www.foodandfeed.fins.uns.ac.rs
FOOD AND FEED RESEARCH
Journal of the Institute of Food Technology – FINS
University of Novi Sad
ISSN
2217-5369
(print version ceased in 2023)
2217-5660 (online)

UDK 613.2:616.34]:637.56
Original research paper
DOI: 10.5937/ffr0-58136

DEVELOPMENT AND CHARACTERIZATION OF FISH MEATBALLS PREPARED WITH MECHANICALLY SEPARATED MEAT OF AMAZON HYBRID SORUBIM COATED WITH SAFFLOWER FLOUR AT DIFFERENT GRANULOMETRIES

Angela Dulce Cavenaghi-Altemio[1], Gustavo Graciano Fonseca[*2]

[1]Federal University of Grande Dourados, Faculty of Engineering, Laboratory of Food Technology, Rodovia Dourados-Itahum km 12, 79825-070 Dourados, Brazil
[2]University of Akureyri, Faculty of Natural Resource Sciences, School of Business and Science, Borgir v. Nordurslod, 600 Akureyri, Iceland

Abstract: The aim of this work was to develop a food alternative for consumers with celiac disease. Thus, fish meatballs were prepared from mechanically separated meat of Amazon hybrid sorubim (*Pseudoplatystoma reticulatum* x *Leiarius marmoratus*) and breaded with gluten-free safflower flour at two granulometries and characterized. Three treatments were evaluated: wheat flour (control) (T1), safflower at mesh 8 (T2), and safflower at mesh 14 (T3). Characterization was conducted through chemical, physical, microbiological, and sensory analyses. The moisture content of T1 (67.89%) was significantly higher ($p<0.05$) than T2 and T3. There was no significant difference ($p>0.05$) between treatments for protein content (10.85-11.60%). All treatments differed from each other in lipid and ash contents, the prior being higher for T2 (15.89%) and the former for T1 (1.53%). For crude fiber content, there was no difference ($p>0.05$) between T2 and T3, but statistically higher ($p<0.05$) than T1 (5.06%). Meatballs breaded with safflower flour (T2 and T3) presented significantly higher ($p<0.05$) pick-up values and shear force compared to those breaded with wheat flour (T1). These were related to the granulometry of the flour. The much statistically higher ($p<0.05$) redness (a*) observed for T2 and T3 was related to the presence of pigments bind to polysaccharides from flour. The panel mean scores (5.36–7.64) indicate sensory responses spanning indifference to moderate–high liking on the hedonic scale. Samples T2 and T3 presented acceptance indexes above 70% and T1 above 80%. The safflower-flour breading produced a darker color and an increased bitterness that reduced overall sensory appeal relative to the commercial wheat-flour coating, as reflected by lower sensory scores, acceptance index, and purchase-intent ratings. Hence, it is recommended to refine the formulations using alternative ingredients to address these sensory challenges.

Key words: *food alternative, celiac disease, breading, fish valorization*

INTRODUCTION

Sorubins are freshwater fish of considerable commercial importance in Brazil, prized for their high-quality meat, which features a light color, mild flavor, and minimal bone content. Their popularity is evident in the multitude of regional recipes that celebrate the distinct qualities of their meat (Faustino, Nakaghi, Marques, Ganeco & Makino, 2010; Cavenaghi-Altemio, Macedo, Chaves & Fonseca, 2023). Moreover, the by-products generated during their processing can be utilized to produce mechanically separated meat (MSM), a versatile raw material used in value-added products such as fishburgers, meatballs, sausages, and

Corresponding author: Phone: +354 4608000
E-mail address: gustavo@unak.is

breaded products, making them a valuable resource for minimizing fish waste (Marengoni et al., 2009; Palmeira, Mársico, Monteiro, Lemos & Conte Junior, 2015; Adrah & Tahergorabi, 2022).

Meatballs are a traditional culinary delight, typically crafted from a blend of ground meat or fish, mixed with other ingredients, shaped into spherical form, and then either simmered in hot water or fried in oil until cooked (Andhikawati & Akbarsyah, 2021). While meatballs can be sourced from various livestock meats such as beef, pork, chicken, or fish, beef is often favored for its robust flavor, enticing aroma, and hearty texture.

However, it is worth noting that beef may not always be the healthiest option due to its higher saturated fatty acid content, which can contribute to elevated blood cholesterol levels and increase the risk of conditions such as atherosclerosis (hardening and narrowing of the arteries) and coronary heart disease (blockages in the arteries that supply blood to the heart) (Al-Shaar et al., 2020). Conversely, fish-based meatballs offer a healthier alternative, boasting a nutritional profile rich in essential amino acids, beneficial fatty acids, vitamins, and minerals (Renwarin, Tiven, & Liur, 2022).

Breaded products are industrially processed meat items crafted from various animal species, mixed with ingredients, shaped or left unshaped, and coated with a suitable covering (Brazil, 2001). These products boast prolonged shelf life compared to raw meat, as they exhibit reduced oxidation and rancidity. Additionally, the coating offers protection against burning and dehydration during freezing (Neira, Agustinelli, Ruseckaite & Martucci, 2019). The coating process for breaded products typically involves three layers: a pre-flouring layer (predust), a batter layer (suspension of solids in liquid), and a final coating of breadcrumbs. The sequence and quantity of these layers may vary, each serving a specific function in the final product (Varela & Fiszman, 2011; Belusso, Nogueira, Breda, & Mitterer-Daltoé, 2016).

Celiac disease is a well-known form of food intolerance associated with gluten-containing products like wheat, rye, barley, and oats. Symptoms include diarrhea and malnutrition due to nutrient malabsorption resulting from intestinal mucosa atrophy. With gluten elimination, mucosal recovery occurs, restoring digestive and absorption capacities. As there is no cure for celiac disease, gluten-free products are essential for improving celiacs' quality of life. Technological advancements in gluten-free baking have yielded products with favorable sensory attributes and high nutritional value (Wang, Lu, Li, Zhao & Han, 2017). Rice flour, among other gluten-free alternatives like corn flour and cassava flour, is favored for its low glycemic index, providing gradual carbohydrate absorption and increased satiety (Heisler, Antônio, Moura, Mendonça & Granada, 2008).

