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Development and characterization of fish crackers prepared from the bull's eye (*Priacanthus hamrur*, Forsskal, 1775) fish meat and different starches

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Abstract
The Bull's eye fish (*Priacanthus hamrur*), which is present in large biomass in the South-East coast of India, is generally considered an underutilized fish species. An attempt was made to add value, by producing fish crackers. Fish crackers are foods which contain comminuted fish and are classified as "half products" and "intermediate products". It is the most popular snack food in Southeast Asian countries.
Most of the snacks available in the market are mainly based on cereals, which are high in calorie and low in protein content. For this reason, snacks like fish crackers with high protein content was thought to be developed for nutritional enrichment. Different starches flour like rice, sago and tapioca, as a functional ingredient, were used to prepare fish cracker at 50:50% ratio.
The crackers (rice - C1, sago - C2 and tapioca C-3) were subjected to analyses for proximate as well as comparative physicochemical, microbiological and sensory evaluation so as to determine the nutritive value and its quality attributes for general acceptance. Dried cracker had a moisture content of 10 to 12%, protein content of 22 to 24% whereas, lipid content found low but it significantly increased after frying due to oil absorption. Nutritionally all the treatments were at par with each other. However, maximum linear expansion was observed in tapioca based fish crackers (83.03%). Water absorption index (WAI) decreased while water solubility index (WSI) increased for tapioca based fish cracker. Maximum lightness and lower redness as well as yellowness was noticed with sago based fish cracker after frying. Fish crackers incorporated with tapioca starch had a maximum score for the sensory aspect of crispiness (4.6), texture (4.4), odour (3.4) taste (3.8) and overall acceptability (4.4).

Keywords: fish cracker, bull's eye fish, tapioca starch and linear expansion

Introduction
Introduction of new types of fish based products in tune with the changing market trends is need of the day. Present market trends demand for healthy ready-to-cook and ready-to-eat convenient products for present day time starved consumer [17].
One such important traditional fish-based snack food is the crackers known by different names in many countries of Asia. In India they are called wafers or crackers and in Malaysia they are called '*Keropok*'. Ingredients for making fish crackers are starch or flour, seasoning (pepper, garlic, salt, sugar and monosodium glutamate); and the protein ingredient that gives its distinction to the name of the cracker. Starch or flour is a principal ingredient for making fish cracker [7, 26].
Starch based snack foods that are popular among all age groups, do not normally contain adequate quality protein and minerals. Fish crackers can now replace these unhealthy snack foods available in the market by providing utilizable protein and minerals. Starch serves as a functional ingredient that contributes to the expansion of the product. The expansion is directly related to the crispiness, which determines the acceptability of fish cracker [35]. Amylose-amylopectin ratio in starch has a strong effect on the expansion of starch-based snack [12, 30]. Fish cracker made from various flours, which had a different amylose-amylopectin ratio, were compared in their expansion [14]. It was found that linear expansion of cracker correlated positively to the amylopectin content in flour. Types of starch have different compositions and functional properties [24]. Starch composition was shown to influence cracker expansion. Protein in flour seems to inhibit cracker expansion [10].

The type of flour or starch used for making cracker is well known to affect cracker quality. Studies of different kinds of starch/flour was tried and tested [19, 29] for making cracker, for example tapioca, rice or sago starches. From those studies, the emerging consensus appeared to be that sago and tapioca provided better expansion of cracker than the other starches. Tapioca is considered as the staple food for people in many countries and it is the main ingredient along with mince fish for the preparation of fish crackers. Though, other starches like corn, wheat and rice or sago can also be used [14, 28, 34].
The aim of this work was to develop a nutritious fish cracker from Bull's eye fish minced meat and different starches using simple technology with desired quality. As Bull's eye fish (*Priacanthus hamrur*) is abundantly available on Gujarat coast and low in cost, it is desirable to use this abundant resource for the development of value-added protein enriched snack products of high acceptability in the growing market of fish-based snack foods.

