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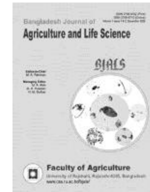

Partial Substitution of Tapioca Flour with Others in Producing Fish Crackers

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ABSTRACT

The replacement of tapioca flour with others is necessary to make fish crackers cheaper and more profitable in Bangladesh. For this purpose, fish crackers were prepared with 25%, 50%, and 75% replacement of tapioca flour (TF) with corn flour (CF), rice flour (RF), and potato paste (PP) to determine linear expansion, hardness/crispiness and color. The highest linear expansion (93.55%) was found in the control sample (100% TF). All values of linear expansion in corn flour (CF) treatments were significantly ($p<0.05$) lower than those of the control sample. There was no significant difference ($p>0.05$) in linear expansion among control, RF1, RF2 and PP1. The lowest hardness (4.9 N/mm) was observed in the control sample (100% TF); nearly the same results were found in RF1 and PP1, representing the highest level of crispiness. Lightness (L*) value was higher with increasing the amount of corn flour, but lowered gradually with increasing the amount of rice flour and potato paste. Therefore, only 25% replacement of TF with RF appeared to yield good results in terms of linear expansion and crispiness. On the other hand, the 25% replacement of TF with PP appeared to yield good results in terms of hardness/crispiness, but not for linear expansion. To sum up, only a 25% replacement of TF with RF would be possible without hampering linear expansion, crispiness and color, which could reduce the price of fish crackers.

Introduction

Fish crackers are one of the popular snack foods in Southeast Asian countries. For all social classes, fish crackers can be a fashionable, ready-to-eat (RTE) snack. Fish crackers are a great substitute for potato crackers. The components required to produce high-quality fish crackers are crucial. The components of crackers' dough are starch, sugar, salt, fish mince, monosodium glutamate, and water.

Starch is an essential component in making fish crackers. Starch is a carbohydrate (polysaccharide) comprising a large number of glucose entities. It is the primary source of energy in the majority of basic foods, such as potatoes, cassava, sago, arrowroot, and grain products (including wheat, corn, barley, rye, rice, oats, sorghum, and millet) (Awokoya et al., 2018). It includes amylose and amylopectin as macromolecules. The gelatinization properties of starch are of supreme importance in dealing with starch-centered food products as much as other thermal properties. The final quality attributes of the snack products are mostly determined by the starch's gelatinization process (Beleia et al., 2006). Compared to other starches, tapioca starch stands out due to its low residual material level, low amylose concentration, and high amylopectin and amylose molecular weights (Mishra and Rai, 2006). Both natural and modified tapioca starch have been used as food ingredients for particular emphasis on its lack of flavor contribution to food systems, which enables accurate and fast detection of

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the item's flavor, tapioca starch is typically used in other food applications as a binding agent and stabilizer (Breuninger et al., 2009). In Bangladesh, the price of tapioca flour varies between 250-300 taka per kilogram. According to Adzahan (2002), native starches typically result in unfavorable gels when the pastes are chilled and weak-bodied, cohesive, rubbery pastes when heated. The differences in the structure and composition of starches derived from various sources determine their characteristics and how they interact with other food ingredients to impart the desired flavor and texture to the finished product. Starch from Zea mays (corn) accounts for 80% of the starch produced for the global market. It is extensively utilized as a thickener, stabilizer, colloidal gelling agent, water retention agent, and glue. The price of corn flour is around 160 taka per kilogram. Rice flour is made from superbly powdered rice. Rice flour inhibits liquid separation; it is often utilized as a thickening agent in cooled or frozen formulations. The price of rice flour is about 110 taka per kilogram. Root tubers, such as potato tubers, are considered unconventional sources of stem cells. As the only edible portion of the plant, potato tubers have up to 25% starch in their fresh mass (Šimková et al., 2013). If the starch level is too high, the potatoes will be tough and coarse, and if it is too low, the potatoes won't be crisp. The price of potatoes is around (30-50) taka per kilogram. The proportion of fish to starch also affects the crispiness and linear expansion of fish crackers (King, 2002). Fish cracker quality is affected by steaming times and additives to food (sodium polyphosphate, sodium bicarbonate, and ammonium bicarbonate) (Cheowet al., 1999; Nurulet al., 2009).It is more likely that a decrease in the crackers' overall carbohydrate content, which leads to a reduction in the amount of amylopectin present, is overall responsible for the decline in the degree of linear expansion. According to Thanatuksorn et al. (2007), crispiness is a crucial and distinct quality that must be carefully regulated in deep-fried goods. Distinct fracture occurrences and brittle fracture force distinguish it. However, the crackers are not yet available in Bangladesh due to the unavailability of high-quality tapioca flour in the market. The unavailability of good quality tapioca flour is the main barrier to expanding this crackers-making technology. Secondly, the price of tapioca flour is comparatively higher than that of the other flours. Therefore, the purpose of this research was to find out the partial replacement of tapioca flour with other sources of starch that maintain all of the necessary physical characteristics required for fish crackers.