Safflower (*Carthamus tinctorius* L) is a medicinal plant rich in linoleic acid, extracted mainly from its seeds. It has therapeutic properties, including weight management, cholesterol reduction, antibacterial, anti-inflammatory, and anticancer effects. Safflower is also beneficial for treating gynecological diseases, osteoporosis, cardiovascular, and neurological conditions (Asgary, Rahimi, Mahzouni & Madani, 2012), and its flour does not contain gluten (Saleh, 2023).

Thus, the aim of this work was to develop breaded fish meatballs using MSM from Amazon hybrid sorubim (*Pseudoplatystoma reticulatum* x *Leiarius marmoratus*), incorporating gluten-free safflower flour at two granulometries, and to assess their physical, chemical, microbiological, and sensory characteristics, to provide an alternative food for consumers with celiac disease.

MATERIALS AND METHODS

Mechanically separated meat (MSM) of hybrid sorubim

Amazon hybrid sorubim (*P. reticulatum* x *L. marmoratus*) carcasses were supplied by a local fishery processing plant. They were transported to the laboratory under refrigerated conditions and immediately utilized to produce MSM. The MSM was produced in 3 mm particle size using a meat-bone separator (HT 250, High Tech, Brazil), operating at inlet 6 °C and outlet 10 °C, following the procedure outlined by Cavenaghi-Altemio, Ferreira and Fonseca (2020).

Table 1.
Treatments used to coat the fish meatballs prepared from mechanically separated meat of hybrid sorubim

Treatment	Predust	Batter	Breading
T1	Wheat flour	Wheat flour	Wheat flour
T2	Maize flour	Diluted maize flour	Safflower flour (mesh 8)
T3	Maize flour	Diluted maize flour	Safflower flour (mesh 14)

Fish meatballs

The fish meatballs were formulated by mixing the ingredients in the following composition (%, w/w): MSM of hybrid sorubim, 95.80; sodium chloride, 1.5; spice mixtures, 1.2; ascorbic acid, 0.5; soy protein concentrate, 0.5; and sodium polyphosphate, 0.5, and then allowed to rest for 24 h under refrigeration. Portions of 35 g were weighed, molded, and breaded, as shown in Table 1. The samples were stored in polyethylene bags under freezing conditions for 36 h and then thawed for 12 h at 4 °C prior to analyses. Covering flour and commercial liquid breading were supplied by Baptistella. Maize flour (flake type) and wheat flour were purchased from local commerce (Dourados, MS). Safflower flour was obtained from safflower seeds donated by local producers; the seeds were ground in an industrial blender and sieved using a sieve shaker, with mesh sizes 8 (2.36 mm) and 14 (1.18 mm) used for treatments T2 and T3, respectively (Table 1). In industrial production, breaded products are often briefly pre-cooked in oil to fix the coating layers and improve adhesion before freezing. In this study, the breaded fish meatballs were stored frozen without pre-cooking to allow comparison of coating treatments under standardized conditions.

Chemical analysis

Moisture, crude protein, lipid, crude fiber, and ash contents of the breaded fish meatballs made with MSM of hybrid sorubim were determined in triplicate according to the methods described by AOAC (2012). Moisture content was determined by the oven drying method at 105 °C until constant weight (method 950.46), protein content by the Kjeldahl method (method 928.08), lipid content by the Soxhlet method (method 996.06), crude fiber content by chemical digestion (method 978.10), and ash content by using the muffle oven technique (method 920.153). Carbohydrate content was determined by difference using Eq. 1.

$$Carbohydrate\ (\%) = 100 - [Moisture\ (\%) + Crude\ Protein\ (\%) + Lipid\ (\%) + Crude\ Fiber\ (\%) + Ash\ (\%)] \quad (1)$$

Analyses were performed on fried samples prepared under the same conditions as for the sensory evaluation (fried in soybean oil at 180 °C for 3 min), so the results reflect the composition of the products as ready for consumption. The amount of oil absorbed during frying was not specifically measured.

Microbiological analysis

Microbiological analyses on the raw fish meatballs made with MSM of hybrid sorubim were carried out for thermo-tolerant coliforms at 45 ºC, coagulase-positive Staphylococcus, and *Salmonella* sp., following the procedures established by the USDA/FSIS (2019).

Physical analysis

Breading yield (pick-up)

During the breading process, the breaded fish meatballs were weighed prior to breading (initial weight) and after the breading (final weight) for the calculation of the cover yield given by Eq. 2.

$$Breading\ yield\ (\%) = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Final weight}} x100 \quad (2)$$

Shear force

Texture analysis of fried fish meatballs was carried out using a texture analyzer Model TA.XTplus (Stable Micro Systems, Surrey, England) calibrated with a standard weight of 5 kg. Samples were nearly spherical in shape, with a mean diameter of 3.3-3.5 cm.

They were kept at 2 °C and were equilibrated to room temperature (28-30 °C) before analysis and then placed onto the texture analyzer platform to conduct the cutting/shearing test (speed of 1.0 mm/s, distance of 30 mm) using a Warner-Bratzler (*Knife-Guillotine*) shear blade (1 mm thick) to determine the shear force (N). A total of 50 replicates of each treatment were analyzed (Kang & Chen, 2015).

