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RESEARCH PAPER

Development and Characterization of Fried Spotted Sorubim Kibbeh with the Addition of Flaxseed

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Abstract

Fish industry is innovating to create versatile food products from fish valorization, by adding value to fish waste. The aim of this study was to utilize mechanically separated meat (MSM) of spotted sorubim (*Pseudoplatystoma coruscans*), a by-product obtained from processing fish carcasses, to develop fish kibbeh added of flaxseed, to create a functional food. Fish kibbeh formulations contained bulgur flour (F1), a mixture 1:1 of bulgur flour and flaxseed (F2) or flaxseed (F3). pH, shear force (SF), microbiology, sensory attributes and acceptance were evaluated. Results of SF showed that the higher the bulgur wheat content, the harder the texture (12.06 N for T1; 4.02 N for F3) due to differences in the granulometry of the flour. Color, odor and taste did not differ ($p>0.05$) between F1 and F2, but all parameters differed ($p<0.05$) from F3. Texture of F1 and F3 differed ($p<0.05$) from each other, but texture of F2 did not differ ($p>0.05$) from F1 and F3. Average scores of the sensory attributes ranged from 5.47 to 7.80. F1 and F2 presented acceptances indexes above 70%. Purchase intentions were 80, 39.9, and 23.3% for F1, F2, and F3, respectively. Despite F2 demonstrated similar sensory scores to F1, the lower purchase intention indicates that the formulation requires further refinement to become commercially viable.

Introduction

The spotted sorubim (*Pseudoplatystoma coruscans*), a fish species from the Pimelodidae family, is native to the Paraguay-Uruguay and São Francisco River Basins in South America. Known for its rapid growth and efficient feed conversion, this species is highly regarded for its excellent palatability and the absence of intramuscular bones, making it commercially desirable (Faustino et al., 2010; Almeida Filho et al., 2013).

To maximize the use of fish resources, the fish industry has been increasingly exploring new products and alternative processing technologies (Hassoun et al., 2023). One such technology, mechanical separation during fish processing, has been used for many years and remains a promising method for repurposing fish waste (Abdollahi et al., 2021).

Through this process, mechanically separated meat (MSM) can be obtained from fish, producing edible skeletal muscle free from viscera, bones, and skin (Abdollahi et al., 2021; Cavenaghi-Altemio & Fonseca, 2024). MSM can be derived from either a single fish species or a mix of species with similar sensory characteristics, but it is important to note that MSM differs significantly from crushed fish due to its specialized production process (Freire et al., 2023).

Despite having a nutritional profile similar to that of traditional fish fillets, MSM's commercial value remains comparatively low. Developing semi-processed or ready-to-eat products using MSM, such as fish kibbeh, faces challenges in knowledge transfer,

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technology adaptation, and consumer acceptance (Palmeira et al., 2016; Silva et al., 2024).

Kibbeh is a meat product traditionally made from ground beef or lamb mixed with whole wheat and additional ingredients. When produced with other meats, it is designated as “kibbeh” followed by the specific animal species used. Kibbeh can be consumed raw, fried, or baked. Essential components of kibbeh include meat, whole wheat, and water, though it may also contain optional ingredients like salt, fat, animal protein, and various seasonings (Brazil, 2000).

Flaxseed (*Linum usitatissimum*) has gained popularity in food applications due to its high fiber, fatty acids, and protein content, along with its gluten-free nature, making it suitable for individuals with celiac disease. Known to support intestinal health, reduce cholesterol, stabilize blood sugar levels, and lower the risk of breast, colon, and prostate cancer, flaxseed is also a good source of omega-3 and omega-6 fatty acids. Additionally, lignans in flaxseed possess antifungal and antioxidant properties that may inhibit inflammation and prevent arteriosclerosis (Mueed et al., 2023; Pramanik et al., 2023; Shim et al., 2024).

Given these health benefits, flaxseed has been widely incorporated into baked goods, including muffins, bagels, and snack bars, as well as pasta, noodle, biscuits, and buns, dairy products, e.g. yogurt and ice cream, and meat-based products e.g. sausage, pate and kibbeh (Vitorassi, 2012; Goyal et al., 2014; Austria et al., 2016; Mueed et al., 2022; Zhang et al., 2022).