Materials and methods

Sample collection

Fresh tilapia (*Oreochromis niloticus*) fish were purchased from Binodpur Bazar, Rajshahi, and transported to the Quality Control Laboratory, Department of Fisheries, University of Rajshahi, Rajshahi, under live conditions. The tapioca flour (Apple Brand, Thailand) was purchased in Chattogram, and other starch sources, such as rice flour, corn flour, and potatoes were collected from local shops in the area. Additionally, refined soybean oil was bought from the adjacent shop.

Experimental design

It is a comparative experimental design. It includes a treatment (or experimental) group that receives the intervention and a control group that serves as a baseline. The control and treatments group are as follows. Tapioca, corn and rice flour usually contain around 10% moisture, whereas potato paste contain around 80% moisture. Therefore, 450 g potato paste need to be added to make equal to 100 g flour (including moisture). Based on this, potato paste amount was determined accordingly.

Control: Tapioca flour (100%)
T-1 for CF1: Tapioca flour (75%) & Corn flour (25%)
T-2 for CF2: Tapioca flour (50%) & Corn flour (50%)
T-3 for CF3: Tapioca flour (25%) &Corn flour (75%)
T-4 for RF1: Tapioca flour (75%) & Rice flour (25%)
T-5 for RF2: Tapioca flour (50%) & Rice flour (50%)
T-6 for RF3: Tapioca flour (25%) & Rice flour (75%)
T-7 for PP1: Tapioca flour (75%) & Potato paste (25%)
T-8 for PP2: Tapioca flour (50%) & Potato paste (50%)
T-9 for PP3: Tapioca flour (25%) & Potato paste (75%)

Preparation of fish crackers

The fish were washed, executed, and gutted. After removing the skin, the fish were filleted and deboned manually under chilled conditions. The minces were prepared with a blender. For making the control sample (fish crackers), at first, 90g of fish mince was taken in a bowl, and the ingredients, such as 100g tapioca flour, 6g sugar, 5.5g salt, 15g ice (or as required), and 1g sodium bicarbonate, were added and mixed well to make the dough. Similarly, other treatments were prepared by replacing tapioca flour with other types of flour or paste. The dough was then shaped into cylinders and steamed for 40 minutes, followed by refrigeration overnight. The next day, the cylinder-shaped product was cut to a thickness of around 2 mm and placed in an oven at 50°C for 10-12 hours, until the moisture content reading was 10% ± 2%. Dried crackers were then deep-fried in soybean oil at 170 °C to 180 °C. Then, the fish crackers were ready as ready-to-eat (RTE) products.

Physical characteristics of fish crackers

The physical characteristics of fish crackers, including linear expansion, crispness, hardness, and color, were measured.