Materials and Methods

Fish cracker production

The fish was washed with chilled chlorinated water of 2 ppm and flesh was separated from the bones manually after heading, gutting, scaling and cleaning. Fish cracker was prepared as per flow chart shown in Fig. 1. The mince obtained was mixed with different rice starch (C1), sago starch (C2) and tapioca starch (C3) at the fish-to-starch ratio of 50:50 (%) including 1% sodium bicarbonate, 2% salt, 2% seasoning and 200 ml water added to the mixture. The ingredients were mixed mechanically using silent cutter until a smooth paste was obtained. The semi-solid paste was then moulded into a sausage casing having a diameter of 3 to 5 cm and 25 to 30 cm length. The sausage was steamed for 60 minutes. The steamed pastes were cooled in cold water to minimize shrinkage and chilled for 24 hrs. in a refrigerator at 4±1 °C. The cooked and chilled sausage was cut manually into slices about 3 to 4 mm thick and dried in an oven at 60 ºC for 12 hours until a moisture content was around 10 ± 2%. The dry slice of fish cracker was fried in cooking oil at 180 ºC for 10 sec. using electric fryer. The fried crackers were evaluated for different quality analysis.

Table 1: Application of different starch flour in production of fish crackers. Ingredients used for preparation of fish cracker.

Combination – 1 C - 1	**Combination – 2 C - 2**	**Combination – 3 C - 3**
50% Rice Flour (including 2% salt and other ingredients like sodium bicarbonate 1% and 2% seasoning) 50% Fish Meat	50% Sago Flour (including 2% salt and other ingredients like sodium bicarbonate 1% and 2% seasoning) 50% Fish Meat	50% Tapioca Flour (including 2% salt and other ingredients like sodium bicarbonate 1% and 2% seasoning) 50% Fish Meat