Thus, the aim of this study was to develop a functional fish-based kibbeh utilizing MSM from the commercially valuable spotted sorubim species. To enhance its nutritional profile and cater to modern dietary preferences, particularly for those with celiac disease, the traditional bulgur component was replaced with flaxseed. This innovative approach not only explores new applications for MSM in the food industry but also capitalizes on the health benefits of flaxseed, to develop a product that meets the growing consumer demand for nutritious, gluten-free, and functional foods. Furthermore, this study addresses the challenges associated with MSM utilization by evaluating consumer acceptance, optimizing processing techniques, and improving the marketability of MSM products within the fish industry.

Material and Methods

Mechanically Separated Meat (MSM) of Spotted Sorubim

Spotted sorubim (*Pseudoplatystoma corruscans*) eviscerated and headed carcasses, washed with 5 ppm chlorinated water spray, were supplied by a local fishery processing plant (Itaporã, MS, Brazil). They were transported to the Laboratory of Bioengineering from the Federal University of Grande Dourados (Dourados, MS, Brazil), under refrigerated conditions, and immediately utilized to produce the 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. The MSM was immediately utilized to develop the fish kibbehs (Cavenaghi-Altemio et al., 2020).

Fried Fish Kibbeh Obtained from MSM of Spotted Sorubim

The fried fish kibbehs were prepared according to one of three formulations (F1, F2, and F3) described in Table 1. The hydrating of the fine bulgur wheat was obtained with the same amount of warm water before resting for 15 min. After weighing, the ingredients of each formulation were homogenized, molded in kibbeh shape with 25 g (Figure 1A, B, C). Then, the products were pre-fried by immersion in hot soybean oil at 180ºC for 30 s and stored at -20°C for 12 h prior to analysis. The fine bulgur wheat was purchase at the local commerce (Dourados, MS, Brazil). The condiments were supplied by Cavenaghi Eireli (Dourados, MS, Brazil). Approximately 1.5 kg of fish kibbeh was prepared for each formulation during the experiment.

pH and Shear Force

pH of the fried fish kibbehs was measured in triplicate using a digital pHmeter (Hanna Instruments Ltd model HI99163, Bedfordshire, UK) by mixing 25 g of the sample and 10 ml of distilled water, according to the method described elsewhere (Spitzer and Werner, 2002).

Table 1. Composition of three formulations of fried fish kibbeh

Ingredients	Formulations (%)		
	F1	F2	F3
MSM of spotted sorubim	48.4	48.4	48.4
Fine bulgur wheat	48.4	24.2	-
Flaxseed	-	24.2	48.4
Refined salt	1.98	1.98	1.98
Mint	0.48	0.48	0.48
Dehydrated garlic	0.39	0.39	0.39
Dehydrated parsley	0.25	0.25	0.25
Black pepper	0.1	0.1	0.1

Figure 1. (A) Raw kibbeh F1. (B) Raw kibbeh F2. (C) Raw kibbeh F3. (D) Fried kibbeh F1. (E) Fried kibbeh F2. (F) Fried kibbeh F3. (G) Open fried kibbeh. (H) Open fried kibbeh F2. (I) Open fried kibbeh F3. Formulation (F1, F2, and F3) are in accordance with Table 1.

Texture analysis of the fried fish kibbehs was carried out using a texture analyzer Model TA.XT2i (Stable Micro Systems, Surrey, England) calibrated with a standard weight of 5 kg. Fried fish kibbehs kept at 2°C were equilibrated at room temperature (28-30°C) before analysis. Samples of 20 x 20 x 20 mm were placed in the texture analyzer and submitted to a cutting/shearing test (speed of 1.0 mm/s, distance of 30 mm) using a Warner-Bratzler shear blade (1 mm thick) to determine the shear force (N) (Kang and Chen, 2014). A minimum of 10 replicates of each treatment were analyzed.