Linear expansion

After deep-frying the dried crackers in oil at 170-180°C, the linear expansion (%) was determined. Using one oil pen, three lines were drawn on the unpuffed cracker. We measured each line both before and after puffing. Five times, the linear expansion of the fish crackers was calculated using Yu's (1991b) method. The following equation calculates the percentage linear expansion:

Linear expansion (%)

$$= \frac{(\text{Length after puffing} - \text{Lenght before puffing})}{\text{Lenght before puffing}} \text{x } 100$$

Hardness /Crispiness

The crispiness of the fried fish crackers (n = 5) was measured using a texture analyzer (FRTS-100, Imada, Japan) equipped with a spherical ball probe measuring 5 mm in diameter, as per the operational manual. The probe's speed and trigger were adjusted to 10 mm/min and 0.05 N, respectively. The spherical probe was used to pierce the fried crackers, which were placed above a supporting rig. Using breaking, this apparatus was utilized to gauge the fracturability. Hardness was measured as N/mm, which is the inverse of crispiness.

Color

The color of the fried crackers was measured using a colorimeter (NH310, China) according to the operational manual. Initially, the equipment was meticulously calibrated using a white color standard to measure the color of the samples. Once the colorimeter was calibrated using white, it was prepared for measurement. For color measurement, a flat, smooth, homogeneous, and non-directional sample is preferable. Then, the color of the products of five samples in terms of lightness (L*), redness (a*) and yellowness (b*) were measured individually. The value was taken as an average of five readings.

Statistical analysis

Every experiment was run five times. To express the value, the mean ± standard deviation was used. Regarding the variation among linear expansion, color, and texture, one-way ANOVA and the Tukey test were employed in SPSS version 20, with a significance level set at $p < 0.05$ for treatment differences.

Results

Different physical parameters, including linear expansion, hardness/crispiness, and color, were evaluated to assess the quality of fish crackers.

Linear expansion

The linear expansion was 93.55% in the control sample (100% TF), which was higher than that of other treatments. All values for corn flour treatments were significantly ($p <0.05$) lower than those of the control sample. In rice flour treatments, the highest value was 76.08% in RF1 (TF 75% + RF 25%), which was lower than the control. Among the treatments, the lowest value, 18.56%, was found in PP3 (TF 25% + PP 75%). There were no significant differences ($p>0.05$) in linear expansion among Control, RF1, RF2, and PP1 (Fig. 1).

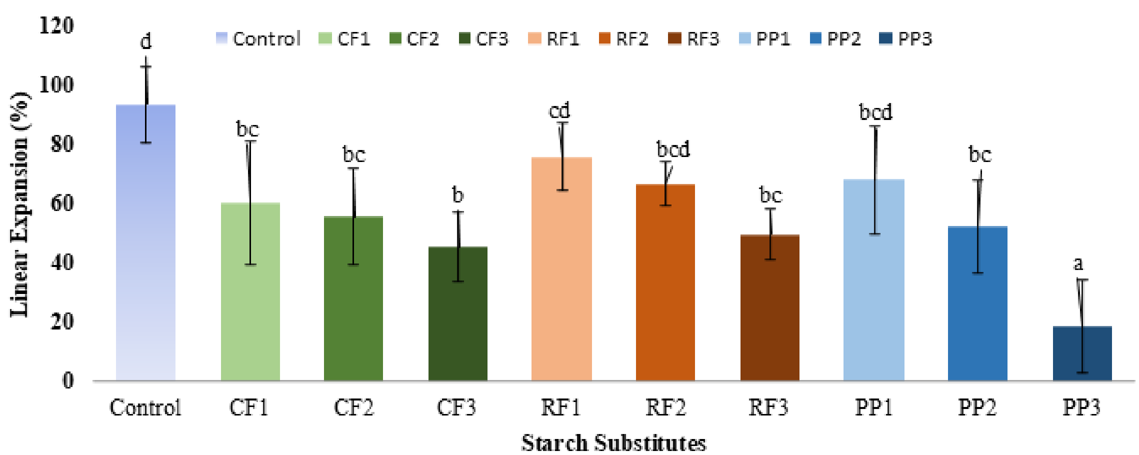

Fig. 1. Linear expansion (%) of fish crackers prepared by different flour substitutes. Different letters on the top of each parameter's bars denote a significant difference among fish crackers ($p < 0.05$), TF = Tapioca flour, CF = Corn flour, RF = Rice flour, PP = Potato paste

