Quality Evaluation of Nutritious Fish Crackers Developed from Three Carp Fish Species

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ABSTRACT

Aims: A large number of food industries are focusing their interests recently on the commercial production of fish crackers for their nutritional values and health benefits. The goal of this study was to develop a set of formulae for the preparation of nutritious and tasty fish crackers using three low-value carp fish species namely mirror carp (Cyprinus carpio var. specularis), Mrigal (Cirrhinus cirrhosis) and Pangasius (Pangasius hypothalamus).

Methodology: Six different fish crackers were developed and their proximate analysis, linear expansion, oil absorption, texture hardness, color components were analyzed as per standard established methods. Sensory attributes were carried out by 60 naïve panelists to evaluate their consumers' acceptance. The obtained data were analyzed by SPSS for Windows (Version 25).

Results: The one-way analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT) of all parameters showed significant differences (at \( P<0.05 \)) among the prepared fish crackers with significantly better results (at \( P<0.05 \)) for Sample 3. The moisture, ash, protein, fat

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and carbohydrate content of the fish crackers ranged from 2.42±0.05–3.18 ± 0.07%, 1.53±0.66–2.87±0.05%, 12.55±0.11–17.82±0.09%, 19.71±0.14–24.26±0.17% and 28.76±0.12–47.56±1.07%, respectively. The linear expansion, oil absorption and texture hardness of the fish crackers varied from 40.86±0.55–60.99±0.65%, 0.98±0.14–7.12±0.21% and 1208.30±109.08–2011.64±98.06 N/cm², respectively. The range of Hunter lab color components e.g. lightness (L*), redness (a*) and yellowness (b*) of the fish crackers were 41.96±0.68–69.15±0.08, 0.89±0.11–9.09±0.08 and 7.51±0.03–30.88±0.06, respectively. For all of the above-mentioned parameters, significantly better results (at P< 0.05) were observed in Sample 3 than the other samples. The 9-point Hedonic scale rating of the fish crackers rated by 200 naïve panelists revealed a significant difference (at P< 0.05) for Sample 3 than the others crackers in terms of appearance (8.30±0.79), taste (8.53±0.78), crispiness (7.63±0.85), aroma (7.91±1.09) and overall acceptability (8.64±0.72).

**Conclusion:** Significantly better results (at P< 0.05) were observed for Sample 3, whereas the results of other samples were also acceptable. Findings of this investigation can also be helpful for the commercial production of value-added, nutritious fish crackers from low-value carp fishes like *Cyprinus carpio var. specularis, Cirrhinus cirrhosis* and *Pangasius hypothalamus*.

### Keywords:
- Fish crackers; proximate analysis; physical characteristics; color components; sensory evaluation; carp fishes.

### 1. INTRODUCTION

Fish has an important nutritional value in human health. Increasing the consumption of fish is one of the recommended ways to improve dietary quality against the worldwide epidemics of obesity and chronic diseases [1]. Fish is a low-calorie food that contains high protein, omega-3 fatty acids, and important minerals like calcium and phosphorus [2]. Ready-to-eat fish crackers are in high demand nowadays [3]. Fish crackers are generally considered as a snack food but can be consumed together with other main dishes [4]. Carp fishes like mirror carp (*Cyprinus carpio var. specularis*), mrigal (*Cirrhinus cirrhosis*), and pangasius (*Pangasius hypothalamus*) are abundant in Bangladesh. But due to the lack of proper processing and the failure of producing value-added food items from these fishes, their production is gradually decreasing [5]. Production of common carp fishes in Bangladesh has dropped down from 4.03 metric tons in 2010 to 3.40 metric tons in 2015 [6].

The flesh of fresh fish is the most important ingredient to produce fish crackers. Starch flour is one of the main ingredients to produce fish crackers [7]. There are many starch flours like tapioca, wheat, corn, sago, rice, mung bean, etc. that are used to prepare fish crackers. Fish crackers are usually produced by mixing minced fish flesh with water and starch and then shaping the dough into different forms like round, oblique, longitudinal, or stick followed by boiling or steaming for gelatinization [8]. Then the gelatinized product is cooled, followed by slicing and drying to the moisture content of around 10% [9]. Gelatinization of starch is a major factor that determines the quality of the final product [4, 10]. Consumers always consider crispiness or crunchiness as the most important sensory quality for snack items [11]. To attain crispiness, the degree of linear expansion of fish crackers should be high as it is closely correlated to the crispiness [12]. So, the degree of linear expansion is an important parameter to evaluate the quality of fish crackers. The linear expansion of fish crackers tends to be poor with excessive steaming time [7]. There is a poor linear expansion in fish crackers when the slicing is more than 2 mm [13]. The gradual development of processed food has a positive impact on the GDP as well as the economy of a country. This development also provides considerable benefits to the average food consumers in their daily life [2].

