REVISTA DESAFIOS
ISSN: 2359-3652
V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

DEVELOPMENT OF *KEROPOK LEKOR*-TYPE SNACK USING BY-PRODUCTS FROM NILE TILAPIA *OREOCHROMIS NILOTICUS*

DESENVOLVIMENTO DE SNACK DO TIPO KEROPOK LEKOR UTILIZANDO SUBPRODUTOS DA TILÁPIA DO NILO OREOCHROMIS NILOTICUS

DESARROLLO DE SNACK TIPO KEROPOK LEKOR UTILIZANDO SUBPRODUCTOS DEL TILAPIA DEL NILO OREOCHROMIS NILOTICUS

Rildo José Vasconcelos de Andrade
rjv_andrade@hotmail.com
Rodrigo Pinheiro Crasto Amaral
rodrigo.crasto.amaral@gmail.com
Eloá Dandara Carvalho da Silva
elocarvalho81@gmail.com
Indira Maria Estolano Macedo
indiramacedo21@gmail.com
Neide Kazue Sakugawa Shinohara
neide.shinohara@ufrpe.br
Humber Agrelli de Andrade
humber.andrade@ufrpe.br
Alfredo Olivera Gálvez
alfredo.galvez@ufrpe.br
Roberta Borda Soares
roberta.bsoares@ufrpe.br
Paulo Roberto Campagnoli de Oliveira Filho
paulo.coliveirafo@ufrpe.br

REVISTA DESAFIOS ISSN 2359-3652

ABSTRACT:
Keropok lekor is a food product originating from and consumed in Asian countries and may contain MSM in its composition. The present study aimed to develop and carry out physicochemical, nutritional, microbiological, and sensory analyses of *keropok lekor* using MSM from Nile tilapia byproducts (0, 10, and 20%) and wheat fiber (0, 1, and 2%). Analyses were conducted on color and instrumental texture, pH, lipid oxidation, water activity, total volatile basic nitrogen, proximate composition, microbiological tests, and sensory evaluation. The inclusion of MSM in the *keropok´*s formulation decreased the redness and yellow, TVB-N, ash, and carbohydrate; it also increased pH, a_w, protein, and moisture. The addition of wheat fiber increased the redness, making the product less luminous and with lower TVB-N. Microbiological analyses indicated that the *keropok* were regulated by the health legislation in Brazil. The sensory analysis showed that the product presented good sensory acceptance with values ranging from "I liked it slightly" to "I liked it moderately", with no difference between the formulations. Therefore, *keropok lekor* made with MSM from Nile tilapia and wheat fiber is safe for human consumption and has good sensory acceptance, being a potential food product to be produced on a commercial scale, recommending the inclusion of 2% wheat bran and the addition of 20% tilapia MSM.

KEYWORDS: Food technology. Fish by-products. Waste utilization. Food sustainability.

RESUMO:
Keropok lekor é um produto alimentício originário e consumido em países asiáticos e pode conter CMS em sua composição. O presente estudo teve como objetivo desenvolver e realizar análises físico-químicas, nutricionais, microbiológicas e sensoriais do *keropok lekor*, utilizando CMS de subprodutos de tilápia do Nilo (0, 10 e 20%) e de fibra de trigo (0, 1 e 2%). Foram conduzidas análises de cor e textura instrumental, pH, oxidação lipídica, atividade de água, nitrogênio básico volátil total, composição centesimal, testes microbiológicos e avaliação sensorial. A inclusão de CMS na formulação do *keropok* diminuiu a vermelhidão e o amarelo, N-BVT, cinzas e carboidratos; aumentou o pH, a_w, proteína e umidade. A adição de fibra de trigo aumentou a vermelhidão, tornando o produto menos luminoso e com menor N-BVT. As análises microbiológicas indicaram que o *keropok* estava de acordo com a legislação sanitária brasileira. A análise sensorial mostrou que o produto apresentou boa aceitação sensorial com valores variando de "gostei levemente" a "gostei moderadamente", não havendo diferença entre as formulações. Portanto, o *keropok lekor* elaborado com CMS de tilápia do Nilo e fibra de trigo é seguro para consumo humano e apresenta boa aceitação sensorial, sendo um potencial produto alimentício para ser produzido em escala comercial, recomendando-se a inclusão de 2% de farelo de trigo e a adição de 20% de CMS de tilápia.

PALAVRAS-CHAVE: Tecnologia de alimentos. Subprodutos de pescado. Utilização de resíduos. Sustentabilidade alimentar.

RESUMEN:
El *Keropok lekor* es un producto alimenticio originario y consumido en países asiáticos y puede contener CMS en su composición. El presente estudio tuvo como objetivo desarrollar y realizar análisis fisicoquímicos, nutricionales, microbiológicos y sensoriales del *keropok lekor*, utilizando CMS de subproductos de tilapia del Nilo (0, 10 y 20%) y fibra de trigo (0, 1 y 2%). Se realizaron

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

análisis instrumentales de color y textura, pH, oxidación lipídica, actividad de agua, nitrógeno básico volátil total, composición proximal, pruebas microbiológicas y evaluación sensorial. La inclusión de CMS en la formulación de *keropoks* disminuyó el enrojecimiento y el amarillo, NBVT, cenizas y carbohidratos; también aumentó el pH, Aw, proteínas y humedad. La adición de fibra de trigo aumentó el enrojecimiento, lo que hizo que el producto fuera menos luminoso y tuviera una NBVT menor. Los análisis microbiológicos indicaron que los *keropoks* estaban de acuerdo con la legislación sanitaria de Brasil. El análisis sensorial mostró que el producto presentó buena aceptación sensorial con valores que van desde "me gustó un poco" hasta "me gustó moderadamente", sin diferencias entre las formulaciones. Por lo tanto, el *keropok lekor* elaborado con CMS de tilapia del Nilo y fibra de trigo es seguro para el consumo humano y tiene buena aceptación sensorial, siendo un producto alimenticio potencial para ser producido a escala comercial, recomendándose la inclusión de 2% de salvado de trigo y la adición de 20% de CMS de tilapia.

PALABRAS CLAVE: Tecnología alimentaria. Subproductos de pescado. Aprovechamiento de residuos. Sostenibilidad alimentaria.

INTRODUCTION

In recent years, fishing and aquaculture production reached 235 million tons, contributing to the increase in healthier eating. The expansion of fish consumption is also linked to the development of fish processing technology, with a greater supply of prepared products, a larger distribution network, and an increase in per capita income in the world (FAO, 2026).

