keywords: Fish crackers, linear expansion, oil absorption, colour, crispiness

Introduction

Fish crackers are popular snack foods in many Southeast Asian countries (Kyaw *et al.,* 2001). They are known as *keropok* in Malaysia, *kerupuk* in Indonesia, *kaew krab pla* in Thailand or *banh phong tom* in Vietnam. Basically, fish crackers are produced by mixing fish flesh with starch and water. The dough is then shaped into round, oblique, stick or longitudinal forms and gelatinized by boiling or steaming (Chng *et al.,* 1991). The gelatinized dough is then cooled, sliced and dried until the moisture content reaches around 10 percent (Huda *et al.,* 2007). The sliced, dried product is fried in cooking oil before eaten as a snack food or together with rice and other daily dishes.

In the olden days, the production of fish crackers followed traditional methods and remained as a cottage industry. Technical knowledge is lacking so the products are usually of poor quality with uneven expansion, dark objectionable colours and varying shapes, sizes and thicknesses. Some researchers introduced mechanization, innovation and improved techniques to obtain better quality and more acceptable products. Peranginangin *et al.* (1996) used certain food additives such as sodium bicarbonate, sodium polyphosphate and ammonium bicarbonate to improve the degree of expansion and the crispiness of the fish crackers. Cheow *et al.* (1999) suggested an optimum time for steaming the fish crackers which gave the best linear expansion and the hardest texture of the steamed gel. Kok *et al.* (2004) developed a puffing machine to cook the fish crackers instead of deep-frying. Fish crackers cooked by the puffing machine had a greater degree of linear expansion than those cooked by deep-frying with the added advantage that no oil was used in the puffing process which resulted in a healthier product.

During the frying process, the crackers expanded into a low density porous product and the degree of expansion, called linear expansion, is one of the important quality parameters of crackers (Yu, 1991b). Fish crackers with the highest linear expansion were preferred by consumers. The degree of linear expansion is related to the most important parameter governing the quality of fish crackers by sensory attribute: its crispiness. Since linear expansion is critically related to the quality of the fish crackers, researchers have identified the factors that influenced the degree of linear expansion. Kyaw *et al.* (1999) reported excessive steaming time will result in the poor linear expansion of the fish crackers. Peranginangin *et al.* (1996) found that the slicing of crackers into a thickness of more than 2 mm will produce fish crackers with a lower degree of linear expansion. The ratio of fish and starch also influences the degree of linear expansion and the crispiness of the fish crackers (King, 2002).

Starch flour is one of the essential ingredients for making fish crackers. Various starch flour such as tapioca, wheat, corn, sago, rice and even mung bean is available for fish cracker making (Mohamed *et al*.,

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1988; Yu, 1993). Pre-gelatinized starch can also be used (Yu and Low, 2001). Studies by Mohamed *et al.* (1989) showed that the linear expansion, oil absorption and the crispiness of the crackers correlated with the total amylopectin content in the flour. The decrease in the degree of linear expansion is more likely due to the reduction of the overall carbohydrate content of the crackers, hence, the total amylopectin content in the cracker. Kyaw *et al.* (1999) found that linear expansion was highest when the starch granules were fully expanded. The incomplete gelatinization of starch during the steaming process causes the reduced linear expansion of the products. Among various starch flours, tapioca flour is known to produce fish crackers with excellent expansion properties (Mohamed *et al.,* 1988; Yu, 1991a, Tongdang *et al.*, 2008). Some researchers also used tapioca flour as an ingredient in their fish cracker formulation (Kyaw *et al*., 2001; Huda *et al*., 2001; King, 2002).