Microbiological Analysis

To assess the microbiological analysis of the fried fish kibbehs, duplicate 25 g samples were aseptically transferred into a stomacher bag containing 100 ml of sterile distilled water containing 0.1% peptone (1% for *Salmonella* sp. determination). Samples were homogenized for 1 min. Ten-fold serial dilutions were prepared using sterile 0.1 peptone solution (9 ml) and spread plated (0.1 ml) in duplicate onto broths and/or agars for detection of typical colonies, biochemical confirmation, and identification, and plate counting for thermo-tolerant coliforms at 45ºC, *Staphylococcus* positive coagulase and *Salmonella* sp., to ensure the food safety of the judges during the sensory analysis, according to the methodology described elsewhere (USDA/FSIS, 1998).

Sensory Analysis

Sensory analyses of the fried fish kibbehs were conducted by 30 trained panelists with ages varying from 20 to 45 years. A vertical structured nine-points hedonic scale of mixed category (9=like extremely; 1=dislike extremely) was used for evaluation of the attributes color, odor, taste, and texture. The samples were fried by immersion in hot soybean oil at 180ºC for 3 min (Figure 1D, E, F). Then, 25 g of each treatment were served to the panellists in disposable containers, in monadic form, randomly coded with three digits. In the same sheet, it was evaluated the purchase intention 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 (Cavenaghi-Altemio & Fonseca, 2024). The acceptance index (AI) was calculated according to Eq. 1. The sample was considered acceptable if the AI was greater than 70% (Stone and Sidel, 2004).

$$AI=\frac{\text{average of the attributed grades}}{\text{maximum attributed grade}}x100 \quad (1)$$

Statistical Analysis

Statistical results were evaluated through analysis of variance (ANOVA) and the Tukey test for comparison of means of pH, shear strength, and sensory attributes, to assess differences between the formulations, at a level of 5% of significance, using the software Statistica 8.0. The evaluations were performed from data obtained at least in duplicate, and the results were presented by the mean ± standard deviation. The acceptance index and the purchase intention were presented in percentage.

Results and Discussion

The pH values were 6.56, 6.50 and 6.45 for F1, F2 and F3, respectively, differing statistically ($p<0.05$) from each other, indicating that fine bulgur wheat and flaxseed influenced the pH of the product (Table 2). The pH value of fried kibbeh can be influenced by various factors, including the choice of ingredients. Measuring pH is essential for assessing microbial safety, as pH levels significantly impact the growth of microorganisms (Luong et al., 2022). For example, the literature reports a pH of 6.1 for standard fried kibbeh (Landim et al., 2024), which aligns with the values observed in this study. This suggests that the relatively low pH found here can inhibit the growth of pathogenic microorganisms. While pH can also affect the quality, texture, and sensory attributes of meat products, it is challenging to directly correlate pH with these other attributes.

The analysis of shear force (SF) shows that the amount of fine bulgur wheat influenced the texture (Table 2). For F1 (100% of bulgur wheat), a harder texture (12.06 N) was observed, while for F3 (0% of bulgur wheat), the texture (4.02 N) was significantly lower ($p<0.05$) than F1 and F2. For F2 (50% of bulgur wheat and 50% of flaxseed), the result obtained (5.89 N) was in-between F1 and F2, differing statistically ($p<0.05$) from both formulations (Table 2). In this case, these results can be related to the granulometry of the flour because the size and the shape of flour particles influence their texture. The bulgur wheat, despite fine, is coarser than flaxseed and can become more uniformly molded than the flaxseed fish kibbehs, thus presenting a higher texture. Additionally, the moisture absorbed by the finer particles contributes to a softer texture and decreases shear force (Hera et al., 2013). Moreover, finer flours can generally retain more gases that expand during frying, leading to a decrease in texture, making the final product less dense, while coarser flours, due to their larger particles, let the gases escape, causing less expansion, which results is a denser, and crunchier texture (Maskat and Kerr 2002) (Figure 1G, H, I).