Many of the carp fishes cultured in Bangladesh have low consumer preference because of their dull taste. Due to their low value in the market, productions of carp fishes are decreasing day by day [14]. The fish sector of Bangladesh can experience a positive boom if these low-value fishes can be utilized to make value-added food products like fish crackers [15]. Production and processing of value-added snack items like fish crackers from these carp fishes can contribute a lot to the developing economy of Bangladesh [2]. Along with high nutritional value and good sensory quality coupled with better formulation and packaging, fish crackers have huge potential to be a very attractive snack food item in
Bangladesh [6,15]. Young children and adolescents of Bangladesh are attracted to unhealthy fast foods and they hardly consume fishes or fish-based food items. Fish crackers can be a good alternative snack item for them [6].

So far, a very few fish-based snack items available in the markets of Bangladesh. Development of nutritious fish crackers forms low-value carp fishes can introduce a new opportunity both in the fish and food sector of Bangladesh and has the potential to become a profitable snack item in the existing market. Focusing on all these reasons, this current investigation was undertaken to develop value-added nutritious fish crackers using three under-utilized, low-value carp fishes of Bangladesh namely mirror carp (Cyprinus carpio var. specularis), mrigal (Cirrhinus cirrhosis) and pangasius (Pangasius hypotalamus).

2. MATERIALS AND METHODS

2.1 Location of the Research

This study was conducted from March to September of 2019. All the experiments described in this study were conducted in the departmental laboratory of Food Engineering and Tea Technology at Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh.

2.2 Raw Material Collection

Mirror carp (Cyprinus carpio var. specularis), mrigal (Cirrhinus cirrhosis), and pangasius fish (Pangasius hypotalamus) were purchased from “Agora” super shop of Subidbazar, Sylhet, Bangladesh and brought to the laboratory of Food Engineering and Tea Technology for immediate processing. Corn flour, salt, sugar, water, potato, garlic, baking powder, soybean oil, and other ingredients were also bought from “Agora” super shop.

2.3 Sample Preparation and Labeling

The fishes were washed thrice under tap water. The flesh of the fishes was separated from the bones by a boner after knobbing, gutting, and cleaning. The flesh was then minced and mixed with flour to prepare six (6) different samples. Sample 1 was prepared by mixing 180 g minced flesh of mirror carp fish with 180 g flour, 2% salt, 1% sugar and 20% water maintaining the fish to flour ratio of 1:1. Sample 2 was prepared by mixing 180 g minced flesh of mirror carp fish with 144 g flour, 2% salt, 1% sugar and 20% water maintaining the fish to flour ratio of 1.25:1. Sample 3 was prepared by mixing 210 g minced flesh of mrigal fish with 210 g flour, 2% salt, 1% sugar, 20% water, 10% potato, 2 g garlic, and slight baking powder maintaining the fish to flour ratio 1:1. Sample 4 was prepared by mixing 150 g minced flesh of pangasius fish with 225 g flour, 2% salt, 1% sugar and 20% water maintaining the fish to flour ratio of 0.67:1. Sample 5 was prepared by mixing 150 g minced flesh of pangasius fish with 100 g flour, 2% salt, 1% sugar and 20% water maintaining the fish to flour ratio of 1:1. Sample 6 was prepared by mixing 150 g minced flesh of pangasius fish with 150 g flour, 2% salt, 1% sugar and 20% water, 10% potato, 2 g garlic, and slight baking powder maintaining the fish to flour ratio 1:1. The sample labels along with their preparation are given in Table 1.