Marine fish is generally used for fish cracker making. Some of the marine fish reportedly used for fish cracker formulation are sardine (*Clupea leiogaster*) (Yu, 1991a), jewfish (*Johnius soldado*) (Kyaw *et al.*, 1999; Kyaw *et al.*, 2001), big-eye (*Brachydeuterus auritus*) (King, 2002), snapper (Lutjanus spp), yellow pike conger (*Ophiocephalus micropeltis*), and featherback (*Natopterus chilata*) (Peranginangin *et al*., 1996). Some commercial fish crackers in Malaysia are found to have used Yellow-banded trevally (*Selaroides leptoleptis*), Wolf herring (*Chirocentrus dorab*) and Round herring (*Dussumieria hasselti*) as the fish source. In Indonesia, Barred spanish mackerel (*Scomberomerus commersoni*) is used as the fish source. Besides using the fresh flesh, the powdered form of the fish is also used for fish cracker formulation. Yu and Tan (1990) used the powdered fish protein hydrolysate while Huda *et al.* (2000; 2001) used powdered surimi in their fish cracker formulation. The powdered form of fish offers many advantages in commercial food production such as ease of handling, lower cost of distribution, easy to store and useful in dry food mixes application. Washwater protein from fishball processing is also used for fish cracker formulation by Yu *et al.* (1994).

Fresh water fish is usually not used as the fish source for fish cracker making due to the shortage of raw materials and many of the fish cracker manufacturers are confined to areas near the coast. However, with the development of aquaculture technology, some cultured fresh water fish can be used as the raw material for fish cracker production. The aquaculture production of catfish (Pangasius spp) has shown spectacular growth in the last few years especially in China and Vietnam (Dzung, 2007). Frozen Pangasius fillet has become a well-known product in supermarkets, being a quality fish sold at a reasonable price (Sorenson, 2007). Individually quick frozen fillets of Pangasius catfish are popularly marketed under exotic or attractive names: Dory fish or Pacific Dory fish, in many Southeast Asian supermarkets (Anthonysamy, 2007). They are also marketed under the name Sutchi fillet in Malaysian supermarkets.

The objective of this study was to determine the effect of different ratios of Dory fish to tapioca flour on the linear expansion, oil absorption, colour and the hardness of fish crackers. The study also assessed the role of fish protein at each stage of the cracker making process in order to relate the significance of the fish content on the expansion, oil absorption, colour and the hardness of the fish crackers.

Materials and Methods

Raw material

Frozen Dory fish fillet (tra Catfish *Pangasius hypophthalmus*) which was imported from Vietnam was purchased from supermarkets at Penang and transported in ice boxes to the processing laboratory, Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, for immediate processing. Tapioca flour (*Manihot esculentus*) and all the other ingredients were obtained from a local shop.

Preparation of crackers

The crackers were formulated using different ratios of fish to tapioca flour: 1:1 (A), 1.5:1 (B), 2:1 (C) and 2.5:1 (D). Other ingredients used in this fish cracker formulation were salt (2%), sugar (1%) and water (20%). The fish fillet was mixed with half of the flour, sugar and brine and blended for 1 minute using a high speed cutter mixer (Malavasi Magicset3, Italy). The remaining tapioca flour and brine were added to the blender and blended for 4 minutes. The blend was stuffed into casings with a diameter of 6 cm and a length of 40 cm and both ends were tied. The blend was cooked in water at 90-95ºC for 30 minutes. Then it was cooled in cold water and frozen storage at -18ºC. The frozen blend was sliced mechanically to a thickness of 3 mm using a meat slicer (Macchi, Italy) and dried overnight in an oven with a temperature at 60ºC (Afos Mini Kiln, England). The dried slices were deep fried in palm cooking oil at 180-200ºC for 1 minute using an electric fryer (Anvil, South Africa).

Proximate composition

The macronutrient of fried crackers was determined according to the AOAC method (2000). The crude protein content was determined by the Kjeldahl method and the crude lipid content was determined by the soxhlet method. The ash content was determined by ashing the samples overnight at 550°C. Moisture content was determined by drying the samples overnight at 105°C and the carbohydrate content was calculated by the difference.