Global fish consumption had an annual increase rate of 3% from 1961 to 2019, and annual per capita consumption reached 20.5 kg.year^{-1}.hab^{-1} in 2019. This is a positive aspect, as fish is a product with high-quality proteins, essential amino acids, polyunsaturated fatty acids, and minerals (iron, calcium, zinc), valuable nutrients for a healthy diet (FAO, 2026). The increase in fish consumption also brings an increase in by-products generated by industrialization that precedes the arrival of the product to the final consumer. As a result, there is a growing need for procedures to utilize these by-products, which can be used to develop innovative food products.

Obtaining mechanically separated meat (MSM) is an alternative to using fish by-products. MSM is obtained from headless and gutted fish or the bones or trimmings resulting from filleting. This raw material can be obtained from a species or a group of similar species and added to the production of sausages, snacks, and breaded products, resulting in high nutritional value (Guimarães et al., 2017).

Keropok lekor is a snack that originates in Asian countries, such as Malaysia, Thailand, and Indonesia, and depending on the location, it can be called *kerupuk, kaew krab*, or fish cracker. For the formulation of this type of product, starch (corn, cassava, or tapioca), water, fish meat, salt, and condiments are included (Nurul Huda et al., 2010). In Asian countries, it is a product

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

widely produced and consumed as street food; however, in Brazil, there are no reports of the commercial production of fish snacks such as *keropok lekor*.

Wheat fiber is a cellulose compound that aids chewing and has physiological properties, such as stimulating intestinal function. In food technology, dietary fibers also have other advantageous characteristics, such as high binding capacity with water and fat, which increases yield and reduces production costs (Sánchez-Alonso et al., 2007).

Considering the commercial potential of *keropok* made with fish MSM and wheat fiber, the objective of this study was to develop and evaluate the physicochemical, nutritional, microbiological, and sensory aspects of *keropok lekor* snacks using mechanically separated meat (MSM) from Nile tilapia (*Oreochromis niloticus*) by-products and supplemented with dietary fiber from wheat.

METHODOLOGY

Raw material

For the experiment, approximately 26 kg of tilapia processing by-products (backbones without fins and heads) were used, acquired from companies located in the metropolitan region of Recife/PE. The by-products were packed in thermal boxes with flaked ice and transported to the Fish Technology Laboratory, Department of Fishery and Aquaculture at the Federal Rural University of Pernambuco, Recife/PE.

Obtaining mechanically separated meat (MSM)

The by-products were thawed, washed with chlorinated water, and kept cold at 6 °C. To obtain the MSM, the tilapia spines were passed through a mechanical deboning machine (PV® 150), where approximately 7 kg of MSM were obtained, representing a yield of nearly 27%. Subsequently, this raw material was divided into polyethylene bags and stored at a temperature of -20 °C until the preparation of *keropok lekor*.

Formulations and elaboration of *keropoks lekor*

To prepare *keropok lekor*, formulations with different proportions of mechanically separated meat (0, 10, and 20%) and wheat dietary fiber (0, 1, and 2%) were used. The other ingredients were added in the same proportion to all formulations: 10% wheat flour; 2.5% salt; 0.2% dehydrated onion and garlic, and 0.2% black pepper (*Piper nigrum*), except corn starch, which was added to complete 100% of the formulation. The ingredients were weighed on a precision scale and mixed using a planetary mixer. Subsequently, ice water (4 °C) was added to

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

the formulation of the wheat flour and starch percentage. In formulations 1 and 2, 70.6 mL were added, in formulations 3 and 4, 56.7 mL were added, and in formulation 5, 61.6 mL were added (Table 1). This was necessary so that the *keropok* dough had a satisfactory consistency for production.

Table 1 - Formulations (in percentage) to obtain *keropok lekor* mass using mechanically separated meat (MSM) from Nile tilapia by-products and supplemented with dietary fiber from wheat

	Formulations (%)				
Ingredients	F1	F2	F3	F4	F5
MSM	0.0	0.0	20.0	20.0	10.0
Wheat fiber	0.0	2.0	0.0	2.0	1.0
Salt	2.5	2.5	2.5	2.5	2.5
Black pepper	0.2	0.2	0.2	0.2	0.2
Dehydrated onion and garlic	0.2	0.2	0.2	0.2	0.2
Wheat flour	10.0	10.0	10.0	10.0	10.0
Corn starch	87.1	85.1	67.1	65.1	76.1
Water (mL)*	70.6	70.6	56.7	56.7	61.6

* Addition of milliliters of ice water to the percentage of wheat fiber and starch in the formulations.

After mixing, portions of approximately 50 g were removed, and small cylindrical rolls approximately 10 cm long were manufactured and sprinkled with wheat flour so that the dough did not stick to the containers. Then, the *keropoks* rolls were cooked in boiling water (100 ºC) for 30 minutes until the starch gelatinized, which was observed through the floating of the *keropoks* during this process. Then, the rolls were cooled in ice water, dried at room temperature, packed in polyethylene bags, and stored in a freezer (-18 ºC).

Experimental design

The study presented two explanatory variables: the percentage of MSM inclusion (0, 10, and 20%) and the percentage of wheat fiber inclusion (0, 1, or 2%). The response variables were: color and instrumental texture, pH, lipid oxidation, water activity, total volatile basic nitrogen, proximate composition, and sensory evaluation. The experimental design used was the composite

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

design with a central point (Table 2). Each test consisted of a package with three *keropoks,* and three tests were carried out at the central point of the study.

Table 2 - Planning for the study of *keropok lekor* with the addition of different percentages of inclusion of mechanically separated meat (MSM) from tilapia filleting residues and wheat fiber

Number of Tests	MSM (%)	Wheat fiber (%)
1	0	0
1	0	2
1	20	0
1	20	2
3*	10	1

*Central point.

Physicochemical analysis

Instrumental color

To measure the instrumental color of the *keropoks*, a portable colorimeter (Konica Minolta®, model CR – 400) operated with a xenon lamp, illuminant C (Y=92.78; x=0.3139; y=0.3200), observation angle of 2º, and measuring area of 8 mm in diameter was used at one point on each of the three snacks included in each of the packages. The colorimeter was calibrated with a white standard before each analysis. The color was expressed using the color standards of the CIELAB system: L* [lightness (+) brighter to (-) darker], a* [color intensity red (+) to green (-)], and b* [color intensity yellow (+) to blue (-)].

Hardness

Hardness analysis was performed with a texturometer (CT3 Texture Analyser Brookfield®). A measurement was taken on each *keropok*. In each case, compression was performed up to 50% of the *keropok* thickness using a TA25/1000 probe at pre-test speed, test, and post-test of 2 mm/s at 25 ºC (Bourne, 2002).

pH determination

The pH was estimated with the assistance of a pH meter using an immersion electrode. A 10-gram sample of *keropok* was obtained and subjected to prior homogenization with 40 mL of distilled water, according to Oliveira Filho et al. (2012).