Instrumental color

The color parameters [CIE L*(lightness), a* (redness), b* (yellowness)] of the fried fish meatballs prepared with MSM from hybrid

sorubim were evaluated using a colorimeter (Minolta Chroma Meter CR 410), with measurements standardized with respect to the white calibration plate (Jiménez & Gutiérrez, 2001). Five readings were taken on the surface of the samples for each treatment. Color differences (Δ) were calculated to allow a numerical comparison between the sample and the standard. The total color variation (ΔE) was expressed according to Eq. 3:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (3)$$

where: ΔL*, Δa*, and Δb* represent the differrences between the L*, a*, and b* values of the sample and the reference, i.e., ΔL* = L*sample – L*reference, Δa* = a*sample – a*reference, and Δb* = b*sample – b*reference, respecttively. Negative or positive signs indicate the direction of the shift (darker/lighter, greener/redder, bluer/yellower), whereas the total color difference (ΔE*) is always non-negative, as it reflects only the magnitude of the difference.

Sensory analysis

Sensory analyses of the fried fish meatballs elaborated with MSM of hybrid sorubim were conducted by 50 non-trained panelists. A nine-point hedonic scale (9=like extremely; 1=dislike extremely) was used for evaluation of the attributes color, odor, taste, and overall acceptability. Samples with 40 mm diameter were fried in soybean oil at 180 ºC for 3 min, stored in a styrofoam box coated with aluminum foil for temperature maintenance, and presented in monadic form, randomly coded with three digits. In the same sheet, the purchase intention was evaluated using a 5-point scale, where 5 = certainly would purchase, 4 = probably would purchase, 3 = perhaps would purchase / perhaps would not purchase, 2 = probably would not purchase and 1 = certainly would not purchase, which was expressed as the percentage of total score. For frequency of consumption of commercial breaded products, a 5-point scale was utilized, where 5 = weekly, 4 = 2 to 4 times a week, 3 = fortnightly, 2 = monthly, and 1 = rarely (Cavenaghi-Altemio, Hashinokuti, Albuquerque & Fonseca, 2018).

In addition to the hedonic and purchase intention evaluations, panelists were asked to provide descriptive comments on the samples, including perceptions of color, taste, and overall characteristics, to gain qualitative insights into their sensory experiences.The acceptance index (AI) was calculated for color, taste, and overall acceptance, according to Eq. 4. The sample was considered accepted if the value was greater than 70% (Stone & Sidel, 2004).

$$AI\ (\%) = \frac{\text{Average of the attributed grades}}{\text{Maximum attributed grade}} x100 \quad (4)$$

Approval of the Ethical Committee for the sensory analysis from the Federal University of Dourados was obtained to perform sensory analysis (number 3.316.959; project Acceptance of fish at different educational levels (Aceitabilidade de peixe em diferentes faixas de escolaridade)).

Statistical analysis

Statistical results were evaluated through analysis of variance (ANOVA) and the Tukey's test for comparison of means, at a level of 5% of significance, using the statistical software Statistica® 7.0. The sensory attributes, the purchase intention, and the consumption frequencies were analyzed in percentage.

RESULTS AND DISCUSSION

Chemical analysis

The results of the proximate composition of the breaded fish meatballs are shown in Table 2. The moisture content of T1 (67.89%) was significantly higher ($p<0.05$) than T2 and T3. There was no significant difference ($p>0.05$) in the protein contents (10.85-11.60%) among the samples from different treatments. All treatments differed significantly for lipid and ash contents, with T2 exhibiting the highest lipid content (15.89%) and T1 the highest ash content (1.53%). For crude fiber, there was no difference ($p>0.05$) between T2 and T3, being statistically higher ($p<0.05$) than T1 (5.06%).

Literature reports 58.20-59.35% moisture for sorubim (*Pseudoplatystoma corruscan*) nuggets (Silva, Bonnas, & Silva, 2015), 56.08% for mandi-pintado (*Pimelodus britskii*) nuggets (Veit et al., 2011), and 63.68% for pacu (*Piaractus mesopotamicus*) and 65.84% for jundia (*Rhamdia quelen*) breaded steaks (Cortez Netto et al., 2010).

The values obtained here were closely related to these reported values due to the relation between the Amazon hybrid sorubim and these species. The higher value observed for T1 can be attributed to the wheat flour's higher capacity to bind water from the MSM. The wheat flour coating of the fish meatballs forms a viscoelastic dough with charge density of gluten

Table 2.
Proximate composition of breaded fish meatballs prepared with mechanically separated meat of hybrid sorubim

Parameter (%)	Treatment		
	T1	**T2**	**T3**
Moisture	$67.89^{a} \pm 0.33$	$58.47^{b} \pm 0.56$	$60.39^{b} \pm 1.29$
Protein	$10.85^{a} \pm 0.01$	$11.60^{a} \pm 0.1$	$11.15^{a} \pm 0.01$
Crude fiber	$5.06^{b} \pm 0.11$	$12.13^{a} \pm 0.58$	$10.94^{a} \pm 0.66$
Lipids	$13.36^{c} \pm 0.06$	$15.89^{a} \pm 0.03$	$15.47^{b} \pm 0.40$
Ash	$1.53^{a} \pm 0.01$	$1.26^{b} \pm 0.01$	$1.50^{c} \pm 0.01$
Carbohydrates	1.31	0.65	0.55

Mean±St. dev. ^{a,b,c}Means with the same letter in a row do not differ statistically at 5% (p>0.05). Treatments (T1, T2 and T3) according to Table 1

proteins, and the water-soluble pentosans in wheat flour, water from the MSM due to its large molecular size and low improving water retention and rheological characteristics of the products (Román-Gutiérrez, Guilbert, & Cuq, 2002; Carillo-Navas et al., 2016).

Brazilian legislation requires a minimum of 10% protein in breaded products (Brazil, 2001), which was achieved by all treatments. Much higher protein values were obtained for pacu (20.45%) and jundia (20.09%) breaded steaks (Cortez Netto et al. 2010).

However, the values were much closer to those reported for sorubim nuggets (13.18-13.74%) (Silva et al., 2015) and maldi-pintado nuggets (14.67%) (Veit et al., 2011). Thus, beyond the differences between fish species, the different values can also be explained by the addition of different concentrations of other ingredients in the formulations. All formulations in the present investigation were free from added non-meat protein ingredients.