Linear expansion

The percentage linear expansion was obtained on deep frying the dried crackers in oil at 180-200ºC. The un-puffed cracker was ruled with three lines across using a fine oil pen. Each line was measured before and after puffing. The percentage linear expansion was calculated according to the method used by Yu (1991b) as follows:

$$LE\ (\%) = \frac{\text{Length after puffing} - \text{length before puffing}}{\text{Length before puffing}} \times 100$$

Oil absorption

Oil absorption was measured according to the method proposed by Mohamed *et al.* (1988). The crackers were weighed before and after frying in palm oil (at 180-200ºC). They were ground and dried in the oven overnight and their moisture content was determined.

$$OA\ (\%) = \frac{\text{W of moisturelles fried sample} - \text{W of moisturelles unfried sample}}{\text{W of moisturelles unfried sample}} \times 100$$

Colour

The colour of the ground fried cracker sample before and after puffing was measured using a colorimeter (Minolta CM 300m, Japan). The colour reading includes lightness (L^*), redness (a^*) and yellowness (b^*). The equipment was standardized with a white colour standard.

Hardness

Hardness was measured by a penetration test using the Texture Analyzer (TA-XT2 Stable Micro System, England). The conditions of the texture analyzer were as follows: pre-test speed, 2.0 mm/s; post-test speed, 5.0 mm/s; distance, 5.0 mm; time, 5.0s; trigger type, auto and trigger force, 10 g. The dried slices were fried in oil at 180-200ºC for 1 minute. The crackers were put above a support rig and penetrated using ball probes (p/0.25 s stainless steel ball probe). This rig was used to measure the fracturability by means of a penetration test. One parameter was measured : hardness (N/cm2).

Statistic analysis

The data collected was analyzed using the Statistical Package Social Science (SPSS) version 15.00. The means of treatment showing significant differences ($p<0.05$) were subjected to Duncan's Multiple Range Test.

Results and Discussion

The proximate composition of the crackers is shown in Table 1. There were significant differences ($p<0.05$) in the proximate composition of the samples studied except for moisture content. As a dried product, the lower moisture content of the fish crackers was expected. Similar results were also reported by Yu (1991b), King (2002) and Huda *et al.* (2007) with moisture content of 9%, 12% and approximately 9-13% respectively. As expected, the protein content of the crackers increased with an increase in the proportion of fish (Yu, 1991b; Peranginangin *et al.*, 1996; Huda *et al.*, 2000; King, 2002). It is commonly known that fish is a good source of protein while tapioca flour contains a lower amount of protein. Peranginangin *et al.* (1996) reported wholly tapioca crackers contain only 0.78% of protein and this increased to 8.13% in the crackers with 40% proportion of fish.

Increasing the fish proportion not only increases protein content but also increases the fat content. A similar trend, but with different degrees of increase, was also reported by Yu (1991b), Peranginangin *et al.* (1996), and King (2002). Starch is not a source of fat. The fat content of tapioca flour and sago flour is only 0.1% (Yu, 1991b). However, the degree of the fat content increase depends on the fish species: higher with oily fish (fat content >8% and lower with lean fish (fat content <4%). As the protein content increased, the carbohydrate contents were reduced by increasing the fish proportion. However, the carbohydrate content maintained its position as the main component of fish crackers. Huda *et al.* (2007) reported that commercial fish crackers contained carbohydrates within the range of 65 – 80%. The higher and lower content of carbohydrates are one of the reasons for the important substitution of starch flour with fish to provide a more nutritional food product.

Linear expansion, oil absorption and the hardness of the crackers are shown in Table 2. There were

Table 1. Proximate composition of crackers with different ratio of fish and tapioca flour

Cracker (fish : flour)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
A (1.0 : 1.0)	9.86±0.16^{a}	10.12±0.42^{a}	0.99±0.12^{d}	5.91±0.06^{b}	73.43±0.81^{a}
B (1.5 : 1.0)	8.70±0.31^{b}	14.29±0.82^{b}	1.67±0.23^{c}	6.47±0.04^{a}	60.50±1.22^{b}
C (2.0 : 1.0)	8.54±0.32^{b}	18.23±1.02^{c}	2.48±0.26^{b}	5.75±0.10^{c}	66.66±1.96^{c}
D (2.5 : 1.0)	8.50±0.44^{b}	23.81±0.93^{d}	2.70±0.20^{a}	6.52±0.07^{a}	59.74±1.46^{d}

*Value is means of 6 determinations.
a-d Mean with the same letter within the same column are not significantly different (p<0.05)