Total volatile basic nitrogen (TVB-N)

Total volatile basic nitrogen (TVB-N) was estimated according to Howgate (1976). A sample of approximately 10g of each *keropok* was previously homogenized with a mixture of 60

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

mL of 10% trichloroacetic acid (TCA) solution for 1 minute and kept at rest for two hours. Then, the sample was filtered through medium filtration quantitative filter paper (Unifil ø150 mm), pipetted (25 mL of filtrate + 1 g of magnesium oxide) into a flask of the nitrogen distiller apparatus, distilled with 15 mL of mixed indicator (compound of methyl red and bromocresol green), and titrated with 0.02N HCL. It was then calculated with the following:

$$\text{TVB} - \text{N}\left(\frac{\text{mgN}}{100\text{g}}\right) = \frac{\text{vol HCL (mL)} \times \text{normality of HCL} \times 14\ \times \text{vol ext. TCA}\ \times 100}{25 \times \text{sample weight}}$$

Lipid oxidation (TBARS)

Lipid oxidation analysis was performed using the thiobarbituric acid reactive substances (TBARS) method, according to Vyncke (1970). To calculate TBARS values, tetramethoxypropane was employed as the standard, with the results expressed in milligrams of malondialdehyde per kilogram of sample.

Water activity (a_w)

Water activity was estimated for pre-homogenized *keropoks* in a food processor at a temperature of 25 ºC in an Aqualab CX-2 equipment (Decagon Devices®).

Proximate composition

The proximate composition of raw materials MSM, wheat fiber, and *keropoks* was calculated according to AOAC (2012). Firstly, moisture analysis was carried out by gravimetry in an oven with air circulation at 105 ºC until constant weight. After the moisture analysis, the dry matter was subjected to other proximate composition analyses. Crude protein was calculated using the Kjeldahl method (N x 6.25), lipid was extracted with petroleum ether in a Soxhlet extractor, ash content was evaluated by incineration in a muffle furnace at 550 ºC for 5 hours, the percentage of carbohydrate was calculated by subtracting the sum of the percentages of moisture, protein, lipid, and ash, from a total of 100%. The energy value was calculated by multiplying the protein and carbohydrate by 4 and the lipid by 9.

Microbiological Analysis

For microbiological tests, Compact Dry kits were used: psychrotrophic aerobes - Dry TC®; total coliforms and thermotolerant coliforms (*Escherichia coli*) - Compact Dry EC®; Coagulase-positive *Staphylococcus* - Compact Dry XSA®, and *Salmonella* sp. - Compact Dry SL®. The execution of the assays and the incubation time followed the manufacturer's

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

instructions, and all samples were carried out in triplicate; the results were expressed in Colony Forming Units per gram of sample (CFU/g). The results were compared with RDC 331 (Brasil, 2019a) and IN 60 (Brasil, 2019b).

Sensory analysis

The sensory evaluation was carried out in the Sensory Analysis Laboratory, located in the Department of Consumer Sciences at UFRPE, Recife – Pernambuco, equipped with individual cabins with white fluorescent light, using affective acceptance tests, in incomplete balanced blocks (Meilgaard et al., 2016). The *keropoks* were fried in soybean oil, cut into small pieces, and served with water and crackers to cleanse the palate. Each rater evaluated 3 samples coded with three-digit numbers, served monadically in incomplete balanced blocks. Each formulation was assessed 69 times, by 120 untrained evaluators, recruited among students, staff, and professors at the Rural Federal University of Pernambuco, Recife, PE. The sensory attributes evaluated were color, odor, texture, flavor, and overall acceptance using a 9-point hedonic scale (1 = disliked very much and 9 = liked very much). The study was previously approved by the Human Research Ethics Committee of the University of Pernambuco/ PROPEGE (CAAE: 40677315.0.0000.5207, n. 971.598), and all evaluators signed consent forms.

Statistical analysis

To check whether there were significant differences between the means of the response variables in the different formulations, Shapiro-Wilk tests were initially performed for normality, and Bartlett tests were performed to evaluate the homogeneity of variance. After verifying these prerequisites, analyses of variance (ANOVAs) were conducted. In cases of evidence of a significant difference between means, a Tukey post-test was performed.

Linear models $E(Y)=\beta X$ were used, where $E(Y)$ is the expectation (average) of the response variable, X is the design matrix of explanatory variables, and β is the vector of parameters to be estimated. It was assumed that the response variables follow approximately normal distributions $Y \sim N(\mu,\sigma^2)$. The explanatory variables were considered in their original scale and their squared form. The inclusion of squared transforms was adopted to contemplate non-linearities in the associations between response and explanatory variables.

To select the relevant explanatory variables, the Akaike Information Criterion was used (Akaike Information Criterion – AIC) (Akaike, 1974) in the backward procedure. Using the AIC, the principle of parsimony is favored, and models with a compromise between bias and variance of estimates are selected. At the end of the process, all, part of, or none of the explanatory variables can be maintained in the models. In the latter case, it would mean that the explanatory

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

variables are not relevant to understanding the response variations. At the end, only the equations of the selected models are shown.

Adjusted coefficients of determination (R^2) were calculated, as the models selected using the AIC could contain different numbers of parameter estimates. Hypothesis tests were carried out to check whether there was evidence that the estimates were significantly different from zero. Residual analyses were performed to verify that the assumption of normality was not violated (Shapiro-Wilk test) and whether the selected models presented bias. In the end, the selected models were used to make predictions and project surfaces of response averages in the plane of explanatory variables. The results were presented in equations with the respective parameter estimates and significance tests for the estimated adjusted coefficients of determination values, and in graphical expressions of the surface analyses.

RESULTS AND DISCUSSIONS

The results of the analysis of *keropoks* produced with tilapia by-products are shown in Table 3.

