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Snacks Fortified with Protein Concentrate from Spotted Goatfish (*Pseudupeneus maculatus*) and Passion Fruit (*Passiflora edulis*) Shell Flour

Running head: Spotted Goatfish and Passion Fruit Snacks

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SUMMARY

Research background. Spotted goatfish (*Pseudupeneus maculatus*) is of great economic importance on the coast of Pernambuco, Brazil, being relevant in the internal and exportation markets. The fish is exported in different forms, as a whole, gutted, and fillets, generating protein-rich waste. The present study aimed to produce protein concentrate from spotted goatfish and add value by developing a nutritional, high-protein snack. In addition, the flour of passion fruit peel was used to improve the fiber content in the product.

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Experimental approach. The snacks were formulated with sour cassava starch, corn meal, condiments, 0 or 5 % spotted goatfish protein concentrate, and 0 or 2 % passion fruit peel flour. The products were compared regarding the physico-chemical, microbiological, and sensory aspects.

Results and conclusions. The products complied with microbiological parameters for quality and safety. The snacks with added spotted goatfish protein concentrate had higher protein content than the control. Furthermore, the use of passion fruit peel flour improved the texture and acceptability of the snack.

Novelty and scientific contribution. The scientific contribution of this study constitutes the improvement of snacks using co-products from the fish and juice industries, generating a product with improved nutritional quality concerning protein and fiber. In addition, the use of agricultural waste fits with improved sustainability.

Keywords: added value; fish co-products; protein supplementation; fiber supplementation; ready-to-eat foods; sustainability

INTRODUCTION

Fish are sources of important nutrients, including protein and long-chain polyunsaturated fatty acids, namely eicosapentaenoic acid/docosahexaenoic acid (EPA/DHA), associated with reduced heart disease risk (*1*). Even though fish production in Brazil has increased significantly in the last decades, fish consumption is still low nearly 10 kg per capita/year (*2*), lower than that recommended by the World Health Organization (12 kg per capita/year) (*3*) and the world average of 20.6 kg per capita/year in 2021 (*2*). Several factors contribute to the low consumption, including cultural factors, high cost, difficulty in preparation, and low conservation quality of the fish. Expanding the use of processing technologies and offering consumers more elaborate and presentable products that are quick and easy to prepare, such as nuggets, pâtés, snacks, and other ready-to-eat products, are ways of stimulating fish consumption (*4*). Including smaller fish with low commercial value and incorporating by-products from the fish industry into newly developed products are also crucial for enhancing sustainability.

Spotted goatfish (*Pseudupeneus maculatus*) constitute a fishing resource of great economic importance from artisanal fishing in the State of Pernambuco, Brazil (*5*). The commercial destinations of this species are regional open-air markets, fishmongers, and the export market, mainly to the United States and Europe (*6*). This fish is exported whole, gutted, or as fish fillet, generating waste that could be used, preventing pollution, and adding value to the fish chain (*7*).

By-products from fish processing have been intensified in recent decades to mitigate the negative environmental impacts caused by direct disposal, providing economic gains and expanding food production (*8*). A co-product obtained from by-products of fish processing is fish protein concentrate, which has an average of 75 % proteins, is chemically stable, has low moisture and fat content, is highly digestible, can be deodorized, is easy to store, and is of low cost. It is a dehydrated and minced product with a great hydration capacity, making it possible to include it in food products (*9*).

Yellow passion fruit (*Passiflora edulis*) is Brazil's most planted type of passion fruit, cultivated in more than 27 states, including Pernambuco. The industrialization of passion fruit is generally focused on juice and nectar production. In this process, 54 thousand tons of by-products, such as seeds and peels, are generated per year in Brazil (*10*,*11*). Passion fruit peel flour can be used as an ingredient in the preparation of functional foods, replacing conventional flour, adding technological characteristics to the product, and ensuring the use of waste (*12*,*13*).

Some studies have already been carried out on the production of snacks with fish meat, for example, where the optimum conditions for the development and study of the shelf life of extruded corn snacks with shrimp powder were evaluated (*14*). It was observed that it is possible to produce snacks with the addition of shrimp powder due to the good technological results, as well as being healthier than traditional snacks and having a shelf life of up to 6 months when stored at room temperature. Another study evaluated the sensory acceptance of snacks with between 3 and 9% fish protein (*15*). The study showed that it is possible to add up to 7% fish protein while maintaining good sensory characteristics in terms of smell, texture, taste, and sensory acceptance. The influence of adding minced fish or freeze-dried fish protein to extruded corn snacks was evaluated in terms of physicochemical, microbial, and sensory aspects during 6 months of storage at room temperature (*16*). The study showed that extruding corn with minced fish or freeze-dried fish protein produces protein-rich products with a shelf life of between 5 and 6 months, making them a good option for providing consumers with nutritious snacks. However, despite these studies, there are still no reports of snacks fortified with spotted goatfish protein concentrate and passion fruit peel flour. Therefore, this study aimed to develop a functional snack with a higher protein and fiber content using residues from the processing of agro-industries (spotted goatfish flour and passion fruit peel flour).