The difference in fiber content in T1 was evident because despite the fiber content of whole-grain wheat ranges is concentrated in the bran, thus most of the fibers are removed in the milling process and largely absent in refined flour (Baba & Malik, 2018), while the crude fiber content of safflower leaves ranges from 8.77 to 9.58% (Kumar, Kuna, Padmavathi, Rani & Sarkar et al., 2016).

The statistical differences observed for the lipid content may be explained by the use of safflower flour breading in T2 and T3, which has higher lipid content than wheat flour, whereas T1, containing wheat flour, has a lower lipid content in its composition. However, all treatments presented levels of lipids higher than the lipid content (8.80-8.95%) of sorubim nuggets in the study by Silva et al. (2015).

Literature reports ash contents of 2.7% for mandi-pintado nuggets (Veit et al., 2011) and in the range of 0.87-0.88% for sorubim nuggets (Silva et al., 2015). The observed variations in ash content between the present formulations and those reported in other studies are likely attributable to differences in the mineral composition of the breading flours employed.

Physical analysis

It was observed that products breaded with safflower flour (T2 and T3) presented statistically higher ($p<0.05$) pick-up values compared to those breaded with wheat flour (T1) (Table 3). This phenomenon arises from the fact that coarser particles exhibit more irregular surfaces, offering larger areas for adhesion to the food surface. Consequently, they can create a thicker and more textured coating on the food surface, leading to higher pick-up values. Conversely, finer particles result in a smoother coating (Hera, Talegón, Caballero & Gómez, 2013). However, given that mesh 8 (T2) retains larger particles than mesh 14 (T3), it would be expected to also observe a higher pick-up for T2 in comparison to T3. Fish meatballs coated according to T2 and T3 exhibited the highest average shear force values (Table 3).

The variability in shear force can be attributed to the granulometry of the flour. This is because the size and shape of flour particles impact their ability to adhere to the surface of the food being coated. Finer particles tend to adhere more tightly and uniformly, enhancing the adhesion of the breading to the food item (Maskat & Kerr, 2004; Pang, Guan, Yang, Li & Bian, 2021). As a result, a smoother and more consistent texture with reduced variation in shear force may be achieved.

Table 3.
Pick-up, shear force, and instrumental color of breaded fish meatballs prepared with mechanically separated meat of hybrid sorubim

Response	Treatments		
	T1	T2	T3
Pick-up (%)	$44.57^{b} \pm 2.20$	$54.37^{a} \pm 2.56$	$53.94^{a} \pm 2.01$
Shear force (N)	$2.35^{b} \pm 0.46$	$5.55^{a} \pm 1.03$	$5.61^{b} \pm 1.16$
L*	$31.89^{b} \pm 2.78$	$39.29^{a} \pm 2.34$	$41.13^{a} \pm 0.69$
a*	$9.53^{b} \pm 1.59$	$14.56^{a} \pm 0.15$	$13.77^{a} \pm 0.72$
b*	$17.19^{a} \pm 2.70$	$16.58^{a} \pm 2.23$	$19.93^{a} \pm 3.61$
ΔE*	-	$9.04^{a} \pm 1.60$	$10.64^{a} \pm 2.72$

L: lightness; a*: redness, b*: yellowness, ΔE*: color difference. Mean±St. dev. [a,b]Means with the same letter in the same line do not differ statistically at 5% (p>0.05). Treatments (T1, T2 and T3) according to Table 1*

Additionally, the moisture absorbed by finer particles contributes to maintaining a softer texture and lower shear force (Hera et al., 2013; Burešová et al., 2023). Consequently, products coated with larger particle size flour (T2 and T3) exhibited higher shear force values and, consequently, greater crispiness (Maskat & Kerr, 2002) compared to T1, which was coated with finely ground wheat flour. While the type and particle size of the coating flour clearly influence surface texture, it is acknowledged that the internal structure ('body') of the meatballs may also affect shear force. However, since all treatments were prepared with the same MSM formulation and shaping procedure, the observed differences are likely predominantly due to the characteristics of the coating.

In terms of color, it could be expected that T1 would exhibit lower lightness compared to T2 and T3, as finer flour typically forms a more compact coating, reducing oil absorption and yielding a lighter, less greasy final product (Brannan et al., 2014). However, the results (Table 3) showed that T2 and T3 had slightly higher lightness (L*) values than T1 ($p<0.05$).

This may be due to the uniformity achieved in the particle size distribution, which ensured consistency throughout the breading process and resulted in a more uniform appearance across all portions of the food item (Sarkar & Fu, 2022). Additionally, the higher redness (a*) observed for T2 and T3 can be attributed to the presence of carthamin, the pigment responsible for the red color in safflower, which remains stable when bound to polysaccharides during flour processing (Kim et al., 2015). The yellowness (b*) did not differ significantly ($p>0.05$) between treatments (Table 3). Moreover, the overall color difference (ΔE*) relative to the control (T1) indicated that T2 and T3 were both significantly different from T1 but not from each other ($p<0.05$). This suggests that while lightness and redness changed slightly, the total color change was moderate and comparable between T2 and T3, reflecting only small perceptible differences in the final product.

Microbiological analysis

Microbiological analyses for coliforms at 45 ºC, coagulase-positive Staphylococci (CPS), and *Salmonella* sp. were performed on the fish meatballs to ensure food safety for the panelists prior to conducting the sensory analysis (Table 4).

The results of the microbiological analysis showed no significant differences between T1, T2, and T3. All treatments complied with the limits established by the Brazilian Health Surveillance Agency (Brazil, 2019), which sets maximum tolerances of 10^2 CFU/g for coliforms at 45 ºC, 5×10^2 CFU/g for coagulase-positive Staphylococci, and requires the absence of *Salmonella* sp. These results indicate that appropriate hygienic-sanitary practices were followed at all stages of handling and processing.