Table 3 - Results of physicochemical analysis of *keropok lekor* prepared with mechanically separated tilapia by-products and supplemented with wheat fiber[1]

Physicochemical analysis	F1*	F2	F3	F4	F5
L* (*luminosity*)	$84.23^{a} \pm 0.59$	$78.97^{b} \pm 1.07$	$80.43^{ab} \pm 2.05$	$80.75^{ab} \pm 0.68$	$82.25^{ab} \pm 2.28$
a (redness)*	$0.21^{b} \pm 0.02$	$1.28^{a} \pm 0.54$	$0.08^{b} \pm 0.04$	$0.39^{b} \pm 0.21$	$0.27^{b} \pm 0.14$
b* *(yellowness)*	$7.21^{b} \pm 0.08$	$9.60^{a} \pm 0.42$	$10.31^{a} \pm 0.22$	$10.86^{a} \pm 0.56$	$10.32^{a} \pm 0.64$
Hardness (N)	$4.36^{a} \pm 1.11$	$5.99^{a} \pm 1.31$	$5.28^{a} \pm 0.71$	$5.04^{a} \pm 0.65$	$6.40^{a} \pm 0.49$
pH	$6.03^{d} \pm 0.03$	$6.15^{c} \pm 0.05$	$6.62^{a} \pm 0.03$	$6.69^{a} \pm 0.01$	$6.39^{b} \pm 0.03$
Total volatile basic nitrogen (TVB-N mg/100g)	$0.009^{a} \pm 0.00$	$0.006^{b} \pm 0.00$	$0.002^{c} \pm 0.00$	$0.002^{c} \pm 0.00$	$0.002^{c} \pm 0.00$
Lipid Oxidation (TBARS mg/kg)	$0.03^{a} \pm 0.00$	$0.03^{a} \pm 0.00$	$0.03^{a} \pm 0.00$	$0.03^{a} \pm 0.00$	$0.03^{a} \pm 0.00$
Water activity (a_w)	$0.98^{b} \pm 0.00$	$0.98^{b} \pm 0.00$	$0.99^{a} \pm 0.00$	$0.99^{a} \pm 0.00$	$0.98^{b} \pm 0.00$

*F1 = 0% mechanically separated meat (MSM) and 0% wheat fiber; F2 = 0% mechanically separated meat (MSM) and 2% wheat fiber; F3 = 20% mechanically separated meat (MSM) and 0% wheat fiber; F4 = 20% mechanically separated meat (MSM) and 2% wheat fiber; F5 = 10% mechanically separated meat (MSM) and 1% wheat fiber.

[1] Different letters on the same row indicate a significant difference according to the Tukey test ($p<0.05$).

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

Table 3 shows the results of direct comparisons between the means of the different formulations. In the analysis with a linear model, it is possible to identify the effects of the factors (fiber and MSM proportions) as explanatory variables for the different responses. Parameter estimates, adjusted coefficients of determination, and p-values in F tests are shown in Table 4. In cases where the relationships between explanatory variables and responses are significant, p-values are less than 0.05. In cases where both fiber and MSM proportions did not affect the response variables, only the intercepts are shown.

Table 4 - Parameter estimates for the relationships between the proportions of fiber and mechanically separated meat (MSM) and the different response variables. The rightmost columns contain the adjusted coefficient of determination (R^2) and the probabilities (p) calculated using Fisher's tests.

Equation	R^2-adjusted	p
L*=82.9442-1.2342fiber	0.1234	0.06569
a*=0.403333-0.069889MSM+0.343333fiber+0.002211MSM^2	0.5993	0.0003027
b*=7.671667+0.274278MSM+0.735000fiber-0.008272MSM^2	0.7391	$8.456x10^{-06}$
Hardness=5.1162	---	---
pH=6.0466667+0.0332778MSM+0.0450000fiber-0.0002556MSM^2	0.9734	$3.437x10^{-14}$
TVB-N =$8.417x10^{-03}$-$7.850x10^{-04}$MSM-$8.167x10^{-04}$fiber+$2.517x10^{-05}$MSM^2	0.8543	$6.297x10^{-08}$
TBARS=$3.067x10^{-02}$-$5.556x10^{-04}$MSM+$3.444x10^{-05}$MSM^2	0.1216	0.1207
Aw=$9.827x10^{-01}$-$9.144x10^{-04}$MSM+$5.739x10^{-05}$MSM^2	0.8086	$1.338x10^{-07}$
Moisture =21.054167-0.173028MSM-0.270833fiber+0.010381MSM^2	0.4663	0.003196
Protein =9.058118+0.023973MSM^2	0.8179	$1.137x10^{-08}$
Lipid =1.1820-0.4225fiber	0.1116	0.07638
Ashes =$1.555x10^{-02}$+$1.798x10^{-03}$MSM-$1.131x10^{-04}$MSM^2	0.5261	0.0004673
Carbohydrates = 69.979543-0.027140MSM^2	0.8181	$1.122x10^{-08}$
Energy = 320.9986	---	---
Color=7.14256	---	---
Odor=6.7463	---	---
Texture =6.43396	---	---
Flavor=6.61635	---	---
Overall acceptance =6.73795	---	---

Physicochemical analysis

Instrumental color

The color characteristics of *keropoks* produced with tilapia MSM and wheat fiber can be seen in Table 3. There was a change in luminosity (L* value) ($p<0.05$) between the formulations, ranging from 78.97 to 84.23. A significant effect ($p<0.05$) was observed for the wheat fiber factor,

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

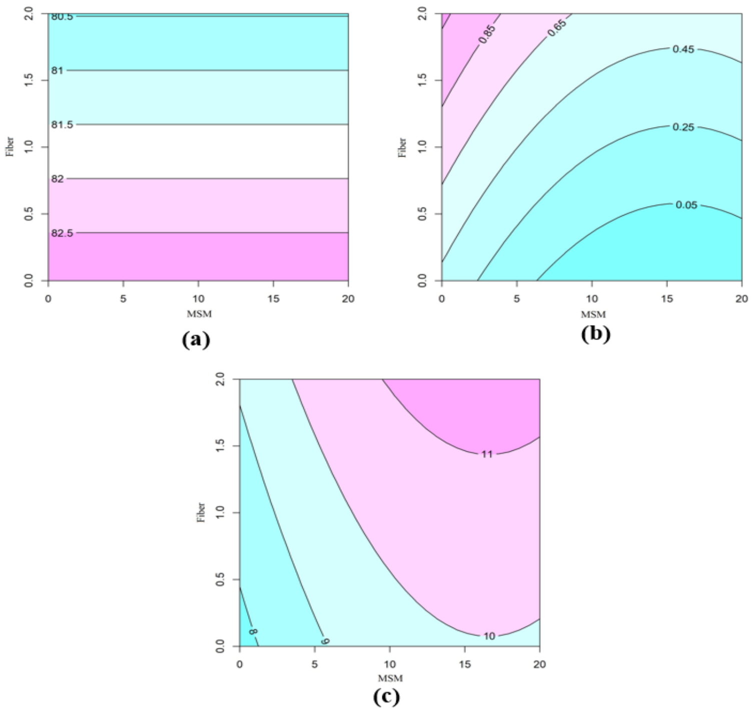
where increasing the amount of this ingredient made the *keropoks* less luminous (lower L* value) (Figure 1a). The darker color of the wheat fiber probably caused this. Rekola et al. (2023) and Ahn et al. (2019) observed that the inclusion of bran in meat products changes the luminosity of the food, with foods with the addition of vegetable bran having lower L* values than products without the addition of bran, that is, similar to what was observed in the present study.