MATERIALS AND METHODS

Spotted goatfish protein concentrate

Spotted goatfish were purchased from local stores and kept frozen until processing. The fish were washed with chlorinated water to remove surface mucus, pre-processed (scaling, beheading,

gutting, and skinning), and filleted as described by Santos *et al.* (*17*). Then, mechanically separated meat was obtained, using a mechanical deboning machine (PV 150, PV Máquinas®, Chapecó, Brazil). Following, the obtained mechanically separated meat was used to produce the spotted goatfish protein concentrate type A, as described by Amaral *et al.* (*18*). The mechanically separated meat was washed using three parts of cold water to one part of mechanically separated meat. The material was stirred for 2 min in a dough mixer (BPS-12, SkyPan, Skymsen®, Brusque, Brazil) and left to rest for 3 min. Subsequently, the fat from the supernatant was manually removed with a sieve, the mechanically separated meat was filtered in a nylon bag (porosity of 0.042 mm^2) and manually pressed until the excess water was removed, maintaining moisture control by weighing the product before and after the mechanically separated meat washing process. This same procedure was repeated once more, totaling two washing cycles. The third mechanically separated meat washing cycle was performed with a 0.05 % phosphoric acid solution (H_3PO_4) for the deodorization of the product and to reach the isoelectric point (pH close to 5.0). Another water washing cycle was performed, totaling four cycles. Then, the mechanically separated meat was placed inside aluminum trays in thin layers and dried in an oven at 65 °C for 15 h. The remaining fat present in the dried material was extracted with ethanol (1:2, mechanically separated meat: ethanol), and next, it was dried in an oven at 65 °C for 3 h to remove the remaining fat. Then, the material was crushed, sieved through 20 and 35 mesh sieves, packed in Ziploc® bags, and stored at -20 °C until analysis.

Passion fruit peel flour

Passion fruits (*Passiflora edulis*) were purchased from local stores. The peels were washed, and the pulp and film were removed and disinfected with chlorine (200 ppm). Subsequently, the peels were macerated in drinking water twice, for 12 h at 6 °C, to eliminate bitter taste. Then, the flour was produced as described by Coelho *et al.* (*19*). After maceration, the peels were dried in a forced air circulation oven (TE-394/3, Tecnal®, Piracicaba, Brazil) at 70 °C for 12 h, cooled, and milled in a food processor (Viva Collection RI 7761, Philips Walita®, São Paulo, Brazil). The flour was sieved (Bertel ISO 3310/1, Bertel Indústria Metalúrgica Ltda, Caieiras, Brazil) into particle sizes ≤425 μm.

Formulation and production of snacks

The snacks were formulated with different proportions of spotted goatfish protein concentrate, passion fruit peel flour, sour cassava starch, cornmeal, salt, and black pepper (Table 1). The condiments were added in the same proportion to all formulations: 1 % salt and 0.1 % black pepper. The amount of water added was standardized at 40 % of the formulations.

The snacks were prepared according to Netto *et al.* (*19*), with a few modifications. The corn meal was mixed with water and cooked for 5 min at 70 ºC until a firm and homogeneous dough was obtained. After cooling, the dough was mixed manually with the sour cassava starch to form a uniform mass. Then, the other ingredients were added and molded into a cylindrical shape, approximately 3 cm in diameter. The dough was cooked in boiling water (100 °C) for 10 min, cooled in ice water, dried at room temperature, and placed in the refrigerator (6 °C) for uniform refrigerator drying (36 h). Afterward, the dough was sliced into 3 mm thick disks, dried in an oven at 50 ºC for 4 h, cooled to room temperature (25 ºC), and stored frozen (-20 ºC) raw. Then, before analysis, the snacks were fried in soybean oil at 180–200 ºC for 5 min.