- Rice Flour
- Sago Flour
- Tapioca Flour

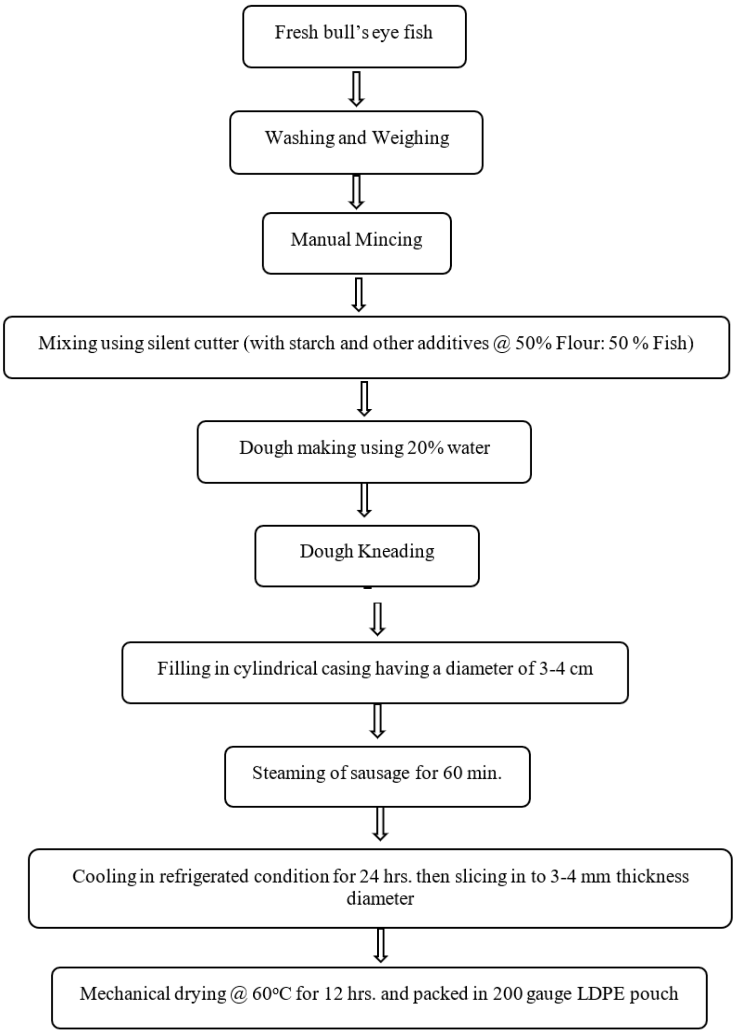

Fig 1: Flow chart for development of fish cracker.

Biochemical analysis

Determination of proximate composition

Proximate composition analyses were performed according to [2] procedures. Water content was determined by drying samples at 105±2 ºC until a constant weight was obtained. Wet samples were used for determination of crude fat, protein and mineral contents. Crude fat was measured by solvent extraction method in a soxhlet system where n-hexane was used as solvent. Crude protein content was calculated by using nitrogen content obtained by Kjeldahl method. A conversion factor of 6.25 was used for calculation of protein content. Total mineral content was determined by incinerating samples at 550±10 ºC for 5 hours. The weight of the residual ash, expressed as a percentage of the wet sample weight, was taken as the total inorganic residue.

Texture analysis

Texture analyser (TA-XT Plus, Stable Micro Systems, UK) was set up with a spherical probe (P/0.25S) of 0.50 cm diameter and force/displacement measurement of a 25 kg load cell. The crackers were put above a HDP/CFS crisp fracture support rig and penetrated using ball probes. Fish crackers were tested at the conditions of speed 2 mm.s-1, trigger force 10 g and travel distance of the probe 15 mm [27]. The peak (maximum force) was recorded and represented the hardness. The initial slope was denoted by distance of probe traveled until rupture occurred.

Determination of linear expansion (LE%)

The percentage linear expansion was obtained after deep frying the dried crackers in oil at 180 ºC. The un-puffed cracker was ruled with three lines across using a marker pen. Each line was measured before and after puffing. The percentage linear expansion was calculated according to the method used as [36] follows:

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

Determination of oil absorption (%)

The percentage oil absorption was calculated according to the standard method [35] which is given below:

$$\text{Oil Absorption (\%)} = \frac{\text{Weight of cracker after frying} - \text{weight of cracker before frying}}{\text{Weight of cracker before frying}} \times 100$$

The fish cracker were weighed before and after frying in sunflower oil, using a digital balance. This was done in four replicates and the average was taken.

Determination of bulk density (g/cm^3)

Fish crackers volume (v) was determined in triplicate in each replication using sesame seed displacement [21]. An electronic balance accurate up to ± 0.001 g was used for weight (m) determination. Density (ρ) was calculated as

Bulk Density (ρ) = m / v

Water Absorption Index (WAI) and Water Solubility Index (WSI)

WAI and WSI were determined in triplicate following the method described by Yagci and Gogus (2009) [32]. Each ground cracker (3g) was dispersed in 30 ml of distilled water and stirred using a vortex mixer. This dispersion was allowed to stand for 30 min in a water bath at 30º C. Subsequently, the dispersion was centrifuged at 3000 rpm for 15 min using the centrifuge (Remi Instruments, Bombay, India). The supernatants were poured into a petridish and dried at 110 ºC and weigh. WAI and WSI were calculated using following equations:

$$\text{WAI (g/g)} = \frac{\text{Weight of hydrated residue}}{\text{Dry weight of the sample}}$$

$$\text{WSI (\%)} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Dry weight of the sample}} \times 100$$

Determination of colour

The colour property of fish crackers samples was measured by using Colour Reader CR-10 (Konica Minolta Sensing Inc. Japan). For determination of colour, the sample was ground to powder with the help of grinder. The powder was completely filled in petridish provided that no light is allowed to pass during the measuring process. The lightness (L^*), redness (a^*) and yellowness (b^*) values were recorded. The equipment was standardized with a white colour standard.