Sensory analysis

The means and standard deviations for the sensory attributes of color, odor, taste, and overall acceptance of the fish meatballs by the acceptance test are expressed in Table 5. All the sensory attributes evaluated were statistically higher ($p<0.05$) for T1 in comparison to T2 and T3. The latter two treatments did not present statistical difference ($p<0.05$) between them.

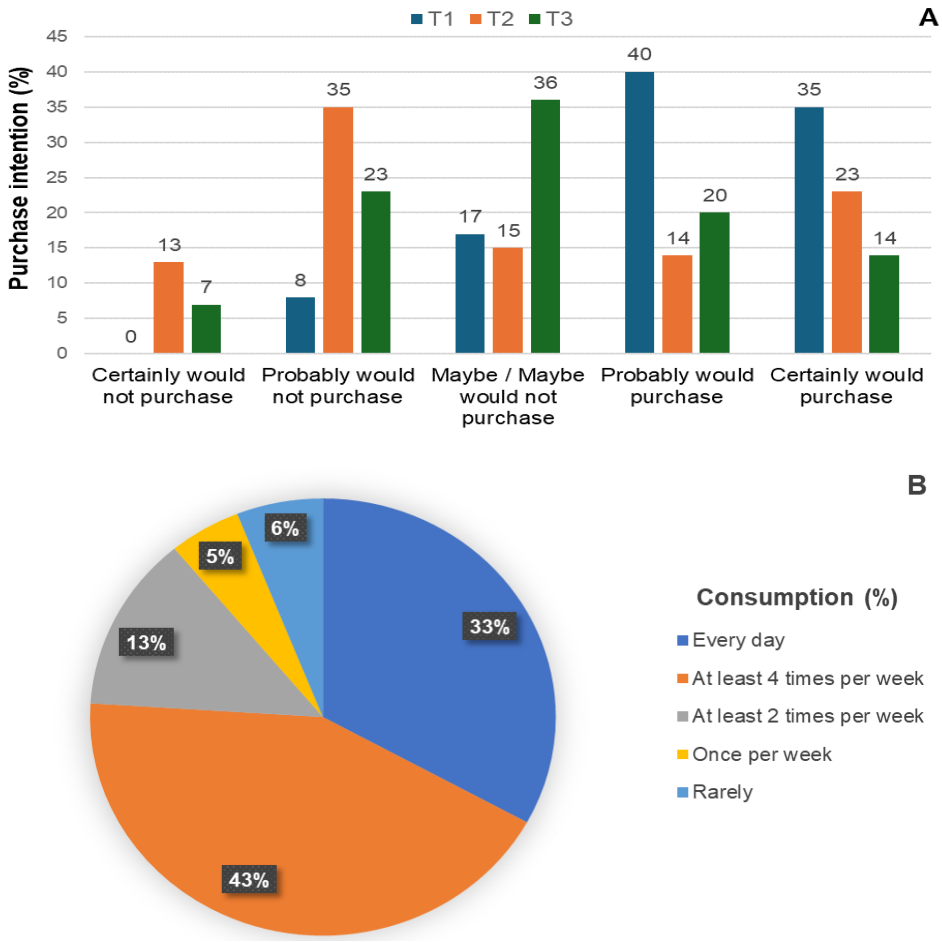

Figure 1. Purchase intention (%) of breaded fish meatballs made with MSM of hybrid sorubim (A) and frequency of consumption (%) of breaded products (B). Treatments (T1, T2 and T3) according to Table 1

The average scores of the sensory attributes of all treatments varied from 5 (neither like not dislike) to 8 (liked very much) on the hedonic scale, in an average range of 5.36 to 7.64. All treatments presented acceptance indexes above 70% for T2 and T3, and above 80% for T1 (Table 5).

Fig. 1A shows the percentage of the purchase intention frequencies of the fish meatballs. T1 had the highest percentage of purchase intention (35%) for "certainly would purchase", followed by T2 and T3. For the sum of the frequencies of the intentions "certainly would purchase" and "possibly would purchase" were 75, 37, and 34% for T1, T2, and T3, respectively, with a rejection index ranging from 0 to 13%.

Fig. 1B shows the frequency of consumption of breaded products by the judgers. It varied from rarely to every day. Most of the judges (43%) stated that they consume these products at least four times per week. Adding it to the percentage of attendance "every day", a total of 76% is obtained, indicating that most of the judgers are regular consumers.

The samples from the treatments with safflower flour (T2 and T3) were described as very dark and had a bitter taste, which explains the lower scores for attributes color, appearance, and overall acceptance for these products.

On the other hand, T1 obtained higher scores because it received a commercial coating, thus pleasing the judges, unlike treatments T2 and T3, which were covered with safflower flour that has different characteristics compared to commercial breaded products in general.

The lower average scores for the sensory attributes obtained for T2 and T3 explain the much lower purchase intentions spanning between "certainly would purchase" and "possibly would purchase" in comparison to T1.

Table 4.
Microbiological analyses of the breaded fish meatballs prepared with mechanically separated meat of hybrid sorubim

Microbiological analyses	Treatments		
	T1	T2	T3
Coliforms at 45 ºC (CFU/g est.)	$<5.0 \times 10^2$	$<5.0 \times 10^2$	$<5.0 \times 10^2$
Coagulase positive Staphylococci	Negative	Negative	Negative
Salmonella sp. (in 25 g)	Absence	Absence	Absence

Treatments (T1, T2 and T3) according to Table 1. CFU: counting forming units

Table 5.
Sensory attribute scores and the acceptance indexes of breaded fish meatballs prepared from mechanically separated meat of hybrid sorubim

Sensory attributes	Treatments		
	T1	T2	T3
Color	$7.64^a \pm 0.98$ (88.6)	$5.36^b \pm 2.12$ (71.7)	$5.72^b \pm 1.54$ (78.8)
Odor	$6.72^a \pm 1.11$ (85.8)	$5.68^b \pm 1.46$ (79.5)	$5.74^b \pm 1.53$ (78.9)
Taste	$7.20^a \pm 1.31$ (84.6)	$5.38^b \pm 2.04$ (72.5)	$5.66^b \pm 1.78$ (76.1)
Overall acceptance	$7.26^a \pm 1.44$ (83.4)	$5.78^b \pm 1.68$ (77.5)	$5.60^b \pm 1.50$ (78.9)

Mean±St. dev. ^{a,b}Means with the same letter in the same line do not differ statistically at 5% ($p>0.05$). Values in parenthesis are referred to the acceptance index (%). Treatments (T1, T2 and T3) according to Table 1

However, T2 and T3 were still considered acceptable due to their acceptance indexes greater than 70% (Stone & Sidel, 2004).