Proximate composition

The proximate composition of the raw materials (spotted goatfish protein concentrate and passion fruit peel flour) and the snacks were determined by an official AOAC methodology: moisture analysis was carried out by gravimetric method in an oven at 105 ºC until constant mass (*20*). Crude protein was determined by the Kjeldahl method (*N*×6.25) (*21*). Lipid analysis was performed by Soxhlet extraction with petroleum ether (*22*). Ash was quantified after incineration in a muffle furnace at 550 ºC for 5 h (*23*). Carbohydrates were calculated by difference (subtracting moisture, protein, lipids, and ash from 100 g). The caloric value was calculated by multiplying the amounts of protein and carbohydrate by 4 and fat by 9, respectively (*24*).

Water activity

The water activity (a_w) was determined at a temperature of 25 ºC using Aqualab CX-2 equipment (Decagon Devices®, Pullman, USA).

CIE Lab color characteristics

The instrumental color of the snacks was determined using a portable colorimeter (CR-400, Konica Minolta®, Tokyo, Japan) calibrated with a white standard before each analysis. It was operated using a xenon lamp as a light source, illuminant C (Y=92.78; x=0.3139; y=0.3200), an observation angle of 2º, and a measuring area of 8 mm in diameter at 3 points. The color was expressed using the color standards of the “Commission Internationale de L'Eclairage” (CIE) system - *L** (lightness (+) lighter to (-) darker), *a** (red color intensity (+) to green (-)) and *b** (color intensity from yellow (+) to blue (-)).

Expansion of the dough

The dough was expanded by immersing the snacks in soybean oil at 180–200 ºC for 5 min. The snacks (*N*=3 per treatment) were marked with three lines of the same diameter using a fine-tipped pen. The length of each line was measured before and after frying, as described by Nurul *et al.* (*25*). The percentage of expansion was calculated according to the equation described by Yu *et al.* (*26*):

$$\text{Expansion} = \left(\frac{(\text{length after frying} - \text{lenght before frying})}{(\text{lenght before frying})}\right) \cdot 100 \qquad /1/$$

Microbiological analyses

The samples were collected aseptically, weighed, and submitted to serial dilution in peptone saline solution for microbiological analysis. For counting *E. coli* and determining the presence or absence of *Salmonella*, the commercial kits Compact Dry EC® and Compact Dry SL® were used (Nissui Pharmaceutical Co. Ltd., Tokyo, Japan). *B. cereus* counts were determined using the APHA 31.61:2015 plating method (*27*). The count of molds and yeasts was carried out using the APHA 21:2015 plating method (*28*). The results were compared with the requirements of the current Brazilian biscuit legislation, established by Resolution 331 (*29*) and Normative Instruction 60 (*30*).

Sensory evaluation

The sensory evaluation was conducted with 64 untrained panelists, of both genders, between 16 and 67 years old, 36 % male and 64 % female. The analysis was carried out in the Food Sensory Analysis Laboratory of the Department of Consumer Sciences - UFRPE, using individual cabins with white, fluorescent light. The snacks were fried at 180 ºC for 5 min and served in white disposable cups, coded with three-digit numbers, along with water to clean the taste buds between samples. The order of presentation of the samples followed the balanced complete block design according to Wakeling *et al.* (*31*). The Assessment Form included the candidate profile (age, gender), the acceptance test, and the ordering test about preference, as described by Minim (*32*). In the acceptance test, a 9-point hedonic scale was used (1 - disliked very much to 9 - liked very much). The sensory attributes evaluated were appearance, color, odor, texture, flavor, and overall acceptance. The ordering test was used to determine the preference between the formulations. It was carried out according to Silva (*33*). The study was previously approved by the Research Ethics Committee of the Federal Rural University of Pernambuco (CAAE: 49517221.8.0000.9547).

Statistical analysis

The experimental design used was completely randomized with 4 treatments: (1) Control (no spotted goatfish protein concentrate and no passion fruit peel flour), (2) (addition of 5 % spotted goatfish protein concentrate and no passion fruit peel flour), (3) (addition of 2 % passion fruit peel flour and no spotted goatfish protein concentrate), and (4) (addition of both 5 % spotted goatfish protein concentrate and 2 % passion fruit peel flour), and three repetitions each.

The laboratory analyses' results were initially evaluated for normality and homogeneity of variances. When the prerequisites (normality and homogeneity) were achieved, a one-factor analysis of variance (One-way ANOVA) was performed for physicochemical and sensory analyses. Subsequently, the mean comparison test (Tukey test) was applied at a 5 % significance level. The statistical analyses were carried out by the Jamovi statistical program (*34*).