Sensory analysis

Sensory evaluations were conducted using a five-member trained panel. Panellists were trained to evaluate the fish cracker for crispiness, texture, taste/flavor, odour and overall acceptability on a using 5-point hedonic scale according to standard procedure [11] as Like very much (5), Like moderately (4), Neither like nor dislike (3), Dislike moderately (2), Dislike very much (1). The limit of acceptability was 3 for all the samples.

Statistical analysis

Data obtained from all the tests were analyzed by using one-way analysis of variance (ANOVA) and followed by Duncan multiple range test of the Statistical Package for Social Science version 22.0 (SPSS inc., Chicago, Illinois, U.S.A) [23]. Statistical significance was indicated at the 95% confidence level. Values expressed are means of three determinations ± standard deviation.

Results and Discussions

Biochemical composition of fish cracker

To evaluate the nutritional status of crackers proximate composition was analysed for the dried and fried fish cracker prepared using different starches i.e. rice, sago and tapioca (C-1, C-2 and C-3) with Bull's eye fish mince at ratio of 1:1. The proximate composition of dried and fried fish cracker are given in Table 2 and 3 respectively. There were significant differences (p<0.05) observed in the proximate composition of the dried and fried samples. Dried fish cracker had moisture contents of 10.88±0.36%, 12.79±0.29% and 10.09±0.45% for rice based, sago based and tapioca based fish crackers respectively while the fried cracker showed 3.16±0.16%, 2.96±0.08% and 2.91±0.12% respectively. Similar results were also reported by several scientist [8, 9, 36] with moisture content of 9%, 12% and approximately 9-13% respectively.

Protein content of dried fish crackers varied between 24.65±0.47%, 22.92± 0.18% and 23.88±0.15% for rice, sago and tapioca based fish crackers whereas fried crackers content 22.73±0.41%, 20.24±0.26% and 19.98±0.17% respectively. The protein content of the crackers increased with an increase in the proportion of fish [6, 8, 18, 29, 36]. It is commonly known that fish is a good source of protein while starch flours like rice, sago and tapioca contains relatively a lower amount of protein. The protein content of the fried crackers was even lower than that of the dried crackers because of displacement of protein by proportion absorption of oil during frying.

Increasing the fish proportion not only increases protein content but also increases the lipid content. A similar trend, but with different degrees of increase, was also reported by several worker [9, 36]. Lipid content for rice, sago and tapioca based cracker was found around 2.38±0.41%, 2.52±0.09% and 2.30±0.13% for dried cracker and fried cracker had 9.02±0.11%, 23.78±0.15% and 14.70±0.38% in rice based, sago based and tapioca based fish crackers respectively. The fat content of rice flour, sago flour and tapioca flour are only 0.1% [36]. However, the degree of the fat content increase depends on the fish species: higher with oily fish and lower with lean fish (fat content <4%). Higher ash content was observed in fish cracker made from rice: fish combination (6.16±0.04%) followed by sago: fish cracker (5.58±0.12%) and lowest concentration was analysed in tapioca: fish cracker (5.04±0.09%) for the dried fish cracker. Fired cracker also exhibited similar trend as 5.13±0.07%, 4.97±0.05% and 4.64±0.05% for rice based, sago based and tapioca based fish crackers respectively.