For redness (a* value), it can be seen in Table 3 that there was a difference ($p<0.05$) in the *keropok*s, varying between 0.08 and 1.28. Increasing the percentage of MSM inclusion decreased the redness (a*), while the addition of wheat fiber made the products redder (higher a* value) (Figure 1b). It is possible that this occurred because the MSM utilized in the study was derived from tilapia spines devoid of dorsal fins, which consequently exhibited a whitish hue. The increase in redness with the addition of wheat fiber may have occurred because the product is naturally redder. Another point to be noted is that products with dry pasta, such as the one in the present study, may have a decrease in lightness and an increase in redness, which may be associated with the Maillard reaction, which is an enzymatic reaction that causes browning of food (Lu et al., 2018).

The yellowness (b* value) showed significant variation between formulations ($p<0.05$), with values between 7.21 and 10.86 (Table 3). Formulations with a higher percentage of MSM showed higher b* values (Figure 1c). The possible cause of the increase in the yellowness color is the decrease in the amount of starch in the formulation with more MSM (F3 and F4, Table 1). A different result from that observed by Silva et al. (2016), where the use of diverse types of flour (wheat, banana, and eggplant) did not cause variation in the yellowness in saramunete burgers (*Pseudupeneus maculatus*).

REVISTA DESAFIOS ISSN 2359-3652

Figure 1 - Values of color L* (a), a* (b), and b* (c) of *keropok lekor* made with tilapia by-products and supplemented with wheat fiber



Instrumental texture

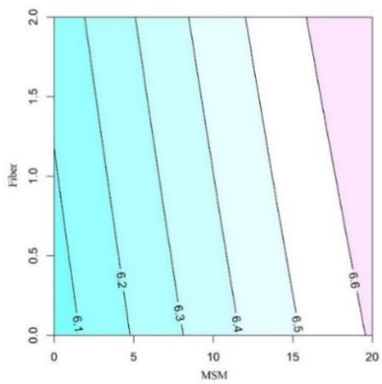
The hardness of the *keropoks* did not show a significant difference between formulations (p > 0.05) (Table 4), with values varying between 4.05 – 6.32 N. Muthia et al. (2010) observed that sausages made with different types of flour can change the texture, mainly due to the diverse sizes of the granules. Therefore, using flours of the same nature should not result in a significant change in texture. As corn starch and wheat flour were used in the present study for all formulations, it is believed that this was the reason for the lack of significant difference between the hardness of the *keropoks*.

pH determination

The pH of *keropoks* showed significant variation (p<0.05) between formulations (Table 3). Adding MSM caused a greater effect on pH than wheat bran (Figure 2). Tilapia MSM caused greater variation due to meat characteristics. The pH values were close to those observed by Signor et al. (2019) and Alexandre et al. (2022) in studies with tilapia MSM, with values of 6.5 to 6.9, respectively. The addition of wheat bran may have caused a change in the pH of the *keropoks* due to its slightly alkaline characteristics. Differently, Presenza et al. (2022) observed that adding wheat bran to the tambaqui burger (*Colossoma macropomum*) did not cause a significant difference in the pH of the product.

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

Figure 2 - pH values of *keropok lekor* made with tilapia by-products and supplemented with wheat fiber



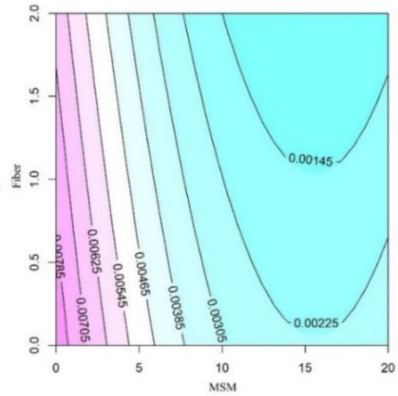
Total volatile basic nitrogen

The values of total volatile basic nitrogen (TVB-N) of *keropoks* were low but with significant variations between formulations (p<0.05) (Table 3). The addition of MSM and wheat fiber caused a decrease in TVB-N (Figure 3). TVB-N corresponds to ammonia, dimethylamine, and trimethylamine, which are formed by the breakdown of nucleotides and the release of the amine group from that of the amino acid (deamination), through the action of bacterial enzymes (Veloso et al., 2019). The current study yielded results that were not anticipated, as the increase in meat composition is generally associated with an elevated tendency for protein deterioration, which in turn leads to elevated levels of TVB-N. This phenomenon of low TVB-N values may be linked to cooking the *keropok* for 30 minutes in boiling water, which may have leached the TVB-N compounds.

Even with the detection of TVB-N, the levels are well below the recommended acceptability limit for fish in Brazil, which is 30 mg 100 g^{-1} (Brasil, 1997). When TVB-N is within the permitted limits, it indicates that biogenic amines are in a concentration suitable for safe commercialization.

REVISTA DESAFIOS ISSN 2359-3652

Figure 3 - Variation values of total volatile basic nitrogen (TVB-N mg/100g) content of *keropok lekor* made with tilapia by-products and supplemented with wheat fiber



Lipid oxidation (TBARS)

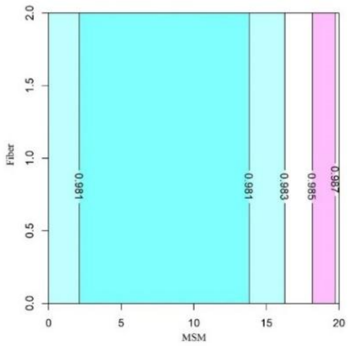
The TBARS values of the *keropoks* were low and without significant difference (p>0.05) between formulations, indicating that the product had lipid oxidation stability during its manufacture. The TBARS test quantifies malonaldehyde, which is one of the main degradation products of fatty acids formed during oxidation and is one of the main quality parameters to be analyzed in products with high-fat content. According to Pankyamma et al. (2014), TBARS values can be significantly influenced by the lipid content of foods, where it was observed that cereal snacks fortified with fish oil presented higher values as the lipid content increased. In contrast to the findings of the present study, which indicated low lipid values for *keropok*.

Water activity (a_w)

The water activity (a_w) of *keropoks* showed significant variation (p<0.05) among formulations (Table 3), with higher values as the percentage of MSM increased (Figure 4). The highest a_w value in *keropoks* with the presence of MSM was due to the high-water content in their composition and to the starch gelatinization process, which solubilizes amylose and promotes water retention. The same was observed by Pulgarín et al. (2023) when they performed water activity analysis in hydrogels based on cornstarch, where they observed values in the range 0.97 to 0.98, and the values were influenced by amylose, similar to that found in the present study.