RESULTS AND DISCUSSION

The a_w and the moisture and ash contents of the spotted goatfish protein concentrate (Table 2) were similar to those described by Amaral *et al.* (*18*). The protein content was higher, but the lipid share was lower than that found by Amaral *et al.* (*18*), probably due to variations in the age of the fish and season (*35*). Spotted goatfish protein concentrate had a low percentage of carbohydrates (Table 2), with its caloric value increased due to the amount of lipids. In their research, Correa *et al.* (*36*) prepared pirarucu flour (*Arapaima gigas*) and found a protein content of 50.5 % and a lipid content of 7.8 %. The protein content was lower than that found in this study, probably because the preparation of the flour did not involve the protein concentration step. The lipid content was similar because pirarucu is a low-fat fish.

The instrumental color of the spotted goatfish protein concentrate in the present study differed from that obtained by Amaral *et al.* (*18*), with the *L** value being higher (lighter), the *a** value being lower (less red) and the *b** value being higher (more yellowish) (Table 2). As the methodology adopted was similar, the variations may be related to the natural color variation of this species of fish.

As indicated in Table 2, passion fruit peel flour had low moisture, protein, lipid, and water activity contents. These results are similar to those published by Cazarin *et al.* (*12*) and Garcia *et al.* (*37*).

The lightness of the snacks was higher in the Control treatment, while in the other treatments, the *L** values were lower, with no significant difference between treatments (Table 3). This result is reported by Huda *et al.* (*38*), which states that the type of flour used in fish snacks affects the lightness of the product. Furthermore, the addition of spotted goatfish protein concentrate (spotted goatfish protein concentrate and spotted goatfish protein concentrate + passion fruit peel flour treatments) also

decreased the *L** value. According to Nurul *et al.* (*25*), the higher the fish meat content, the lower the *L** value in snacks, as fish meat has its coloring pigment, which, depending on the species, will darken the product. The lower lightness observed in the fried snacks from the treatments with the addition of spotted goatfish protein concentrate and passion fruit peel flour is a result of the darkening of proteins and carbohydrates (higher values in these treatments) due to the Maillard reaction (*39*). In general, the *L** values of the snacks in the present study were close to those observed by Zzaman *et al.* (*39*). The redness (*a** value) of the snacks was lower in the control treatment, being higher and with no significant difference between the other treatments (Table 3). The highest value of *a** is related to the use of passion fruit peel flour and spotted goatfish protein concentrate (treatments with passion fruit peel flour and spotted goatfish protein concentrate, passion fruit peel flour, and spotted goatfish protein concentrate) (Table 2), which have pigments that give a redder color. Ribeiro *et al.* (*40*) obtained higher *a** values in pasta with the addition of yellow passion fruit peel flour. The values in this study were similar to those found by Huda *et al.* (*38*) when they analyzed fish snacks from different producers in Malaysia (average of 3.84, ranging from 1.03 to 5.89) and Tamsir *et al.* (*41*), who found values from 2.13 to 4.57. The lower yellowness value was measured in the control treatment, while the highest value was in the spotted goatfish protein concentrate + passion fruit peel flour treatment, and spotted goatfish protein concentrate and passion fruit peel flour treatments had intermediate values, with no significant difference. The *b** values found in the present study were higher than those found by Huda *et al.* (*38*), which ranged from 7.77 to 20.62 (average of 16.12). This difference can be explained by the ingredients used in the snacks, such as corn flour, passion fruit peel flour, and spotted goatfish meat, which have high yellowness values. The greater yellowness (higher *b** value) observed in fried snacks from treatments with the addition of spotted goatfish protein concentrate and passion fruit peel flour is the result of the darkening of proteins and carbohydrates (higher values in these treatments) due to the Maillard reaction (*42*).

A significant variation ($p<0.05$) was observed in the expansion of snacks between treatments (Table 3). Snacks made only with the addition of passion fruit peel flour showed the greatest expansion, followed by the control treatment. Passion fruit peel flour led to an increase in the linear expansion of snacks, probably due to the high carbohydrate content of this ingredient (Table 2), moreover, the greatest expansion is achieved when the starch granules in the snacks are fully expanded (*38*). The treatments with spotted goatfish protein concentrate, and spotted goatfish protein concentrate and passion fruit peel flour showed less expansion, and there was no significant difference ($p>0.05$) between treatments (Table 3). The inclusion of spotted goatfish protein concentrate negatively affected the product expansion. This may have occurred due to the interaction

of the protein with the starch granules, making starch gelatinization difficult (*39*) and, therefore, lowering the expansion of the snacks.