Thus, the observed results indicated that the texture of fried kibbeh is significantly ($p<0.05$) influenced by the type and amount of flour used, with bulgur wheat contributing to a firmer texture compared to the softer consistency achieved with flaxseed due to differences in particle size and moisture absorption.

The results of the microbiological analysis are presented in Table 3. The obtained values were within the limits stablished by the Brazilian Legislation for kibbehs for coliforms at 45ºC (maximum of 10^2 CFU g^{-1}), for *Staphylococcus* positive coagulase (maximum of 5 x 10^2 CFU g^{-1}) and *Salmonella* sp. (absence in 25 g) (Brazil, 2019). The results also followed the international standards, which determine that these products must be free of *Salmonella* sp. and the levels of *Staphylococcus* positive coagulase below 1.0 x 10^2 CFU g^{-1} (ICMSF, 2011). In this sense, the fish kibbehs were considered safe to conduct the sensory analysis.

Sensory attributes of color, odor, taste, and texture of the fried fish kibbeh are presented in Table 4. Color, odor and taste did not differ ($p>0.05$) between F1 and F2, and all differed ($p<0.05$) from F3. No undesirable off-odors and off-colors were detected by the judges, but fish taste was more prominent in F3. The texture of F1 and F3 differed ($p<0.05$) from each other, but the texture of F2 did not differ ($p>0.05$) from F1 and F3. The average scores of the sensory attributes varied from 5 (nether like, nor dislike) to 8 (I liked it a lot) on the hedonic scale, in an average range of 5.47 to 7.80. F1 and F2 presented acceptances indexes above 70%, indicating that the products were considered sensorially accepted (Stone and Sidel, 2004). However, F3 was not accepted for any of the evaluated parameters (Table 4).

Figure 2 shows the percentage of the purchase intention frequencies of the fried fish kibbeh prepared according to F1, F2 or F3. T1 had the highest percentage of purchase intention (40%) for "certainly would purchase", followed by treatments F2 and F3, with 13.3 and 3.3% of the intentions, respectively. The sum of the frequencies of the intentions "certainly would purchase" and "possibly would purchase" were 80, 39.9, and 23.3% for F1, F2, and F3, respectively. F3 was rejected by 36.6% of the panelists.

For comparison, it was reported elsewhere purchase intentions ranging from 73 to 77% for roasted fish kibbeh containing MSM of Nile tilapia (30, 35 or 40%) and flaxseed (20, 15 or 10%). In this study, the acceptance of the different formulations varied significantly depending on the color and taste of the other ingredients and seasonings (50%), as the formulation with the lowest acceptance had a less characteristic fish flavor (Vitorassi, 2012). This suggests that further adjustments to the bulgur wheat-to-flaxseed ratio are necessary to enhance product acceptance while benefiting from the gluten-free properties of flaxseed while the content of MSM of spotted sorubim seems to be appropriate for this kind of product.

Table 2. pH and shear strength of three formulations of fried fish kibbeh.

Determination	Formulation		
	F1	F2	F3
pH	6.56±0.02^a	6.50±0.02^b	6.45±0.01^c
Shear force (N)	12.06±0.32^a	5.89±0.27^b	4.02±0.30^c

Values (means ± standard deviations) with the same superscript letter in the same row do not differ statistically at $p>0.05$. F1, F2, and F3 are in accordance with Table 1

Table 3. Microbiological evaluation of three formulations of fried fish kibbeh.

Microbiological analysis	Formulation		
	F1	F2	F3
Thermotolerant coliforms at 45°C	<1.0 x 10^2 CFU/g	<1.0 x 10^2 CFU/g	<1.0 x 10^2 CFU/g
CPSA	<1.0 x 10^1 CFU/g	<1.0 x 10^1 CFU/g	<1.0 x 10^1 CFU/g
Salmonella sp.	Absence in 25 g	Absence in 25 g	Absence in 25 g

CFU: counting forming units; CPSA: Coagulase positive *Staphylococcus aureus*; F1, F2, F3 are in accordance with Table 1.