Justen et al. (2017) observed a similar effect, where snacks made with tilapia flour presented a_w values between 0.50 and 0.53, and snacks without flour presented a value of 0.57, concluding that the inclusion of flour caused a reduction in the water activity of the snacks.

Figure 4 - Water activity (a_w) values of *keropok lekor* made with tilapia by-products and supplemented with wheat fiber



Proximate composition

According to the results in Table 5, moisture values showed a significant difference between formulations ($p<0.05$), with the formulation with 20% MSM showing the highest value (Figure 5a). The variation in moisture content of *keropoks* was more significant when MSM was added to wheat fiber. In comparing the moisture content of *keropoks* across different studies, Nur Liyana et al. (2019) observed moisture levels ranging from 55.99 to 62.42%. These values are higher than those reported in the present study. This may have occurred due to the *keropok* developed by Nur Liyana et al. (2019) presenting more fish meat in their formulation (50 to 70%).

Table 5 - Proximate composition (mean ± standard deviation) in *keropok lekor* made with tilapia by-products and supplemented with wheat fiber[1].

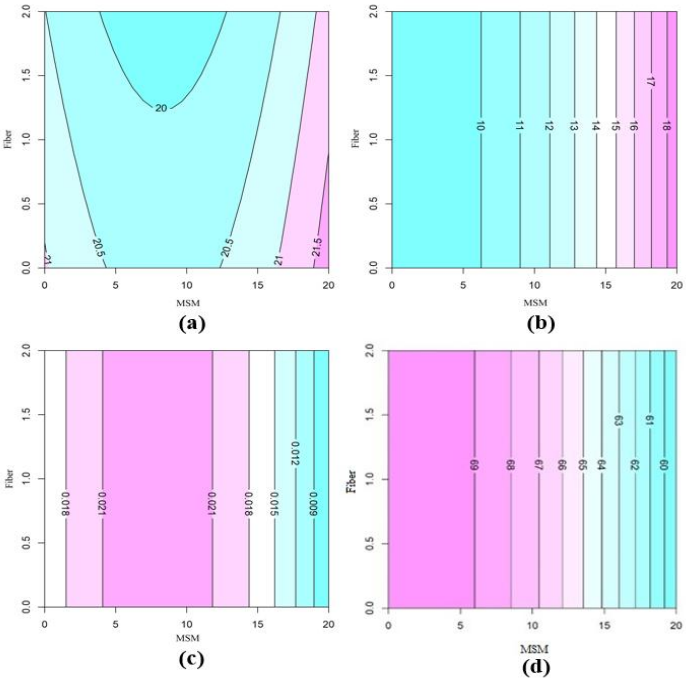
Proximate composition	F1*	F2	F3	F4	F5
Moisture (%)	$21.07^{ab} \pm 0.42$	$20.50^{ab} \pm 0.52$	$21.73^{a} \pm 0.20$	$21.22^{ab} \pm 1.01$	$20.09^{b} \pm 0.65$
Protein (%)	$8.23^{c} \pm 1.36$	$8.83^{c} \pm 0.64$	$17.38^{a} \pm 0.36$	$19.56^{a} \pm 0.31$	$11.92^{b} \pm 2.43$
Lipid (%)	$1.72^{a} \pm 1.96$	$0.11^{c} \pm 0.15$	$1.03^{a} \pm 0.39$	$0.96^{a} \pm 0.22$	$0.50^{b} \pm 0.24$
Ash (%)	$0.01^{b} \pm 0.00$	$0.02^{a} \pm 0.00$	$0.01^{b} \pm 0.00$	$0.01^{b} \pm 0.00$	$0.02^{a} \pm 0.00$
Carbohydrates (%)	$68.96^{a} \pm 3.07$	$70.54^{a} \pm 1.12$	$59.84^{b} \pm 0.56$	$58.25^{b} \pm 1.48$	$67.47^{a} \pm 2.43$
Energetic value (Kcal)	$324.29^{a} \pm 9.32$	$318.47^{a} \pm 2.27$	$318.21^{a} \pm 1.18$	$319.91^{a} \pm 3.48$	$322.04^{a} \pm 2.66$

*F1 = 0% mechanically separated meat (MSM) and 0% wheat fiber; F2 = 0% mechanically separated meat (MSM) and 2% wheat fiber; F3 = 20% mechanically separated meat (MSM) and 0% wheat fiber; F4 = 20% mechanically separated meat (MSM) and 2% wheat fiber; F5 = 10% mechanically separated meat (MSM) and 1% wheat fiber.

[1]Different letters on the same row indicate a significant difference according to the Tukey test ($p<0.05$).

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

Figure 5 - Variations in moisture (a), protein (b), ash (c), and carbohydrates (d) content of *keropok lekor* made with meat mechanically separated from tilapia by-products and supplemented with wheat fiber



The protein percentage of *keropoks* increased with increasing MSM inclusion (Figure 5b). This result was also observed by Zim et al. (2019) in *keropoks* with MSM from mackerel (*Decapterus russelli*).

The percentage of lipids from *keropoks* was low, less than 2%, and with no significant difference ($p>0.05$) between formulations (Table 5). This may have happened because tilapia meat has a low amount of lipids in its composition. This result was also observed by Zim et al. (2019), where *keropoks* made with the addition of MSM from *Decapterus russelli* presented values between 1.22% and 1.38%.

The percentage of ash in the *keropoks* showed significant variation ($p<0.05$) between formulations (Table 5 and Figure 5c), with an increase in the fraction of MSM increasing the ratio of ash. This result is similar to that observed by Afifi et al. (2023), who observed higher ash values in *keropoks* formulated with 32% fish DMI (average of 1.72%). The same was detected by Nur Liyana et al. (2019), where there was a greater amount of ash in *keropoks* with a 50% MSM formulation, with values between 1.56 and 2.22%.

There was no evidence of significant differences in the average energy values between the different formulations (Table 5). Wheat fiber and tilapia MSM did not affect the values because these products have low energy values. Chambó et al. (2017) also did not observe a significant variation in energy value with tilapia meat in rolls enriched with tilapia flour.

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

For carbohydrate analysis, there was significant variation. The carbohydrate averages in formulations with 20% MSM (T3 and T4) were lower than observed in formulations in which there was no addition of MSM or in which its concentration was 10% (Table 5). The addition of wheat fiber had no effect; however, with the addition of MSM, a change in values was observed (Figure 5d). This was due to the 20% formulation having a lower amount of corn starch in its composition. Differently, in the study by Kingwascharapong et al. (2024), evaluating *keropok lekor* with sardine meat (*Sardinella gibbosa*), the authors obtained carbohydrate values of approximately 29%, which is well below that found in the present study, probably due to the amount of flour added by the authors being much smaller.