However, the values found for the expansion of the snacks were low, as, according to Huda *et al.* (*38*), the expansion of fish snacks must be greater than 77 % to obtain the desirable crunchiness of the product. It is possible that during the dehydration process, there was a change in the consistency of the dough and the formation of the gel, preventing the formation of fine muscle bundles evenly distributed in the starch gel typical of fresh fish protein (*38*).

The proximate composition of the fried snacks is indicated in Table 4. There was no significant difference ($p>0.05$) in moisture between treatments. All of them were similar to literature values (*19*,*39*).

When comparing ash contents in the snacks, the treatments with added spotted goatfish protein concentrate (spotted goatfish protein concentrate and spotted goatfish protein concentrate + passion fruit peel flour) and control treatment showed higher values. Baskar *et al.* (*43*) found a significant increase in the percentage of ash in extruded snacks enriched with fish flour. The same result was also observed in a study with the fortification of carp or shark protein concentrate in biscuits (*44*). However, the ash content of the spotted goatfish protein concentrate was about half that of the passion fruit peel flour. Thus, the main difference was that the percentage of spotted goatfish protein concentrate in the snacks was 2.5 times higher than that of passion fruit peel flour (Table 1). Furthermore, the process of obtaining mechanically separated meat can grind bones together, which will increase the concentration of ash in the product (*7*). Ash values found are lower than those observed in the literature, which ranges from 2.3 to 8.9 in fried fish snacks (*19*,*39*,*45*). This difference can be explained by the ingredients used, mainly the percentage of salt used. In the author´s formulations mentioned above, the rate of salt varied between 2 and 3 %, while in the present study, the salt concentration was 1 %. In the present study, neither monosodium glutamate nor sodium bicarbonate was used, as in the study carried out by Zzaman *et al.* (*39*), or a larger number of seasonings as in the study carried out by Zim *et al.* (*45*).

In the snacks, the highest percentage of protein was found in the treatment with spotted goatfish protein concentrate and passion fruit peel flour, followed by the spotted goatfish protein concentrate treatment (Table 4). This shows the importance of adding spotted goatfish protein concentrate to the protein fortification of snacks. This result confirms what was found by Baskar *et al.* (*43*) and Correa *et al.* (*36*), who found an increase in the percentage of protein in snacks enriched with fish flour. The rate of protein in fish snacks is related to the species of fish and the proportion of fish meat and added starch (*42*).

The highest percentage of lipids was found in the control, spotted goatfish protein concentrate, and passion fruit peel flour treatments, with no significant difference among them. The lowest value was found in the treatment with spotted goatfish protein concentrate and passion fruit peel flour. The addition of fish protein concentrate reduces oil absorption during frying, explained by the lower linear expansion at the time of frying (Table 3) and the consequent lower formation of air areas and lower oil absorption. The lipid values of fried snacks made with tilapia mechanically separated meat found by Netto *et al.* (*19*) presented an average of 16.53 % and were similar to those observed in the Control and passion fruit peel flour treatments.

There was no significant difference between treatments regarding carbohydrates. The values found are similar to those published by Netto *et al.* (*19*), ranging from 66.74 % to 75.87 %, and Huda *et al.* (*38*), which ranged from 53.62 to 80.43 %.

Among the snacks, the spotted goatfish protein concentrate + passion fruit peel flour treatment presented a lower caloric value than the other treatments, which is explained by the lower percentage of lipids due to the lower oil absorption capacity caused by the lower expansion in this treatment (Table 3). The values found were like those reported by Netto *et al.* (*19*) in fried snacks, ranging from 446.60 to 449.50 kcal/100 g, and lower than that published by Neiva *et al.* (*46*), which found a value of 518.07 kcal/100 g.

There was no significant difference between treatments concerning water activity (Table 4). The water activity values of the snacks in the present study were higher than those observed by Netto *et al.* (*19*), which varied between 0.39 and 0.48, and Neiva *et al.* (*46)*, who observed water activity of 0.36 in fish snacks. Water activity values below 0.6 inhibit microbial growth (*47*) and, consequently, snacks from all treatments showed good preservation characteristics and stability. A series of factors, such as the presence of starch in the formulation and the drying and frying processes, can lead to low water activity in snacks (*16*).

Salmonella was not detected in any of the treatments. According to legislation, the counts of *B. cereus* and *Escherichia coli*/g were below 2 log CFU/g (*27,28*). The mold and yeast analysis counts were 1 log CFU/g for all treatments. The results were compared with established microbiological standards in Brazil, and all of them met the requirements for biscuits, therefore proving to be safe for consumption.