2.4 Preparation of Fish Crackers

The ingredients were mixed manually until the smooth dough was obtained. The dough was then turned into a sausage-like shape with 4-6 cm in diameter and 40 cm in length. The

<table>
<thead>
<tr>
<th>Sample labels</th>
<th>Fish type</th>
<th>Minced flesh (g)</th>
<th>Flour (g)</th>
<th>Salt (%)</th>
<th>Sugar (%)</th>
<th>Water (%)</th>
<th>Potato (g)</th>
<th>Garlic (g)</th>
<th>Baking powder</th>
<th>Fish: flour ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>Mirror carp</td>
<td>180 g</td>
<td>180 g</td>
<td>2%</td>
<td>1%</td>
<td>20%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1:1</td>
</tr>
<tr>
<td>Sample 2</td>
<td>Mirror carp</td>
<td>180 g</td>
<td>144 g</td>
<td>2%</td>
<td>1%</td>
<td>20%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.25:1</td>
</tr>
<tr>
<td>Sample 3</td>
<td>Mrigal</td>
<td>210 g</td>
<td>210 g</td>
<td>2%</td>
<td>1%</td>
<td>20%</td>
<td>10%</td>
<td>2 g</td>
<td>slight</td>
<td>1:1</td>
</tr>
<tr>
<td>Sample 4</td>
<td>Pangasius</td>
<td>150 g</td>
<td>100 g</td>
<td>2%</td>
<td>1%</td>
<td>20%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.5:1</td>
</tr>
<tr>
<td>Sample 5</td>
<td>Pangasius</td>
<td>150 g</td>
<td>225 g</td>
<td>2%</td>
<td>1%</td>
<td>20%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.67:1</td>
</tr>
<tr>
<td>Sample 6</td>
<td>Pangasius</td>
<td>150 g</td>
<td>150 g</td>
<td>2%</td>
<td>1%</td>
<td>20%</td>
<td>10%</td>
<td>2 g</td>
<td>slight</td>
<td>1:1</td>
</tr>
</tbody>
</table>
Sausage was then encased in polyethylene casings. Then they were steamed at 90-95°C for 90 minutes. The steamed dough was cooled in running cold water to minimize shrinkage. Then the dough was chilled overnight in a refrigerator at 1-5°C. The polythene casing was then removed from sausage-shaped dough. The chilled dough was then cut into 1-2 mm thick slices. Then those slices were carefully placed in an oven to dry at 60°C for 8-10 hours until a moisture content of 10±2% was obtained. After that, the dried crackers were deep-fried in soybean oil at 180-200°C for 1 minute. The steps for the preparation of fish crackers are shown in Fig. 1.

### 2.5 Proximate Analysis

The moisture, ash, protein, fat, and carbohydrate content of the fish crackers were determined by the method of [16]. The samples were dried at 105°C to determine the moisture content. Complete drying of the samples at 500-600°C in muffle furnace was carried out for the determination of ash content. Kjedahl and soxhlet method was used to determine the protein and fat content of the samples. The percentage of moisture, protein, fat, and ash were then subtracted to calculate the carbohydrate of the fish cracker samples.

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**Fig. 1. Flow diagram showing the preparation of fish crackers**
2.6 Linear Expansion, Oil Absorption, and Texture Hardness

The linear expansion of the fish crackers was measured by the method of [8]. The diameters of the samples were measured using a Vernier caliper. The diameter of the dry chip was determined from the average of three measurements in random directions. Diameters of expanded crackers were evaluated in the same way. Measurements were conducted in 5 replicates for each treatment. The samples were weighed before and after they were fried at 180-200°C using palm oil and their percentage oil absorption was determined according to the method described by [17]. The hardness of the texture of the fish crackers was measured using a texture analyzer (TA-XT2 Stable Micro System) according to the method and condition as described by [18].

2.7 Color Measurement

The Hunter lab color components namely lightness (L*), redness (a*), and yellowness (b*) of the fish crackers were measured by colorimeter (Minolta Spectrophotometer CM3500d) according to the method of [17].

2.8 Sensory Evaluation

Data for sensory evaluation was collected maintaining the recommendations [19]. Sensory evaluation was carried out using the 9-point hedonic scale (1 = 'dislike extremely' to 9 = 'like extremely') to determine the consumer acceptability as described by [20]. A number of 60 naive panelists selected randomly from the students, teachers and staffs of Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh participated in the sensory evaluation. The attributes for the evaluation were appearance, taste, crispiness, aroma, and overall acceptance.

2.9 Statistical Analysis

Data were analyzed using SPSS software (SPSS Inc., Chicago, IL, USA), version 25 for Windows. Results proximate analysis were reported as mean ± standard deviation (SD) for three (3) replicates, n = 3. Results of sensory evaluation for appearance, taste, crispiness, aroma, and overall acceptability were reported as mean ± standard deviation (SD) of 9-point hedonic scale ratings given by 60 naive panelists, n = 60. One-way analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT) (multiple comparison post-hoc test) was used to analyze the statistical difference. Differences with p-values < 0.05 were considered statistically significant.