Table 4. Sensory analysis of three formulations of fried fish kibbeh

Sensory attributes	Formulations		
	F1	F2	F3
Color	7.80±0.9^a (86.7)	7.53±1.0^a (83.7)	6.00±1.9^b (66.7)
Odor	7.40±1.0^a (82.2)	7.53±1.0^a (83.7)	6.10±1.6^b (67.8)
Taste	7.70±1.0^a (85.6)	6.87±1.3^a (76.3)	5.47±1.8^b (68.4)
Texture	7.00±1.3^a (77.8)	6.37±1.9^{ab} (70.7)	5.87±1.9^b (65.2)

Values (means ± standard deviations) with the same superscript letter in the same line do not differ statistically at $p>0.05$. Values in parenthesis are referred to the acceptance indexes (%). F1, F2, F3 are in accordance with Table 1.

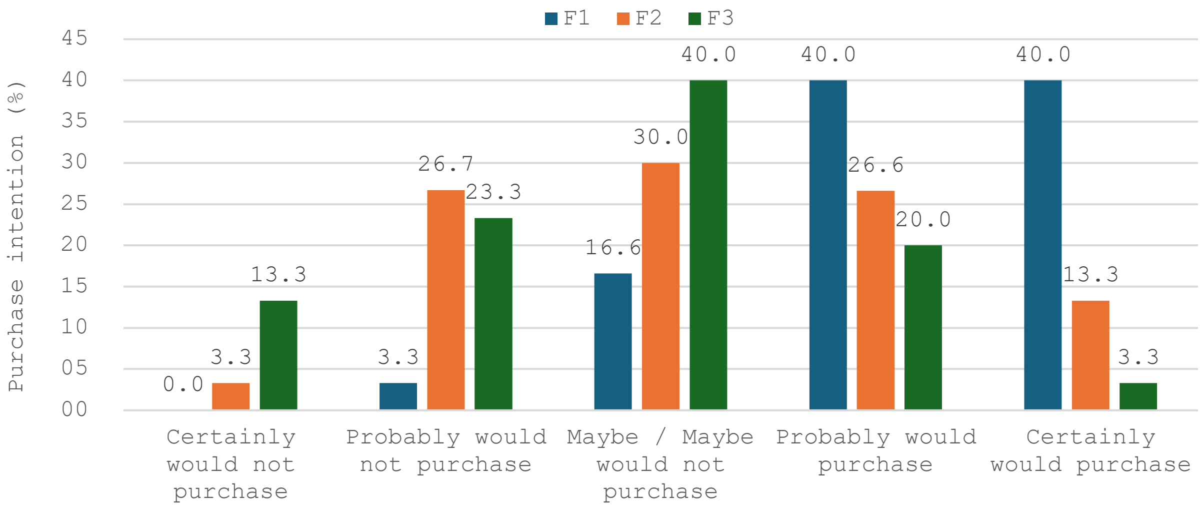

Figure 2. Purchase intention of the fried fish kibbeh. Formulations (F1, F2, and F3) according to Table 1

Conclusion

This study highlights the complex interplay between ingredient composition and particle size in determining the pH, texture and sensory attributes of fried kibbeh, offering valuable insights for product development in the food industry. The fish kibbeh made with 100% flaxseed replacing bulgur wheat (F3) had the lowest averages for the evaluated attributes. Despite all formulations using the same content of MSM of fish, it was evident that bulgur wheat is more effective in reducing the fish flavor in fish kibbehs and maintaining the desired texture. Conversely, fish kibbeh prepared with a 1:1 ratio of bulgur wheat to flaxseed (F2) was much more accepted than the version using only flaxseed. It exhibited color, odor, and taste similar to the fish kibbehs made with bulgur wheat (F1). Nonetheless, in terms of market potential, it is important to note that the formulation containing 100% bulgur wheat (F1) showed great commercial promise, with an 80% purchase intention rate

Ethical Statement

Not applicable.

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Author Contribution

Cavenaghi-Altemio, A. D.: Conceptual idea, Methodology design, Data collection, Data analysis and interpretation; Fonseca, G. G.: Data analysis and interpretation, Visualization and Writing -original draft, Writing -review and editing.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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