As the protein content increased, the carbohydrate contents reduced with increasing the fish proportion. Carbohydrate content in dried fish cracker was 55.93±0.41%, 56.91±0.43% and 58.99±0.33% in rice based, sago based and tapioca based fish crackers respectively. While the content of carbohydrate analysed in fried cracker was 59.97±0.39%, 48.05±0.42% and 57.77±0.44%. Similar results with respect to carbohydrate was showing that commercial fish crackers [8] contained carbohydrates within the range of 65 – 80% for different starches. Higher content of carbohydrates in crackers are one of the reasons for the important substitution of starch flour with fish to provide a more balance and protein rich fish cracker. Total energy value for dried fish cracker was observed to be 343.74±7.82, 339.12±9.46 and 352.18±8.12 (kcal/100 g.) respective to C1, C2 and C3. While the energy value for the fried products increased after frying and was found around 411.98±6.05, 487.18±7.26 and 443.30±7.45 (kcal/100 g.) for rice based, sago based and tapioca based fish crackers respectively. The results are in agreement with the work done by Yu (1991b) [36], King (2002) [9] and Rohani *et al*. (2010) [20].

Table 2: Nutritional quality of dried fish cracker prepared with different starch.

Dried Cracker	C – 1 (Rice : Fish)	C – 2 (Sago : Fish)	C – 3 (Tapioca : Fish)
Moisture (%)	$10.88^a \pm 0.36$	$12.79^b \pm 0.29$	$9.79^a \pm 0.45$
Protein (%)	$24.65^a \pm 0.47$	$22.92^{ab} \pm 0.18$	$23.88^a \pm 0.15$
Lipid (%)	$2.38^a \pm 0.41$	$2.52^a \pm 0.09$	$2.30^a \pm 0.13$
Ash (%)	$6.16^a \pm 0.04$	$5.58^{ab} \pm 0.12$	$5.04^{ab} \pm 0.09$
Carbohydrates (%)	$55.93^b \pm 0.41$	$56.91^a \pm 0.43$	$58.99^a \pm 0.33$
Total energy (Kcal/100 g)	$343.74^a \pm 7.82$	$339.12^b \pm 9.46$	$352.18^a \pm 8.12$

n = 4, mean ± SD. ^{a,b} Value with different superscripts in a row for each parameter differ significantly (p<0.05). Value presented was based on dry weight.

Table 3: Nutritional quality of fried fish cracker prepared with different starch.

Fried Cracker	C – 1 (Rice : Fish)	C – 2 (Sago : Fish)	C – 3 (Tapioca : Fish)
Moisture (%)	$3.16^b \pm 0.16$	$2.96^a \pm 0.08$	$2.91^a \pm 0.12$
Protein (%)	$22.73^a \pm 0.41$	$20.24^{ab} \pm 0.26$	$19.98^c \pm 0.17$
Lipid (%)	$9.02^a \pm 0.11$	$23.78^c \pm 0.15$	$14.70^b \pm 0.38$
Ash (%)	$5.13^a \pm 0.07$	$4.97^a \pm 0.05$	$4.64^a \pm 0.05$
Carbohydrates (%)	$59.97^a \pm 0.39$	$48.05^b \pm 0.42$	$57.77^a \pm 0.44$
Total energy (Kcal/100 g)	$411.98^c \pm 6.05$	$487.18^a \pm 7.26$	$443.30^{ab} \pm 7.45$

n = 4, mean ± SD. ^{a,b,c} Value with different superscripts in a row for each parameter differ significantly (p<0.05). Value presented was based on dry weight.

Physicochemical and sensory quality assessment

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 characteristic [22, 35]. Physicochemical properties of fish crackers are shown in Table 4. There were significant differences (p<0.05) in linear expansion, oil absorption and the hardness of each sample. Maximum linear expansion was recorded for tapioca based fish cracker (C3) followed by sago (C2) and rice based fish crackers (C1). Linear expansion of rice, sago and tapioca based fish crackers were found as 18.10±5.46, 43.32±8.54 and 83.03±4.73 (%) respectively. Among various types of flour used in fish crackers, tapioca starch showed maximum linear expansion of fish crackers was demonstrated by several workers [5, 22, 35]. According to Yohii and Arisaka (1994) [33], protein reduced the expansion of amylopectin in rice and sago starch during frying and caused a reduction in the linear expansion.