3. RESULTS AND DISCUSSION

3.1 Proximate Components

The proximate analysis of the fish crackers after deep frying is shown in Table 2. Significant differences (P< 0.05) were observed in all samples with regard to moisture, ash, protein, fat, and carbohydrate.

The moisture content of the fish crackers ranged from 2.42±0.05% to 3.18 ± 0.07%. Comparatively lower moister content was observed in Sample 3 (2.42±0.04%) while comparatively higher moisture content was present in sample 2 (3.18±0.07%) and sample 5 (3.11±0.67%). Moisture content before frying was around 10-11%. Moisture was evaporated during frying due to heat. These results are supported by the reports of [8,17] and [21]. The optimum quality of fish crackers mostly depends on moisture content [8]. The excess level of moisture content reduces the linear expansion whereas fish protein and starch are incompletely gelatinized because of the low level of moisture content [17].

The ash content present in the fish crackers varied from 1.53±0.66% to 2.87±0.05%. Ash content was comparatively higher in sample 2 (2.87±0.05%) and sample 5 (2.67±0.04%). Comparatively lower ash content was present in sample 3 (1.83±0.06%) and sample 6 (1.53±0.66%). These results are consistent with that of [7].

The protein content was within the range of 12.55±0.11% to 17.82±0.09%. Protein content was comparatively higher in sample 2 (17.82±0.09%) and sample 4 (16.76±0.17%). Sample 3 (12.55±0.11%) and sample 5 (13.82±0.07%) had comparatively lower protein content. The protein content of the samples decreased with a decrease in the proportion of fish [8]. These results conform to the reports of [21] and [22]. The spices of the fish along with the meat to starch ratio directly influence the protein content of the fish crackers [17].

The range of fat content present in the fish crackers was 19.71±0.14% to 24.26±0.17%. Fat
content was observed to be comparatively lower in sample 3 (19.71±0.14%) and sample 6 (21.71±0.14%). Sample 2 (24.26±0.17%) and sample 4 (24.68 ± 0.19%) had comparatively higher fat content than the other samples. Fat content was higher in the fish crackers prepared with a higher amount of fish flesh content [23]. Similar findings were reported by [21,7,22] and [12]. However, results regarding fat content varied slightly from the report of [23] where fat content of fish crackers was within the range of 19.8-21.4%. The species of fish play a major role in the fat content of the fish crackers [17]. This slight variation in fat content might have caused due to the higher lipid content of mirror carp and pangasius fish than the fishes used by [23].

The carbohydrate content of the fried fish crackers varied from 28.76±0.12% to 47.56±1.07%. The starch in flour contributes to the carbohydrate content in fried fish crackers. A comparatively higher percentage of carbohydrate was observed in Sample 5 (47.56±1.07%) and Sample 3 (43.23±0.23%) whereas a comparatively lower percentage of carbohydrate content was observed in Sample 4 (26.12±0.06%) and Sample 2 (28.76±0.12%). Similar results in carbohydrate contents were reported by [17].

3.2 Linear Expansion, Oil Absorption, and Texture Hardness

The linear expansion, oil absorption, and texture hardness of the fish crackers are given in Table 3. Significant differences (at $P< 0.05$) were observed for the linear expansion, oil absorption, and texture hardness of Hunter lab color components for the prepared fish crackers samples.

The linear expansion of the fish crackers ranged from 40.86±0.55% to 60.99±0.65%. A comparatively higher linear expansion was observed in sample 3 (60.99 ± 0.65%) with fish to flour ratio of 1:1 whereas comparatively lower linear expansion was observed in sample 4 (40.86 ± 0.55%) with fish to flour ratio of 1.5:1. It should be noted that comparatively higher linear expansion was observed in samples where fish and flour ratios were 1:1 (Sample 3 and Sample 6). When the ratio of fish to starch increased, the linear expansion of fish crackers decreased [7]. The linear expansion of the samples might have been impeded because of the reaction of fish protein with starch granules [8]. These results are in agreement with the reports of [4,8,13,17, 21,24].