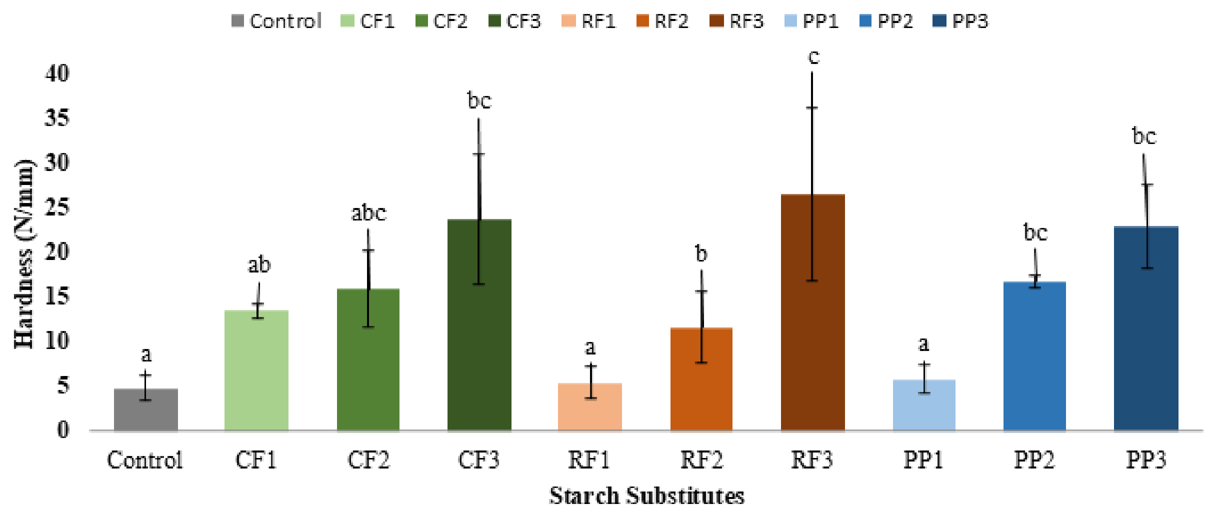

Fig.2. Hardness (N/mm) of fish crackers prepared by different flour substitutes. Different letters on the top of each parameter's bars denote a significant difference among fish crackers ($p < 0.05$), TF = Tapioca flour, CF = Corn flour, RF = Rice flour, PP = Potato paste

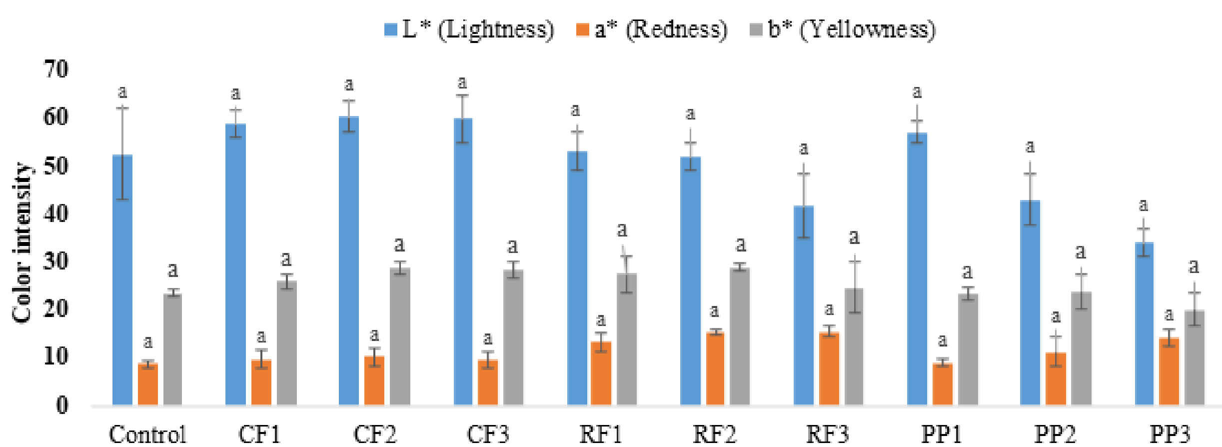

Fig. 3. Color of fried fish crackers prepared by different flour substitutes. Different letters on the top of each parameter's bars denote a significant difference among fish crackers ($p < 0.05$), TF = Tapioca flour, CF = Corn flour, RF = Rice flour, PP = Potato paste