The appearance and color of snacks from the Control, passion fruit peel flour, and spotted goatfish protein concentrate treatments were better accepted (Fig. 1). This shows that the appearance and color of snacks prepared with the addition of passion fruit peel flour and spotted goatfish protein concentrate improved when used separately. This result can be seen in Table 3, in which snacks from the spotted goatfish protein concentrate + passion fruit peel flour treatment had lower lightness (*L**

value) and greater redness (*a** value), being darker than the other treatments. Netto *et al.* (*19*) also observed lower color scores of fish snacks with a darker color. The values found by the previous authors were similar to those obtained in the present study, between 6.0 and 7.0 ("I liked it slightly"). Zim *et al.* (*45*) observed greater scores for the orange-colored snack, with a rating of "I liked it moderately" (6.0 points), while other snacks received a "slightly liked" (5.0 points) rating. Tamsir *et al.* (*41*) also found values between 6.0 and 7.0 ("I liked it slightly") in the appearance and color attributes of keropok-type snacks.

The odor of the snacks did not show a significant difference ($p>0.05$) among treatments with average scores equivalent to "I liked it slightly". This may have happened because these ingredients have a mild odor. Netto *et al.* (*19*) found similar values in the odor attribute for snacks made with mechanically separated tilapia meat, ranging from 6.53 to 6.80 ("I liked it slightly"). Zim *et al.* (*45*) obtained "I liked it slightly" evaluations for fish snacks made with a traditional formula, while snacks with added seasonings were evaluated as "I liked it moderately". Shaviklo et al. (*16*) studied the inclusion of minced fish or freeze-dried fish protein in snacks. They did not observe variation in the odor acceptance of corn snacks.

The best score regarding the texture of the snacks was those made with passion fruit peel flour. At the same time, the least rated were snacks from spotted goatfish protein concentrate and spotted goatfish protein concentrate + passion fruit peel flour treatments (Fig. 1). This may indicate that the addition of spotted goatfish protein concentrate may have damaged the texture of the snacks. This result is directly related to the expansion (Table 3), in which the PFPF treatment showed the greatest expansion, and the spotted goatfish protein concentrate and spotted goatfish protein concentrate + passion fruit peel flour treatments showed the lowest expansion. Netto *et al.* (*19*) reported a decrease in the sensory acceptance of the texture attribute with an increase in the percentage of inclusion of tilapia mechanically separated meat in snacks. The values found by the researchers ranged from 5.6 (40 % addition) to 7.6 (20 % addition). Tamsir *et al.* (*41*) found higher texture score values for keropok-type snacks fried in oil, between 5.0 and 6.0 ("neither like/dislike").

The best flavor result was for the treatment with the addition of passion fruit peel flour, while the least rated was in spotted goatfish protein concentrate + passion fruit peel flour (Fig. 1). This may indicate that the addition of spotted goatfish protein concentrate worsened the taste of the snacks, which may be related to the fish flavor not being common in Brazilian snacks, causing lower acceptance. Netto *et al.* (*19*) observed a decrease in the sensory acceptance of the flavor attribute with the increase of tilapia mechanically separated meat in snacks (inclusion from 20 to 40 %). Zim *et al.* (*45*) obtained "I liked it slightly" (5 points) evaluations for fish snacks made with a traditional formula. In comparison, snacks with added seasonings were evaluated as "I liked it moderately" (6

points). Tamsir *et al.* (*41*) found values between 6.0 and 7.0 (“I liked it slightly”) in the flavor attribute for keropok-type snacks fried in oil.

The overall acceptance of snacks showed better results in the control treatment or the one with the addition of passion fruit peel flour. However, the combination of spotted goatfish protein concentrate and passion fruit peel flour or only spotted goatfish protein concentrate was the least accepted (Fig. 1). Netto *et al.* (*19*) reported a decrease in global acceptance with the inclusion of 20 to 40 % of tilapia mechanically separated meat in snacks. The values reported by the researchers varied between 5.9 (40 % addition) to 7.0 (20 % addition). Zim *et al.* (*45*) obtained “I liked it slightly” (5 points) evaluations for fish snacks made with a traditional formula. In comparison, snacks with added seasonings were evaluated as “I liked it moderately” (6 points). Tamsir *et al.* (*41*) found values between 6.0 and 7.0 (“I liked it slightly”) in the global acceptance attribute for keropok-type snacks made by frying in oil. However, comparing sensory analysis results obtained by tasters from different countries is very difficult due to the subjectivity of this type of analysis. In addition to cultural differences between panelists, other factors such as the type of seasoning and salt content determine the panelists' acceptance.