Microbiological analyzes

The results of the microbiological analyses of *keropoks* made with tilapia by-products can be seen in Table 6.

Table 6 - Microbial count (Aerobic psychrotrophic, *Escherichia coli*, coagulase-positive *Staphylococcus*, and *Salmonella* sp.) of *keropok lekor* made with by-products from the industrialization of tilapia. Average counts (log CFU/g)[1].

Parameters	Formulations				
	F1	F2	F3	F4	F5
Aerobic psychrotrophic	<2	<2	<2	<2	<2
Escherichia coli	<2	<2	<2	<2	<2
Staphylococcus	<2	<2	<2	<2	<2
Salmonella sp.	Absent	Absent	Absent	Absent	Absent

[1]Limit of detection < 2 log CFU/g for the Compact Dry® kit.

There was an absence of *Salmonella* sp. in all formulations. The counts of *E. coli*, coagulase-positive *Staphylococcus,* and Aerobic psychrotrophic were below 2 log CFU/g. These results are by Brazilian legislation that determines the absence of *Salmonella* sp., and 10^3 CFU/g of positive coagulase and *Staphylococcus* below 10^4 CFU/g. These results indicate that *keropok* made with tilapia by-products has satisfactory hygienic conditions and is a safe product for human consumption, according to RDC 331 (Brasil, 2019a).

Sensory analysis

There was no significant difference in the sensory aspects of color, odor, texture, flavor, and overall acceptance of *keropoks* (Table 7).

REVISTA DESAFIOS ISSN 2359-3652

Table 7 - Averages in sensory analyses of *keropoks lekor* made with mechanically separated meat (MSM) from tilapia by-products and supplemented with wheat fiber[1]

Sensory evaluation	F1*	F2	F3	F4	F5
Color	$7.22^a \pm 1.69$	$7.19^a \pm 1.48$	$7.00^a \pm 1.69$	$7.16^a \pm 1.51$	$7.14^a \pm 1.56$
Odor	$6.71^a \pm 1.55$	$6.63^a \pm 1.70$	$6.74^a \pm 1.72$	$6.66^a \pm 1.57$	$6.83^a \pm 1.61$
Texture	$6.43^a \pm 2.22$	$6.32^a \pm 2.04$	$6.71^a \pm 2.02$	$6.50^a \pm 2.06$	$6.36^a \pm 2.03$
Flavor	$6.46^a \pm 2.11$	$6.48^a \pm 1.79$	$6.65^a \pm 1.80$	$6.64^a \pm 1.90$	$6.69^a \pm 1.65$
Overall acceptance	$6.66^a \pm 1.82$	$6.73^a \pm 1.50$	$6.68^a \pm 1.56$	$6.77^a \pm 1.65$	$6.77^a \pm 1.44$

*F1 = 0% mechanically separated meat (MSM) and 0% wheat fiber; F2 = 0% mechanically separated meat (MSM) and 2% wheat fiber; F3 = 20% mechanically separated meat (MSM) and 0% wheat fiber; F4 = 20% mechanically separated meat (MSM) and 2% wheat fiber; F5 = 10% mechanically separated meat (MSM) and 1% wheat fiber.
[1]Different letters on the same row indicate a significant difference according to the Tukey test ($p<0.05$).

Acceptance of the color of the *keropoks* received an average rating of 7.14, equivalent to "I liked it moderately". Results obtained in the color parameter for *keropoks* prepared with MSM from fish of the species *Rastrelliger kanagurta* (Indian mackerel) and *Trachurus trachurus* (chicharro) did not show significant color changes, receiving average scores of 6.03 ("I liked it slightly") (Murad et al., 2017). The greater acceptance of the color in the present study may have occurred due to the color of the tilapia meat being light to the fish used in the other study, and the frying process that makes the *keropoks* more similar to snacks found in Brazilian commerce.

The odor of *keropoks* received an average rating of 6.71 ("I liked it slightly") in all formulations. A similar result was obtained in a fish burger made with mechanically separated meat (MSM) from tilapia filleting waste, which received an average score of 7.3 (Costa et al., 2019). This probably happened because MSM was obtained from filleting waste, presenting a more pronounced fish odor.

The *keropoks* received an average score of 6.7 for the texture. This result is lower than that observed by Bacelar et al. (2021), who developed MSM nuggets from tilapia filleting waste and cassava dough, where acceptance was 7.2. This variation in texture acceptance may have occurred because they are different products, in addition to variations in formulation.

The flavor of the *keropoks* received an average rating of 6.58 ("I liked it slightly") in all formulations, showing that, regardless of the formulation, the flavor was well accepted. When compared with the study by Raúl et al. (2018), where a biquara (*Haemulon plumierii)* burger was prepared with the addition of wheat fiber, which received an average score of 6.45, it was observed that the product in the present study had a better flavor acceptance.

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

The overall acceptance of *keropoks* received an average score of 6.72 points for all formulations (“I liked it slightly”), indicating good acceptance of the products prepared in the study. This shows the potential of *keropoks* as a fish snack and quick meal, being a healthier option to meet people's limited time when preparing fish-based meals.

FINAL CONSIDERATION

The addition of Nile tilapia mechanically separated meat (MSM) and wheat fiber caused variations in the physicochemical parameters of *keropok lekor*. Notwithstanding, microbiological and sensory evaluations indicate that the final product is safe for human consumption and meets consumer acceptance standards. These findings highlight the importance of a detailed understanding of the interactions between ingredients and their effects on the properties of technological products made with fish meat. Therefore, *keropok lekor* made with Nile tilapia MSM and wheat fiber is a potential food product to be produced on a commercial scale, where it is recommended to include 2% wheat bran and add 20% tilapia MSM.

Acknowledgements

To the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 001, “Fundação de Amparo à Ciência e Tecnologia de Pernambuco” (FACEPE) for the financial support received and the laboratory technician José Carlos de Andrade Alves from the Department of Consumer Sciences of the Federal Rural University of Pernambuco, for his total assistance in carrying out the physicochemical analyses.

REFERENCES

AFIFI, L. I.; ARIFIN, N.; FAUJAN, N. H.; RAMLY, N. Physicochemical properties and sensory preference of *Keropok Lekor* with partial replacement of fish flesh with oyster Mushroom. *Malaysian Journal of Science Health & Technology*, v. 9, n. 2, p. 128-135, 2023.

AHN, B. S.; KIM, B. G.; JEON, E. B.; LEE, I. S.; OH, K. S. Quality characteristics by grade of commercial frozen surimi. *Korean Journal of Fisheries and Aquatic Sciences*, v. 52, n. 6, p. 555-561, 2019.