Highest oil absorption was observed in tapioca based fish cracker followed by sago and rice based fish crackers (Table 4). The oil absorption of rice, sago and tapioca based fish crackers were found as 6.82±1.98, 21.58±0.77 and 25.30±1.90 (%) respectively. High oil absorption was observed in fried fish cracker made up with tapioca starch at fish contents of 50%. This could be due to the highly expanded of the fried crackers. Mellema (2003) [13] suggests that the evaporation of water causes oil absorption, as the oil gets pulled into pores to replace the lost water. The greater the linear expansion, the higher the surface area, hence more oil absorbed on the surface. Suhaila and Norhasyimah (1994) [25] also reported a positive correlation 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. Significant differences (p<0.05) in hardness for the combination were observed. Hardness for combination of rice, sago and tapioca based fish crackers were found as 1549.70±534.17, 1098.90±344.26 and 1462.10±181.25 (N/cm^2) respectively. The results are in agreement with the work done on the microstructure analysis of fish crackers [4] found that poorly expanded fish crackers contained large aggregates of fish protein. This prevented the starch gel from expanding in hot cooking oil, and the denser structure of cracker increased its hardness. However, no significant difference was observed in the bulk density for the fish cracker.

WAI in dried fish cracker was recorded as 5.04±0.08, 5.68±0.10 and 4.45±0.13 (g/g) in rice, sago and tapioca based fish crackers respectively. However, water solubility index (WSI) showed no significant difference for these three combinations. Analysis of WSI observed was 13.26±0.07%, 12.64±0.08% and 13.80±0.24% for all the combination respectively. WAI and WSI are considered as indicators of the degree of starch gelatinization and its degradation. The higher content of soluble polysaccharides released from the starch polymer chains after gelatinization can effect on the increase of WSI and the decrease of WAI values.

The colour of fish cracker plays an important role in the assessment of fish crackers, as the surface colour reflects not only the heterogeneous surface formed as a result of frying but also the non-homogeneous oil distribution. Significant differences ($p<0.05$) were observed for all the combination. It can be seen from the colour L^* value and colour b^* value decreased in sago and tapioca starch comparing to the rice starch for the dried crackers. Whereas, a^* value of dried fish cracker was higher in sago starch incorporated crackers followed by rice and tapioca starch crackers. However, the colour L^* value increased for the sago and tapioca starch and colour a^* and b* value was decrease for the rice and sago incorporated crackers after frying. The colour value L^*, a^* and colour b^* value decreased in rice starch mixed fish crackers.

Table 4: Physicochemical, microbiological and sensory characteristics of fish cracker developed from different starches and Bull's eye meat.