Table 2. Linear expansion, oil absorption, hardness of crackers with different ratio of fish and tapioca flour

Cracker (fish : flour)	Linear Expansion (%)	Oil absorption (%)	Hardness (N/cm2)
A (1.0 : 1.0)	107.69±3.44^{a}	39.79±1.08^{a}	1312.34±98.45^{a}
B (1.5 : 1.0)	71.09±6.45^{b}	11.15±0.65^{b}	1493.43±204.31^{ab}
C (2.0 : 1.0)	56.28±8.18^{c}	9.39±0.56^{c}	1639.55±185.86^{bc}
D (2.5 : 1.0)	37.18±7.36^{d}	7.89±0.60^{d}	2366.49±249.72^{c}

*Value is means of 6 determinations.
a-d Mean with the same letter within the same column are not significantly different (p<0.05)

significant differences (p>0.05) in linear expansion, oil absorption and the hardness of each sample. The linear expansion of the fried fish crackers decreased with the increased ratio of fish to starch (Chinnaswawamy and Hanna, 1990; Yu, 1991b; Yu *et al.*, 1994; Paranginangin *et al.*, 1997; Cheow *et al.*, 1999; Huda *et al.*, 2001). It would appear that the fish protein interacted with the starch granules in a way that inhibited expansion (Yu, 1991a) The slight increase of linear expansion with the addition of fish protein was only found at the early stage of the fish protein addition. This could be due to the fact that the wet fish provided available water for starch gelatinization or sufficient protein which when heat denatured was able to resist collapse during the starch expansion (Cheow *et al.*, 1999). In the crackers, the starch component gelatinized and expanded on frying. The degree of the gelatinization of the starch is one of the factors which influences the degree of expansion of half-products when immersed in hot oil (Lachmann, 1969). The degree of expansion of the finished product is influenced by the amylase : amylopectin ratio of the flour. At least 50% or more of amylopectin and 5—20% of amylase are required for a good quality cracker (Yu, 1991a).

At a ratio of fish to tapioca flour (1:1) the linear expansion was 107.69%. Crackers with a ratio of fish to flour which was greater than (2:1) showed reduced expansion to less than 71%. Siaw *et al.* (1995) found that a linear expansion of 77% was the minimum level for acceptability. At a protein content of 10%, the linear expansion of 107.69% was well within the acceptable limits. However, samples with higher protein contents at a ratio of fish to tapioca flour which were greater than 1:1 were not acceptable. Huda *et al.* (2007) reported that commercial fish crackers showed a wide range of linear expansion which is within 38 - 145%.

The oil absorption of the fried crackers is higher in the sample with higher linear expansion and lower in the sample with lower linear expansion. Mohamed *et al.* (1988) found a similar trend and this is because more oil was trapped on the surface layer of the bigger air "cells" when expansion increased. Huda *et al.* (2000; 2001) and King (2002) reported that as a result of oil absorption, the fat content of fried fish crackers is higher in the sample with the higher linear expansion compared to the sample with a lower linear expansion. As shown in Table 2, the more the degree of the expansion of the crackers, the more air cells will form and the more oil was trapped; consequently, the higher the degree of oil absorption.

The hardness of fried crackers increased with the decrease in linear expansion. As was mentioned early, the lower degree of linear expansion is related

Table 3. Hunter colour L*, a*, b* values of unfried crackers with different ratio of fish and tapioca flour

Cracker (fish : flour)	L*	a*	b*
A (1.0 : 1.0)	80.53±0.23[b]	-0.17±0.03[a]	13.66±0.08[c]
B (1.5 : 1.0)	82.29±0.42[a]	-0.69±0.10[b]	10.71±0.32[d]
C (2.0 : 1.0)	82.35±0.26[a]	-0.90±0.09[c]	14.55±1.01[b]
D (2.5 : 1.0)	77.14±0.76[c]	-0.55±0.22[b]	17.16±0.77[a]

*Value is means of 6 replications.
a-dMean with the same letter within the same column are significantly different ($p<0.05$)

Table 4. Hunter colour L*, a*, b* values of fried crackers with different ratio of fish and tapioca flour