Literature reports purchase intentions of 60% for pacu and 73% for jundia steaks breaded with wheat flour (Cortez Netto et al., 2010). These values are closely related to those obtained for T1. These results underline the significant influence that the choice of breading flour has on the physical and sensory characteristic of the breaded products.

CONCLUSIONS

Breaded meatballs prepared from mechanically separated meat of Amazon hybrid sorubim and coated with safflower flour present a good dietary choice for people with gluten restrictions because they are rich in protein, fiber, and lipids while low in carbohydrates; however, the safflower coating's dark color and bitter flavor were less preferred by the panelists than the commercial wheat-flour coating.

This was evident from the lower scores across sensory attributes, acceptance index, and purchase intention. Hence, it is recommended to refine the formulations using alternative ingredients to address these sensory challenges.

AUTHOR CONTRIBUTIONS

Conceptualization, A.D.C.-A.; Methodology, A.D.C.-A.; Investigation, formal analysis, validation, A.D.C.-A.; Writing-original draft preparation, review and editing, G.G.F.; Supervision, G.G.F.

DATA AVAILABILITY STATEMENT

Data contained within the article.

ACKNOWLEDGEMENTS

The authors are indebted to the Brazilian research funding agencies CNPq, CAPES and FUNDECT for their financial support.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Adrah, K., & Tahergorabi, R. (2022). Ready-to-eat products elaborated with mechanically separated fish meat from waste processing. In C. M. Galanakis (Ed.), *Sustainable Fish Production and Processing* (pp. 227–257). Cambridge: Academic Press. https://10.1016/B978-0-12-824296-4.00006-2

Al-Shaar, L., Satija, A., Wang, D. D., Rimm, E. B., Smith-Warner, S. A., Stampfer, M. J., Hu, F. B., & Willett, W. C. (2020) Red meat intake and risk of coronary heart disease among US men: prospective cohort study. *British Medical Journal*, *371*, m4141. https://doi.org/ 10.1136/bmj.m4141.

Andhikawati, A., & Akbarsyah, N. (2021). The effect of different types of fish on physical characteristic of fish meatball. *Asian Journal of Fisheries and Aquatic Research*, *13*(5), 1–6. https://doi.org/10.9734/ajfar/2021/v13i530274

AOAC (2012). Official methods of analysis of AOAC International (19th ed.). Gaithersburg: Association of Official Analytical Chemists.

Asgary, S., Rahimi, P., Mahzouni, P., & Madani, H. (2012) Antidiabetic effect of hydroalcoholic extract of *Carthamus tinctorius* L. in alloxan-induced diabetic rats. *Journal of Research in Medical Sciences*, *17*, 386–392.

Baba, A. Y., & Malik T.-H. (2018). Nutritional contents in wheat (*Triticum aestivum* L.). The ABCs of Agriculture Science (pp. 212-219). Educreation Publishing.

Belusso, A. C., Nogueira, B. A., Breda, L. S., & Mitterer-Daltoé, M. L. (2016). Check all that apply (CATA) as an instrument for the development of fish products. *Food Science and Technology*, *36*, 275–281. https://doi.org/10.1590/1678-457X.0026

Brannan, R. G., Mah, E., Schott, M., Yuan, S., Casher, K. L., Myers, A., & Herrick, C. (2014). Influence of ingredients that reduce oil absorption during immersion frying of battered and breaded foods. *European Journal of Lipid Science and Technology*, *116*(3), 240–254. https://doi.org/10.1002/ejlt.201200308

Brazil. (2001). Normative Instruction Nº. 6, from February 15th, 2001. Ministry of Agriculture, Livestock and Supply (MAPA).

Brazil. (2019). Resolution RDC ANVISA/MS (Brazilian National Health Surveillance Agency/Ministry of Health) nº. 60 of December 23rd, 2019. Technical Regulation on Microbiological Standards for Food. Brazilian Official Gazette, Brasília, DF, Brazil, December 26th, 2019. Section 1, page 133. https://in.gov.br/en/web/dou/-/instrucao-normativa-n-60-de-23-de-dezembro-de-2019-235332356

Burešová, I., Lullien-Pellerin, V., Červenka, L., Mlček, J., Šebestíková, R., & Masaříková, L. (2023). The comparison of the effect of flour particle size and content of damaged starch on rice and buckwheat slurry, dough, and bread characteristics. *Foods*, *12*(13), 2604. https://doi.org/10.3390/foods12132604

Carrillo-Navas, H., Guadarrama-Lezama, A., Vernon-Carter, E., Garcia-Diaz, S., Reyes, I., & Álvarez-Ramírez, J. (2016). Effect of gelatinized flour fraction on thermal and rheological properties of wheat-based dough and bread. *Journal of Food Science and Technology*, *53*, 3996–4006. https://doi.org/10.1007/s13197-016-2399-1

Cavenaghi-Altemio, A. D., Hashinokuti, A. A., Albuquerque, D. M., & Fonseca, G. G. (2018). Transglutaminase addition increases quality and acceptation of sausages obtained from mechanically separated meat of hybrid sorubins. *Emirates Journal of Food and Agriculture*, *30*, 952–958. https://doi.org/10.9755/ejfa.2018.v30.i11.1860