The control and the passion fruit peel flour treatments were preferred for the ordering (preference) test (Table 5). This result can be improved by decreasing the amount of spotted goatfish protein concentrate and passion fruit peel flour included in the formulation, and also by adding some seasonings, which could improve acceptability.

CONCLUSIONS

Fortification with spotted goatfish protein concentrate improved the nutritional quality and increased the protein concentration of snacks. However, there was lower expansion and lower acceptance of the texture of the snacks. The addition of passion fruit peel flour generated technological gains in the snacks by improving their expansion. The developed snacks were moderately accepted by consumers. The scientific contribution of this study constitutes the improvement of snacks using co-products from the fish and juice industries, generating a product with improved nutritional quality concerning protein and fiber. In addition, the use of agricultural waste fits with improved sustainability.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

A.B. Benevides contributed to the design and execution of the experiment, processing and interpreting the data, preparing the manuscript, and writing and revising the manuscript. R.P.C. Amaral contributed to the design and execution of the experiment, the processing and interpretation of the data, and the writing of the manuscript. E.D.C. Silva contributed to the design and execution of the experiment, the processing and interpretation of the data, and the writing of the manuscript. M.I.S. Maciel contributed to interpreting the data and writing and revising the manuscript. N.K.S. Shinohara contributed to the design and execution of the experiment, the interpretation of the data, and the writing and revising of the manuscript. M.B.A. Gloria contributed to interpreting the data and writing and revising the manuscript. P.R.C. Oliveira Filho contributed to the design of the experiment, data interpretation, writing, and revising the manuscript.

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Table 1. Formulations to produce snacks without (Control) and with spotted goatfish protein concentrate and/or passion fruit peel flour

Ingredient	Treatment			
	Control	Spotted goatfish protein concentrate	Passion fruit peel flour	Spotted goatfish protein concentrate and passion fruit peel flour
			m/g	
Sour cassava starch	593.4	563.4	581.4	551.4
Corn meal	395.6	375.6	387.6	367.6
Spotted goatfish protein concentrate (5.0 %)	-	50.0	-	50.0
Passion fruit peel flour (2.0 %)	-	-	20.0	20.0
Salt (1.0 %)	10.0	10.0	10.0	10.0
Black pepper (0.1 %)	1.0	1.0	1.0	1.0
Total	1000.0	1000.0	1000.0	1000.0

Table 2. Proximate composition, caloric value, water activity, and CIE *L**, *a**, *b** color characteristics of the passion fruit peel flour and spotted goatfish protein concentrate

Parameter	Passion fruit peel flour	Spotted goatfish protein concentrate
w/(g/100 g):		
Moisture	10.66±0.20	3.61±0.17
Protein	5.67±0.20	81.90±0.66
Lipid	2.26±0.08	7.93±1.21
Ash	6.08±0.20	3.02±0.10
Carbohydrate	74.6±0.26	3.43±0.50
E/(kcal/100 g)	341.44±0.31	412.67±7.19
a_w	0.63±0.00	0.50±0.01
*L**	74.04±2.08	58.61±2.10
*a**	4.00±0.25	3.54±0.41
*b**	28.29±0.19	29.50±0.61

Table 3. CIE Lab color characteristics (*L**, *a**, and *b**) before and after frying and expansion of fried snacks made without (control) and with spotted goatfish protein concentrate and/or passion fruit peel flour

Parameter	Treatment			
	Control	Spotted goatfish protein concentrate	Passion fruit peel flour	Spotted goatfish protein concentrate and passion fruit peel flour
Before frying:				
*L**	(63.17±5.33)^{a}	(65.05±1.97)^{a}	(64.36±3.46)^{a}	(58.17±1.84)^{a}
*a**	(-0.90±1.06)^{b}	(2.50±0.26)^{a}	(3.16±0.61)^{a}	(4.00±0.27)^{a}
*b**	(34.27±4.90)^{a}	(33.54±1.70)^{a}	(33.59±3.67)^{a}	(30.54±0.75)^{a}
After frying:				
*L**	(72.53±2.46)^{a}	(64.77±1.16)^{b}	(63.14±1.38)^{b}	(59.63±2.72)^{b}
*a**	(-1.87±0.42)^{b}	(2.36±1.49)^{a}	(3.15±0.64)^{a}	(4.36±0.54)^{a}
*b**	(26.60±1.61)^{b}	(32.22±2.25)^{ab}	(31.95±2.59)^{ab}	(33.58±2.10)^{a}
Expansion/%	(13.45±3.42)^{b}	(3.23±0.28)^{c}	(23.42±8.01)^{a}	(3.52±0.95)^{c}