The percentage of oil absorption of the fish crackers was within the range of 0.98±0.14% to 7.12±0.21%. The trend in percentage oil absorption of the fish crackers was similar to that of linear expansion. The percentage of oil absorption was comparatively higher in Sample 3 (7.12±0.21%) with Sample 4 showing a comparatively lower percentage of oil absorption at 0.98±0.14%. Previously, [17] had reported a directly proportional relationship between percentage linear expansion and oil absorption. The results of the percentage oil absorption observed in this study are similar to those of [17] and [18].

The range of texture hardness of the fish crackers were 1208.30±109.08 N/cm² to 2011.64±98.06 N/cm². Comparatively lower texture hardness was observed in Sample 3 (1208.30±109.08 N/cm²) while Sample 4 exhibited comparatively higher texture hardness (2011.64±98.06). An inversely proportional relationship was observed between the linear expansion and texture hardness of the fish crackers. Similar results were also reported by [17] and [18]. The starch in fish crackers does not tend to expand for the protein structure in fish, which in turn induces the texture hardness of fish crackers. The texture hardness in fish crackers can also be dubbed as crispiness. Higher crispiness in fish crackers means lower texture hardness, which is a desirable sensory attribute for consumers [21].

3.3 Color Measurement

The results of color measurement are represented in Table 4. Significant differences (at $P< 0.05$) were observed for the $L^*$, $a^*$, $b^*$ properties of Hunter lab color components for the prepared fish crackers samples. The range of lightness ($L^*$), redness ($a^*$) and yellowness ($b^*$) of the fish crackers were 41.96±0.68 to 69.15±0.08, 0.89±0.11 to 9.09±0.08 and 7.51±0.03 to 30.88±0.06, respectively. Comparatively better values of $L^*$, $a^*$, and $b^*$ were observed in Sample 3 to be 69.15 ± 0.08, 9.09 ± 0.08, and 30.88 ± 0.06, respectively. The presence of a comparatively higher amount of fish protein in Sample 3 may have contributed to the better results of these Hunter lab color components of Sample 3 [17]. These results are in agreement with those of [17,18,21].
3.4 Sensory Evaluation

The scores of sensory evaluations of the fish crackers evaluated by 60 naïve panelists are given in Table 5. The scores were given based on appearance, taste, crispiness, aroma, and overall acceptability. The DMRT test followed by ANOVA suggests that sample 3 was significantly better (at $P<0.05$) than the other samples concerning all of the sensory attributes. Sample 3 scored the highest Hedonic score in terms of appearance ($8.30 \pm 0.79$), taste ($8.53 \pm 0.78$), crispiness ($7.63 \pm 0.85$), aroma ($7.91 \pm 1.09$) and overall acceptability ($8.64 \pm 0.72$). Potato and garlic have a natural ability to enhance taste and aroma. Sample 3 might have been preferred more by the panelists than the other samples because of the presence of potato, garlic, and baking powder in its recipe. Although the Hedonic scale ratings of sample 3 were comparatively higher, the Hedonic scores of other samples were also satisfactory. The results of sensory evaluation reported in this study are consistent with that of [7] and comply with the reports of [8,13,17,21] and [23].

Table 4. $L^*$, $a^*$, $b^*$ properties of Hunter lab color components for the fish crackers

<table>
<thead>
<tr>
<th>Samples</th>
<th>$L^*$</th>
<th>$a^*$</th>
<th>$b^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>50.18±0.23$^a$</td>
<td>0.89±0.11$^a$</td>
<td>12.43±0.21$^a$</td>
</tr>
<tr>
<td>Sample 2</td>
<td>60.20±0.19$^a$</td>
<td>1.18±0.04$^a$</td>
<td>14.22±0.10$^a$</td>
</tr>
<tr>
<td>Sample 3</td>
<td>69.15±0.08$^f$</td>
<td>9.09±0.08$^e$</td>
<td>30.88±0.06$^e$</td>
</tr>
<tr>
<td>Sample 4</td>
<td>38.83±0.31$^a$</td>
<td>1.98±0.04$^a$</td>
<td>7.51±0.03$^a$</td>
</tr>
<tr>
<td>Sample 5</td>
<td>41.96±0.68$^b$</td>
<td>2.63±0.13$^d$</td>
<td>9.01±0.92$^b$</td>
</tr>
<tr>
<td>Sample 6</td>
<td>48.28±0.98$^c$</td>
<td>5.71±0.05$^c$</td>
<td>18.18±0.51$^c$</td>
</tr>
</tbody>
</table>

All results are expressed as mean values ± standard deviation of five replicates (n=3). Values in columns with different letter superscripts are significantly different at $P<0.05$.