Cracker (fish : flour)	L*	a*	b*
A (1.0 : 1.0)	75.04±0.63[a]	-0.64±0.11[c]	10.56±0.43[a]
B (1.5 : 1.0)	76.01±0.61[a]	1.09±0.35[a]	15.53±0.73[a]
C (2.0 : 1.0)	69.08±1.13[b]	1.70±0.83[b]	18.02±2.37[b]
D (2.5 : 1.0)	68.16±1.81[b]	1.53±0.32[b]	18.95±0.75[b]

*Value is means of 6 replications.
[a-d]Mean with the same letter within the same column are significantly different ($p<0.05$)

to the increase of fish protein. Cheow *et al.* (1999) studied the microstructure of fish crackers and found that poorly-expanded fish crackers contained large aggregates of fish protein. This prevented the starch from expanding in hot cooking oil and made the filaments more dense and thick and the final result was the increase in the hardness value.

Hardness can also be determined by sensory evaluation and usually by using the terms for crispiness with an opposite term for hardness. Low hardness will be shown as a high crispiness score and consumers prefer fish crackers with a high crispiness score. Paranginangin *et al.* (1997) found that increasing linear expansion will increase the crispiness score of fish crackers which means that the product becomes lower hardness value. Similar results were also reported by Yu (1991a, 1991b).

The colour characteristics of un-fried and fried fish crackers are shown in Table 3 and 4. All the colour values showed significant differences ($p<0.05$) between each un-fried and fried crackers. Both of the un-fried and fried samples showed similar trends: increasing the fish ratio or decreasing the tapioca flour ratio will contribute to darker products, which is shown by the lower L* value. Tapioca flour is a white colored product while fish flesh contains some pigments which contribute to the colour of the product. A variety of nitrogenous compounds such as myoglobin, hemoglobin and hemocyanins contribute to the colour of the fish and shellfish (Haard *et al.*, 1994). The colour of fish flesh will vary depending on the species. Paranginangin *et al.* (1997) found that fish crackers made from snapper fish were shown to be the darkest as compared to the pike conger and the featherback fish.

Although no statistical analysis was made between the colour of un-fried and fried fish crackers, as shown by Table 2, the frying process would result in the loss of the lighter colour of the fried product. A frying process with a high temperature contributes to the denaturation and oxidation of fish protein which lead to the darker colour of the product. The formation of coloured compounds related with involvements of H2O released from amino acid and in Maillard-type reactions (Sikorski and Pan, 1994). Ngadi *et al.* (2007) stated the decrease in the L* value in the fried food sample may be attributed to Maillard browning and caramelizing at a high frying temperature. The rate of Maillard reaction depends on its chemical environment such as the chemical composition of food, water activity, pH and the reaction temperature. Since the difference among the samples is only in protein content, the different protein content is responsible for the degree of loss of the L* value. The loss of the L* value is higher in the sample with an increase in the ratio of fish (11.6% at the fish starch ratio 2.5:1 compared to 6.8% at the fish starch ratio 1:1).

However, there were some losses of the L* value during the frying process. The L* value of the product resulting from this study is higher compared to the L* value of commercial fish crackers. Huda *et al.* (2007) determined the colour characteristics of commercial fish crackers and found the range of L*, a* and b* values was 18.69 – 47.99, 1.03 – 5.89, and 7.77 – 20.62, respectively. The lighter product which resulted in this study may be related to the different fish species, different types of starch, the washing treatment or the processing method. Yu (1991a) and Huda *et al.* (2000; 2001) found that the panel preferred the lighter colour of the fish crackers.

Conclusions

The results of this study clearly showed that the effect of the different ratios of fish and tapioca flour on fish cracker formulation showed different qualities of crackers, depending on the ratios of protein and starch. Increasing the ratio of fish to flour, thus increasing the amount of protein in the fish-flour cracker mixture, will decrease linear expansion, oil absorption and the lightness value. Meanwhile the hardness of the products will increase. It is apparent that dory fish can be used for fish cracker formulation at the ratio of 1:1

Acknowledgement

The authors acknowledge with gratitude the support given by Universiti Sains Malaysia for our research in this area.

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