Results are expressed as mean value±standard deviation, *N*=3. Different superscript letters on the row indicate a significant difference according to the Tukey's test ($p<0.05$)

Table 4. Proximate composition, caloric value, and water activity of fried snacks made without (control) and with spotted goatfish protein concentrate and/or passion fruit peel flour

Parameter	Treatment			
	Control	Spotted goatfish protein concentrate	Passion fruit peel flour	Spotted goatfish protein concentrate and passion fruit peel flour
w(g/100g):				
Moisture	(7.34±0.77)^{a}	(6.54±0.24)^{a}	(6.08±0.39)^{a}	(6.72±0.24)^{a}
Ash	(0.84±0.14)^{ab}	(0.93±0.06)^{a}	(0.67±0.09)^{b}	(1.01±0.07)^{a}
Protein	(2.16±0.42)^{b}	(5.50±0.73)^{a}	(2.31±0.48)^{b}	(5.69±0.21)^{a}
Lipid	(16.13±2.24)^{a}	(11.79±1.79)^{a}	(13.50±2.00)^{a}	(7.07±1.42)^{b}
Carbohydrate	(73.46±2.87)^{a}	(75.18±2.52)^{a}	(77.40±1.96)^{a}	(79.44±1.67)^{a}
E/(kcal/100 g)	(447.67±9.96)^{a}	(428.86±8.85)^{a}	(440.32±9.26)^{a}	(404.12±6.97)^{b}
a_w	(0.58±0.01)^{a}	(0.58±0.01)^{a}	(0.56±0.01)^{a}	(0.56±0.00)^{a}

Results are expressed as mean value±standard deviation, *N*=3. Different superscript letters on the row indicate a significant difference according to the Tukey's test ($p<0.05$)

Table 5. Ordering test (preference) of snacks made without (control) or with spotted goatfish protein concentrate and/or passion fruit peel flour

Treatment	Preference
Control	(175.00±1.10)^{a}
Spotted goatfish protein concentrate	(143.00±1.10)^{b}
Passion fruit peel flour	(188.00±1.04)^{a}
Spotted goatfish protein concentrate and passion fruit peel flour	(124.00±0.97)^{c}

Different superscript letters in the same column indicate significant differences (Tukey's test, $p<0.05$)

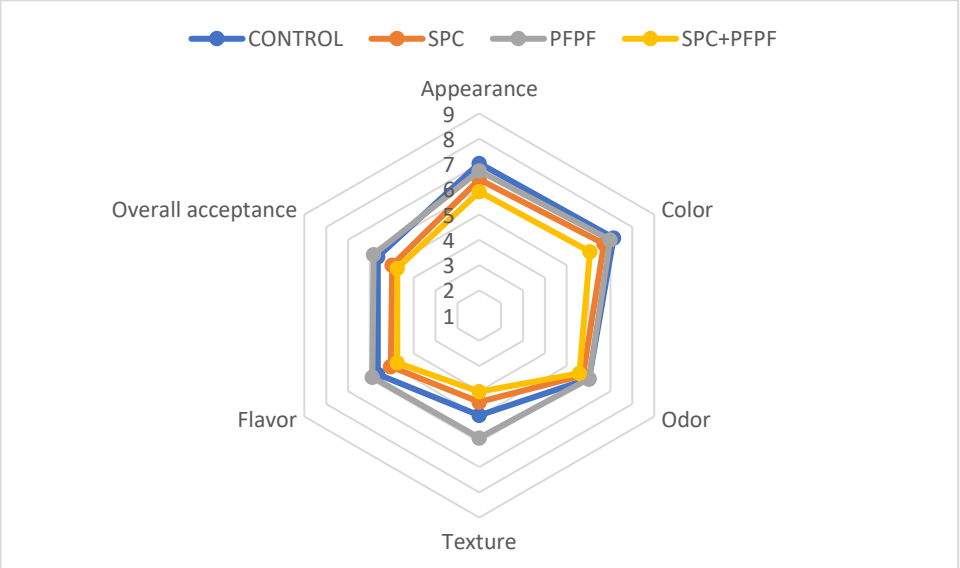

Fig. 1. Radar graph of the sensory evaluation of snacks made without (control) and with spotted goatfish protein concentrate (SPC) and/or passion fruit peel flour (PFPF)