Table 3. Linear expansion, oil absorption, and hardness of texture of the fish crackers

<table>
<thead>
<tr>
<th>Samples</th>
<th>Linear expansion (%)</th>
<th>Oil absorption (%)</th>
<th>Texture hardness (N/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>53.87±0.38$^c$</td>
<td>2.54±0.13$^d$</td>
<td>1602.82±131.16$^d$</td>
</tr>
<tr>
<td>Sample 2</td>
<td>41.40±0.55$^d$</td>
<td>1.28±0.09$^d$</td>
<td>1846.53±200.53$^d$</td>
</tr>
<tr>
<td>Sample 3</td>
<td>60.99±0.65$^c$</td>
<td>7.12±0.21$^c$</td>
<td>1208.30±109.08$^c$</td>
</tr>
<tr>
<td>Sample 4</td>
<td>40.86±0.55$^c$</td>
<td>0.98±0.14$^c$</td>
<td>2011.64±98.06$^c$</td>
</tr>
<tr>
<td>Sample 5</td>
<td>42.53±0.45$^d$</td>
<td>1.99±0.11$^d$</td>
<td>1783.94±182.32$^d$</td>
</tr>
<tr>
<td>Sample 6</td>
<td>59.44±0.35$^c$</td>
<td>5.12±0.08$^c$</td>
<td>1532.46±158.42$^c$</td>
</tr>
</tbody>
</table>

All results are expressed as mean values ± standard deviation of five replicates (n=3). Values in columns with different letter superscripts are significantly different at $P<0.05$.

Table 2. Proximate components of fish crackers after frying

<table>
<thead>
<tr>
<th>Samples</th>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
<th>Carbohydrate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>2.83±0.08$^c$</td>
<td>2.22±0.10$^c$</td>
<td>15.66±0.18$^c$</td>
<td>23.68±0.19$^c$</td>
<td>39.39±0.09$^c$</td>
</tr>
<tr>
<td>Sample 2</td>
<td>2.59±0.07$^e$</td>
<td>2.87±0.05$^d$</td>
<td>17.82±0.09$^e$</td>
<td>24.26±0.17$^e$</td>
<td>28.76±0.12$^b$</td>
</tr>
<tr>
<td>Sample 3</td>
<td>2.42±0.05$^b$</td>
<td>1.83±0.06$^b$</td>
<td>12.55±0.11$^d$</td>
<td>19.71±0.14$^e$</td>
<td>43.23±0.23$^a$</td>
</tr>
<tr>
<td>Sample 4</td>
<td>3.18±0.07$^a$</td>
<td>2.52±0.12$^d$</td>
<td>16.76±0.17$^d$</td>
<td>24.68±0.19$^e$</td>
<td>26.12±0.06$^a$</td>
</tr>
<tr>
<td>Sample 5</td>
<td>3.00±0.67$^a$</td>
<td>2.67±0.04$^c$</td>
<td>13.82±0.07$^e$</td>
<td>22.26±0.17$^c$</td>
<td>47.56±1.07$^a$</td>
</tr>
<tr>
<td>Sample 6</td>
<td>2.75±0.04$^c$</td>
<td>1.53±0.66$^c$</td>
<td>15.65±0.11$^c$</td>
<td>21.71±0.14$^c$</td>
<td>31.84±0.31$^c$</td>
</tr>
</tbody>
</table>

All results are expressed as mean values ± standard deviation of five replicates (n=3). Values in columns with different letter superscripts are significantly different at $P<0.05$.
4. CONCLUSION

In this study, value-added, nutritious, and healthy fish crackers were prepared in this study with different fish to flour ratios of low-value carp fishes like mirror carp, mrigal and pangasius. Comparatively better results for proximate components, linear expansion, oil absorption, texture hardness, L*, a*, b* properties of Hunter lab color components, and sensory attributes were observed in Sample 3 than the other samples. Based on these results, it can be concluded that use *Cirrhinus cirrhosis* fish’s minced flesh and flour in 1:1 ratio with 2% salt, 1% sugar, 20% water, 10% potato, 2 g garlic, and desirable baking powder can be effective in the production of nutritious, healthy fish crackers. The results of this investigation may be helpful in the economical and profitable production of fish crackers for food industries.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