Parameters	Combination – 1 (C-1) Rice: Fish	Combination – 2 (C-2) Sago: Fish	Combination – 3 (C-3) Tapioca: Fish
Physico-chemical parameters			
Oil absorption (%)	$6.82^{a} \pm 1.98$	$21.58^{ab} \pm 0.77$	$25.30^{abcd} \pm 1.90$
Linear expansion (%)	$18.10^{cd} \pm 5.46$	$43.32^{abcd} \pm 8.54$	$83.03^{a} \pm 4.73$
Hardness (N/cm^2)	$1549.70^{abc} \pm 534.17$	$1098.90^{a} \pm 344.26$	$1462.10^{ab} \pm 181.25$
Bulk density (gm/cm^3)			
Dried cracker	$0.85^{a} \pm 0.15$	$0.15^{a} \pm 0.02$	$0.12^{a} \pm 0.00$
Fried cracker	$0.98^{a} \pm 0.09$	$0.08^{a} \pm 0.01$	$0.07^{a} \pm 0.01$
Water absorption index (g/g)	$5.04^{a} \pm 0.08$	$5.68^{ab} \pm 0.10$	$4.45^{a} \pm 0.13$
Water solubility index (%)	$13.26^{a} \pm 0.07$	$12.64^{a} \pm 0.08$	$13.80^{a} \pm 0.24$
Color (*L, a, b*)			
L^* (Dried)	$49.50^{a} \pm 2.59$	$44.38^{b} \pm 1.58$	$35.13^{c} \pm 2.38$
a^* (Dried)	$6.43^{b} \pm 1.02$	$7.18^{c} \pm 1.58$	$5.23^{a} \pm 1.28$
b^* (Dried)	$24.80^{c} \pm 1.70$	$22.83^{b} \pm 2.97$	$18.78^{a} \pm 1.65$
L^* (Fried)	$45.28^{c} \pm 3.36$	$63.08^{a} \pm 1.37$	$60.25^{b} \pm 0.89$
a^* (Fried)	$10.48^{c} \pm 0.54$	$2.70^{b} \pm 0.56$	$1.78^{a} \pm 0.39$
b^* (Fried)	$23.23^{c} \pm 1.48$	$18.68^{a} \pm 2.16$	$20.50^{b} \pm 0.35$
Sensory analysis (n=5 panellists, score on 5 – point scale)			
Crispiness	$2.2^{ab} \pm 0.45$	$2.6^{ab} \pm 0.89$	$4.6^{a} \pm 0.45$
Texture	$2.8^{ab} \pm 0.45$	$2.8^{ab} \pm 0.45$	$4.4^{a} \pm 0.55$
Odour	$3.2^{ab} \pm 0.84$	$3.2^{ab} \pm 0.84$	$3.4^{a} \pm 0.55$
Taste	$2.8^{ab} \pm 0.45$	$3.0^{ab} \pm 0.00$	$3.8^{a} \pm 0.45$
Overall acceptability	$3.0^{ab} \pm 0.00$	$3.2^{ab} \pm 0.89$	$4.4^{a} \pm 0.45$

[a,b,c,d] Value with different superscripts in a row for each parameter differ significantly ($p<0.05$). Each value is represented dry weight based as the mean ± SD of n=4.

Lightness and redness tended to decrease with the ratio of fish meat to tapioca starch flour, whereas yellowness tended to decrease [16]. Thermal treatment (frying) may also affect the color of crackers due to structural changes in starch granules and proteins. Slight browning, including the maillard reaction and the caramelization by heat, as well as changes in pigment concentration caused by dehydration and expansion, might be among the factors that determine the color of cracker [31].

During the frying process, the physical, chemical and sensory characteristics of the food are modified [15]. Maillard reaction, a non-enzymatic browning reaction between amino acids and reducing sugars, is the primary color formation reaction [3, 15]. Addition of fish mince meat caused an increase in the amount of amino acid in the starch mixture. Thus, the maillard browning reaction easily occurred with increase in fish protein resulting in decrease of L^* value, but increase of a^* and b^* values. Although, corroborating results have been reported in the present study.

During sensory analysis, crispiness, texture, odour, taste and overall acceptability of deep fried fish crackers containing tapioca flour was found superior to all combination by the trained panellist. The test panellists found significant difference ($p<0.05$) in the crispness, texture, taste, odour and overall acceptability of the different combinations. However, they rated the crispiness, texture and overall acceptability higher score for the samples of tapioca based fish crackers significantly ($p<0.05$) better than the samples of sago and rice based fish crackers. Best combination of fish crackers in terms of sensory characteristics like crispiness, texture, odour, taste and overall acceptability were observed with tapioca starch. Similar observation reported [1] an excellent brittleness or crispness that is the most important sensory characteristics found in tapioca fish crackers.

Conclusion

Based on the results, it can be concluded that Bull's eye fish meat and tapioca starch used in ratio of 50:50 can be used to develop nutritionally rich fish cracker using a simple technology. Production of fish crackers from low value fish, apart form adding value value to fish and increasing the protein intake in snack food, has the potential to support a small-scale industry in rural areas for malnourished people.

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