Hardness/Crispiness

The hardness value of 4.9 N/mm was found in the control sample (100% TF), which was the lowest compared to the other treatments, indicating the highest level of crispiness. The values of hardness for corn flour treatment were higher than those of the control sample (100% TF). A hardness value of 26.6 N/mm was found in RF3 (TF 25% + RF 75%), which was significantly higher compared to that of the control. There was a highly significant difference ($p<0.05$) between control (100% TF) and RF3 (TF 25% + RF 75%). However, significantly ($p<0.05$) lower hardness was found in the control, RF1, and PP1 samples compared to the RF3 sample (Fig. 2).

Color

The L*, a*, and b* values for the samples are shown in Fig. 3. The main factor influencing variations in the lightness (L∗) value in the current analysis was found to be the decline in linear expansion during fried crackers. In CF1, CF2, and CF3, the linear expansion decreases gradually with a decreasing rate in L* value, except for CF2 (TF 50 %+ CF 50%). In CF2, both the tapioca and corn flour were significantly lighter in color, resulting in a higher level of lightness. An increasing rate in the yellowness (b* value) was also found with the decrease in the linear expansion in the case of CF1, CF2, and CF3. A similar decreasing rate in lightness (L* value) was also observed in RF1, RF2, RF3, PP1, PP2, and PP3, accompanied by a decrease in the rate of linear expansion. In cases of yellowness (b*), a decreasing rate in RF1, RF2, RF3, PP1, PP2, and PP3 was also observed, along with a decrease in linear expansion. A significant difference ($p < 0.05$) was found between PP3 and other treatments in terms of yellowness (b*).

Discussion

Linear expansion is one of the most important characteristics of fish crackers that consumers find acceptable. According to Siaw et al. (1985), a minimal level of acceptability was determined to be a 77% linear expansion. In the present study, the highest linear expansion was 93.55% found in the control (100% TF) sample, which exceeded the minimum level of acceptability. The lowest linear expansion value among the treatments was 18.56% in PP3 (TF 25% + PP 75%), which was lower than the minimum level of acceptability. Nonetheless, commercial fish crackers have been found to show a broad range of linear expansion (38–145%) (Huda et al., 2010). The ratio of amylase to amylopectin in the flour affects the extent to which the final product expands. A high-quality cracker requires at least 50% amylopectin and between 5% and 20% amylose (Yu, 1991a). The linear expansion of fish crackers is influenced by the type and quantity of fish and starch utilized. In crackers, the starch component, gelatinized and expanded, is fried. According to Huda et al. (2001), there is a negative relationship between protein content and linear expansion since increasing the amount of fish used to create the crackers led to a downward trend in the linear expansion of traditional crackers. Additionally, Yu (1991a) found that linear expansion had a negative relationship with protein content and a positive relationship with carbohydrate content and that the type of flour used influenced the extent of expansion in the fish crackers. Rice flour usually contains less protein than corn flour, which results in higher linear expansion in rice flour compared to corn flour. One of the factors influencing how much the half-product expands when soaked in hot oil is the starch's degree of gelatinization (Lachmann, 1969). According to Mohamed et al. (1988), crackers with the highest linear expansion are those made with glutinous rice flour, followed by rice flour, tapioca, corn, sago, wheat, and mung bean flour. Steaming time is another element that could lead to the linear proliferation of fish crackers. According to Kyaw et al. (2001), 20 to 30 minutes of steaming is sufficient to cook the gel; any longer steaming time may cause the increased granules to retain too much water, leading to a poor product. The fish-to-starch ratio, the dough's gel strength during the steaming stage, and the protein content, which influences gel formation and strength while also obstructing vacuole formation and degradation during water evaporation, are other significant factors that affect expansion (Badrie et al., 1992). Temperature, exposure time, and ultimate moisture can all be used for optimum linear expansion (Vasanti et al., 1996). However, by reducing the fish-to-starch ratio in the fish cracker formulation, improved linear expansion of the crackers can be produced (Nurul et al., 2009).