Cavenaghi-Altemio, A. D., Ferreira, R. C., & Fonseca, G. G. (2020). Evaluation of sausages obtained from mechanically separated Nile tilapia (*Oreochromis niloticus*) meat and prepared using different homogenizing and refining processes. *Meat Technology*, *61*, 145–162. https://doi.org/10.18485/meattech.2020.61.2.4

Cavenaghi-Altemio, A. D., Macedo, A., Chaves, A. P., & Fonseca, G. G. (2023). Characterization of fillets of Amazon and real hybrid sorubins. *Vitae*, *30*, 349015. https://doi.org/10.17533/udea.vitae.v30n1a349015

Cortez Netto, J. P., Boscolo, W. R., Feiden, A., Maluf, M. L. F., Freitas, M. A., & Simões, M. R. (2010). Formulation, microbiological analyses, centesimal composition and acceptability of breaded catfish (*Rhamdia quelen*), pacu (*Piaractus mesopotamicus*) and tilapia (*Oreochromis niloticus*). *Revista do Instituto Adolfo Lutz*, *69*, 181–187.

Faustino, F., Nakaghi, L. S. O., Marques, C., Ganeco, L. N., & Makino, L. C. (2010). Structural and ultrastructural characterization of the embryonic development of *Pseudoplatystoma spp.* hybrids. *International Journal of Development Biology*, *54*, 723–730. https://doi.org/10.1387/ijdb.082826ff

Heisler, G. E. R., Antônio, G. A., Moura, R. S., Mendonça, C. R. B., & Granada, G. G. (2008). Viability of substitution of wheat flour for rice flour in school meals. *Aliment Nutrition*, *19*(3), 299–306.

Hera, E., Talegón, M., Caballero, P., & Gómez, M. (2013). Influence of maize flour particle size on gluten-free breadmaking. *Journal of the Science of Food and Agriculture*, *93*(4), 924–932. https://doi.org/10.1002/jsfa.5826

Jiménez, A., & Gutiérrez, G. C. (2001). Color. In J. D. Alvarado & J. M. Aguilera (Eds.), *Métodos para medir propiedades físicas en industrias de alimentos* (pp. 325-346). Zaragoza: Editorial Acribia S.A.

Kang, H. -Y., & Chen, H. -H. (2015). Improving the crispness of microwave-reheated fish nuggets by adding chitosan-silica hybrid microcapsules to the batter. *LWT - Food Science and Technology*, *62*(1), 740–745. https://doi.org/10.1016/j.lwt.2014.04.029

Kim, H. -W., Hwang, K. -E., Song, D. -H., Kim, Y. -J., Ham, Y. -K., Lim, Y. -B., Jeong, T. -J., Choi, Y. -S., & Kim, C. -J. (2015). Wheat fiber colored with a safflower (*Carthamus tinctorius* L.) red pigment as a natural colorant and antioxidant in cooked sausages. *LWT - Food Science and Technology*, *64*(1), 350–355. https://doi.org/10.1016/j.lwt.2015.05.064

Kumar, E. S., Kuna, A., Padmavathi, P., Rani, C. V. D., & Sarkar, S. (2016). Nutrient composition of selected cultivars of safflower (C*arthamus tinctorius* L.) leaves during different crop growth stages: *Journal of Oilseeds Research*, *33*(4). https://doi.org/10.56739/jor.v33i4.137867

Marengoni, N., Pozza, M., Braga, G., Lazzeri, D., Castilha, L., Bueno, G. W., Pasquetti, T. J., & Polese, C. (2009). Centesimal, microbiological, and sensory characterization of fishburgers made with mechanically separated meat of tilapia. *Revista Brasileira de Saúde na Produção Animal*, *10*(1), 168–176. http://revistas.bvs-vet.org.br/rbspa/article/view/13248/14116

Maskat, M. Y., Kerr, W. L. (2002). Coating characteristics of fried chicken breasts prepared with different particle size breading. *Journal of Food Processing and Preservation*, *26*(1), 27–38. https://doi.org/10.1111/j.1745-4549.2002.tb00475.x

Maskat, M. Y., & Kerr, W. L. (2004). Effect of breading particle size on coating adhesion in breaded, fried chicken breasts. *Journal of Food Quality*, *27*(2), 103–113. https://doi.org/10.1111/j.1745-4557.2004.tb00641.x

Neira, L. M., Agustinelli, S. P., Ruseckaite, R. A., & Martucci, J. F. (2019). Shelf life extension of refrigerated breaded hake medallions packed into active edible fish gelatin films. *Packaging Technology and Science*, *32*(9), 471–480. https://doi.org/10.1002/pts.2450

Palmeira, K. R., Másrsico, E. T., Monteiro, M. L. G., Lemos, M., & Conte Junior, C. A. (2015). Ready-to-eat products elaborated with mechanically separated fish meat from waste processing: challenges and chemical quality. *CyTA – Journal of Food*, 14(2), 227–238. https://doi.org/10.1080/19476337.2015.1087050

Pang, J., Guan, E., Yang, Y., Li, M., & Bian, K. (2021). Effects of wheat flour particle size on flour physicochemical properties and steamed bread quality. *Food Science & Nutrition*, 9(9), 4691–4700. https://doi.org/10.1002/fsn3.2008

Renwarin, F., Tiven, N., & Liur, I. (2022). Organoleptic quality of beef meatballs substituted with tuna fish meat (*Thunnus* sp.). *Journal of Education Technology Information, Social Sciences, and Health*, *1*(2), 288–295. https://doi.org/10.57235/jetish.v1i2.149

Román-Gutiérrez, A., Guilbert, S., & Cuq, B. (2002). Distribution of water between wheat flour components: a dynamic water vapour adsorption study. *Journal of Cereal Science*, *36*, 347–355. https://doi.org/10.1006/JCRS.2002.0470

Saleh, F. M. (2023). Development of gluten free biscuit with a combination of sweet potato, yellow lentil and safflower flours. *Egyptian Journal of Chemistry*, *66*(13), 561–567. https://doi.org/10.21608/EJCHEM .2023.189572.7514

Sarkar, A., & Fu, B. X. (2022). Impact of quality improvement and milling innovations on durum wheat and end products. *Foods, 11*, 1796. https://doi.org/10.3390/foods11121796

Silva, R. A., Bonnas, D. S., & Silva, P. F. (2015). Recovery of waste generated in the processing of slices of surubim (*Pseudoplatystoma corruscans*) for preparation of nuggets. *Contextos da Alimentação*, *3*(2), 38–48.

Stone, H. S., & Sidel, J. L. (2004). *Sensory evaluation practices* (3rd ed.). San Diego: Academic Press.

USDA/FSIS. (2019). *Microbiology laboratory guidebook.* Athens, GA, USA: United States Department of Agriculture. Food Safety and Inspection Service.

Varela, P., & Fiszman, S. M. (2011). Hydrocolloids in fried foods. A review. *Food Hydrocolloids*, *25*, 1801–1812. https://doi.org/10.1016/j.foodhyd.2011.01.016

Veit, J. C., Freitas, J. M. A., Reis, E. S., Maluf, M. L. F., Feiden, A., & Boscolo, W. R. (2011). Proximate and microbiological characterization of nuggets of mandi-pintado (*Pimelodus britskii*). *Ciências Agrárias*, *32*, 1041–1048. https://doi.org/10.5433/1679-0359.2011v32n3p1041

Wang, K., Lu, F., Li, Z., Zhao, L., & Han, C. (2017). Recent developments in gluten-free bread baking approaches: A review. *Food Science and Technology*, *37*(1), 1–9. https://doi.org/10.1590/1678-457x.01417

RAZVOJ I KARAKTERIZACIJA RIBLJIH MESNIH OKRUGLICA PRIPREMLJENIH OD MEHANIČKI OTKOŠENOG MESA AMAZONSKOG HIBRIDNOG SORUBIMA I PANIRANIH BRAŠNOM ŠAFRANIKE RAZLIČITIH GRANULACIJA

Angela Dulce Cavenaghi-Altemio[1], Gustavo Graciano Fonseca[*2]

[1]Federalni univerzitet u Grand Doradosu, Fakultet za inženjerstvo, Laboratorija za prehrambene tehnologije, Grand Dorados, Brazil
[2]Univerzitet u Akureriju, Fakultet za nauke o prirodnim resursima, Škola za biznis i nauku, Akureri, Island

Sažetak: Cilj ovog rada bio je razvijanje alternativnog prehrambenog proizvoda za potrošače s celijakijom. Riblje mesne okruglice, pripremljene od mehanički otkoštenog mesa amazonske hibridne ribe sorubim (*Pseudoplatystoma reticulatum* x *Leiarius marmoratus*), pohovane su s bezglutenskim brašnom od šafranike, u dve granulacije. Ispitivanja su obuhvatala 3 tretmana u zavisnosti od vrste brašna za paniranje okruglica: kontrolni (T1)-pšenično brašno; (T2) brašno od šafranike granulacije 8 meša; i (T3) brašno od šafranike 14 meša. Karakterizacija prženih paniranih ribljih okruglica je izvršena ispitivanjem hemijskog sastava, fizičkih osobina, mikrobioloških i senzorskih svojstava. Sadržaj vlage okruglica iz tretmana T1 (67,89%) bio je viši ($p<0,05$) od onih iz T2 i T3. Nije bilo značajne razlike ($p>0,05$) između tretmana u pogledu sadržaja proteina (10,85-11,60%). Uzorci iz svih tretmana su se međusobno razlikovali po sadržaju masti i pepela, pri čemu je sadržaj masti bio viši za uzorke T2 (15,89%), a sadržaj pepela za uzorke T1 (1,53%). U sadržaju sirovih vlakana nije bilo razlike ($p>0,05$) između uzoraka T2 i T3, ali su oni bili statistički veći ($p<0,05$) u odnosu na uzorke T1 (5,06%). Mesne okruglice pohovane u brašnu od šafranike (T2 i T3) pokazale su veće ($p<0,05$) vrednosti za prinos mase i sile smicanja pri sečenju u poređenju s onima pohovanim u pšeničnom brašnu (T1). Ova opažanja su povezana s granulacijom brašna. Mnogo izraženije ($p<0,05$) prisustvo crvene nijanse (a*) opaženo je kod uzoraka T2 i T3 što je posledica prisustva pigmenata vezanih za polisaharide iz brašna šafranike. Prosečne ocene panela u rasponu od 5,36 do 7,64 bodova ukazuju na senzorne odgovore koji se kreću od ravnodušnosti do umerenog do visokog stepena dopadanja na hedonističkoj skali. Uzorci iz tretmana T2 i T3 pokazali su indeks prihvaćanja > 70%, dok su uzorci T1 imali bolji indeks prihvatanja > 80%. Brašno od šafranike kao panir masa je dalo tamnu boju i gorak ukus što je značajno smanjilo ukupnu dopadljivost u odnosu na klasični panir sa pšeničnim brašnom, a što je i vidljivo iz nižih rezultata senzorskih atributa, indeksa dopadljivosti i kupovne namere potrošača. Stoga se preporučuju dalja istraživanja za poboljšanje formulacija korišćenjem alternativnih sastojaka kako bi se odgovorilo na ove senzorne izazove.

Ključne reči: *alternativa hrani, celijakija, pohovanje, valorizacija ribe*

Received: *10 April 2025/* ***Received in revised form:*** *02 September 2025/* ***Accepted:*** *06 October 2025*

Available online: *November 2025*