Hardness and crispiness are important criteria for the acceptability of fish crackers by consumers. When producing fish crackers, crispness is the primary factor that needs to be considered (Abimbola, 2002). Hardness and crispiness have a negative relationship. A low hardness value explains the high crispiness, which is preferred by consumers (Huda et al., 2009). As previously mentioned, the rise in fish protein is associated with a reduced degree of linear expansion. The structure of a fish protein that prevents starch from expanding is linked to the percentage of hardness. Massive collections of fish protein were discovered in inadequately expanded fish crackers by Cheow et al. (1999) during their microstructure investigation. As a result, the hardness value increased because the starch was kept from growing in the heated cooking oil, and the filaments became thicker and more compact. Customers prefer fish crackers with a high crispness score and minimal hardness, as indicated by a high crispness mark. In this case, the highest level of linear expansion was observed in the control (100% TF) sample, and the lowest level of hardness, which indicates the highest level of crispiness in the control sample. The highest level of hardness value (26.6 N/mm) was found in the RF3 (TF 25 %+ RF 75%) sample, indicating its lowest level of crispiness, which is evident in the linear expansion of only 49.73%. Rashed et al. (2021) found that increasing linear expansion will increase the crispiness score of fish crackers, which means that the product has a lower hardness value. Comparable outcomes were also reported by Yu (1991a, 1991b).Fish crackers become harder when they have more fish (Nurul et al., 2009). The product's high resistance and high breaking force were shown by the high hardness levels. The addition of cereal fiber to baked and extruded snacks increased textural hardness and breaking strength, as reported by Sudha et al. (2007) and Yanniotis et al. (2007), respectively. The physical characteristics and texture of crackers are influenced by temperature and cooking time (Saeleaw and Schleining, 2011). When a product is exposed to high heat, it becomes crispy.

The color of the fish crackers is a significant factor in evaluating the product, as it indicates both the non-homogeneous oil distribution and the heterogeneous surface created during the frying process. The color of crackers may also vary as a result of thermal treatment (frying), which alters the structure of proteins and starch granules. Food changes in its physical, chemical, and sensory properties occur throughout the frying process (Moyano et al., 2002). The color of crackers can be affected by various methods, including slight browning due to the Maillard reaction and heat-induced caramelization, as well as variations in pigment concentration resulting from drying and expansion (Wang et al., 2013). Products with compact designs tend to be less attractive because they expand less when puffed (Altan et al., 2008).

The amount and type of fish used in the fish crackers, as well as the quantity and kind of starch added, are just a few of the many variables that might affect the color of the product. Those with a low % percentage of linear expansion tended to have darker colors when compared to those with higher L* values. According to Huda et al. (2001), the color of the crackers can also be affected by the types of additives employed and their thickness. The changes in a* values were mainly linked to myoglobin oxidation, while the gelatinization and puffiness ability of starch capacity caused some variations in b* values (Yang and Park, 1998). Apart from the previously specified elements, a variety of other factors can affect the color of fried crackers, such as the amount of fish to starch in the recipe, the kind of starch and additives used, the thickness of the crackers, the type of fish used, and the Maillard reaction caused by the presence of sugar (Huda et al., 2010).

Conclusion

The partial replacement of tapioca flour with other starches could make fish crackers cheaper and readily available. Only 25% replacement of tapioca flour with rice flour appeared to yield good results in terms of linear expansion and crispiness. On the other hand, the 25% replacement of tapioca flour with potato paste appeared to produce good results in terms of hardness/crispiness, but not for linear expansion. In the case of the color of the fried sample, lightness (L*) was more or less similar in all substituted samples. To sum up, only a 25% replacement of tapioca flour with rice flour would be possible without hampering linear expansion, crispiness, and color.

Authors' Contribution

Conceptualization, MTI, MSA; Methodology, MTI, SNL, and MFA; Investigation, SNL, NJN, and MFA; Writing—original draft preparation, SNL, and MFA; Writing—review and editing, MTI, NJN, and MSA; Supervision, MTI. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflicts of interests.

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