AKAIKE, H. A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, v. 19, n. 6, p. 716-723, 1974.

ALEXANDRE, A. C. S.; ALBERGARIA, F. C.; FERNANDES, L. A. C.; DE SOUSA GOMES, M. E.; PIMENTA, C. J. Effect of natural and synthetic antioxidants on oxidation and storage stability of mechanically separated tilapia meat. *LWT*, v. 154, p. 112679, 2022.

AOAC. *Official Method of Analysis*: Association of Analytical Chemists. 19th Edition, Washington DC. 2012, 121-130 p.

BACELAR, R. G. A.; SOUSA, M. D. S.; SANTOS FILHO, J. H.; DE OLIVEIRA MOURA, N.; MURATORI, M. C. S. Nuggets prepared using mechanically separated meat (MSM) obtained from tilapia carcasses and cassava dough. *Boletim do Instituto de Pesca*, v. 47, 2021.

BOURNE, M. C. (2002). *Food Texture and Viscosity: Concept and Measurement*. 2ed. Elsevier Science & Technology Books. 423p.

BRASIL. *Resolução RDC nº 331, de 23 de dezembro de 2019*. Regulamento Técnico sobre padrões microbiológicos para alimentos. D. O. U. Diário Oficial da União; Poder Executivo, de 26 de dezembro de 2019a.

BRASIL. *Instrução Normativa Nº 60, de 23 de dezembro de 2019, da Agência Nacional de Vigilância Sanitária do Ministério da Saúde*. Estabelece as listas de padrões microbiológicos de alimentos. Diário Oficial, Brasília, 26 de dezembro de 2019, Sessão 1, 133b.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. *Portaria nº 185, de 13 de maio de 1997*. Aprova o Regulamento Técnico de identidade e qualidade de peixe fresco. Diário Oficial da República Federativa do Brasil, 19 maio 1997.

CHAMBÓ, A. P. S.; SOUZA, M. L. R. D.; OLIVEIRA, E. R. N. D.; MIKCHA, J. M. G.; MARQUES, D. R.; MAISTROVICZ, F. C.; GOES, E. S. D. R. Roll enriched with Nile tilapia meal: sensory, nutritional, technological and microbiological characteristics. *Food Science and Technology*, v. 38, n. 4, p. 726-732, 2017.

COSTA, D. P. S.; GONÇALVES, T. M. V.; CONTI-SILVA, A. C. Potentiality of using mechanically separated meats of Nile tilapia in fishburgers: chemical, physical and sensory characterization. *Brazilian Archives of Biology and Technology*, v. 62, p. e19180436, 2019.

FAO. *The State of World Fisheries and Aquaculture 2026*. Sustainability in action. Rome, 2026.

GUIMARÃES, J. L. B.; CALIXTO, F. A. A.; MESQUITA, E. F. M. Produção e utilização da carne mecanicamente separada de pescado: uma revisão. *Higiene Alimentar*, v. 31, n. 268/269, p. 31-35, 2017.

HOWGATE, P. Determination of total volatile bases. Aberdeen: *Torry Research Station*, 1976.

JUSTEN, A. P.; SOUZA, M. L. R. D.; MONTEIRO, A. R.; MIKCHA, J. M.; GASPARINO, E.; DELBEM, Á. B.; DEL VESCO, A. P. Preparation of extruded snacks with flavored flour obtained from the carcasses of Nile tilapia: physicochemical, sensory, and microbiological analysis. *Journal of Aquatic Food Product Technology*, v. 26, n. 3, p. 258-266, 2017.

KINGWASCHARAPONG, P.; PAEWPISAKUL, P.; SRIPOOVIENG, W.; SANPRASERT, S.; PONGSETKUL, J.; MEETHONG, R.; RAWDKUEN, S. Development of fish snack (*Keropok*) with sodium reduction using alternative salts (KCl and $CaCl_2$). *Future Foods*, v. 9, p. 100285, 2024.

LU, X.; BRENNAN, M. A.; SERVENTI, L.; LIU, J.; GUAN, W.; BRENNAN, C. S. Addition of mushroom powder to pasta enhances the antioxidant content and modulates the predictive glycaemic response of pasta. *Food Chemistry*, v. 264, p. 199-209, 2018.

V.13,n.4, julho/2026–DOI:10.21873/vol13n420264

MEILGAARD, M.; CIVILLE, G. V.; CARR, T. B. *Sensory evaluation techniques* (5th ed.). CRC Press. 2016.

MURAD, N. S.; ISMAIL, M. A.; NOR-KHAIZURA, M. A. R.; ISMAIL-FITRY, M. R. The effect of mixing time and mixing sequence during processing on the physicochemical and sensory properties of *keropok lekor*. *Journal of Science and Technology*, v. 9, n. 4, 2017.

MUTHIA, D.; NURUL, H.; NORYATI, I. The effects of tapioca, wheat, sago and potato flours on the physicochemical and sensory properties of duck sausage. International *Food Research Journal*, v. 17, n. 4, 2010.

NUR LIYANA, N.; NOR-KHAIZURA, M. A. R.; ISMAIL-FITRY, M. R. Effect of substituting tapioca starch with various high protein legume flours on the physicochemical and sensory properties of *keropok lekor* (Malaysian fish sausage). *Food Research*, v. 3, n. 1, p. 40 – 48, 2019.

NURUL HUDA, N. H.; LENG ANGLI, L. A.; YEE CHUNGXIAN, Y. C.; HERPANDI, H. Chemical composition, color and linear expansion properties of Malaysian commercial fish cracker (*keropok*). *Asian Journal of Food and Agro-Industry*, v. 3, n. 05, p. 473-482, 2010.

OLIVEIRA FILHO, P. R. C.; VIEGAS, E. M. M.; KAMIMURA, E. S.; TRINDADE, M. A. Evaluation of physicochemical and sensory properties of sausages made with washed and unwashed mince from Nile tilapia by-products. *Journal of Aquatic Food Product Technology*, v. 21, n. 3, p. 222-237, 2012.

PANKYAMMA, V.; BASU, S.; BHADRAN, S. S.; CHOUKSEY, M. K.; GUDIPATI, V. Fish oil-fortified extruded snacks: Evaluation of physical properties and oxidative stability by response surface methodology. *Journal of Food Process Engineering*, v. 37, n. 4, p. 349-361, 2014.

PRESENZA, L.; DE FREITAS FABRÍCIO, L. F.; GALVÃO, J. A.; DE SOUZA VIEIRA, T. M. F. Simplex-centroid mixture design as a tool to evaluate the effect of added flours for optimizing the formulation of native Brazilian freshwater fish burgers. *LWT*, v. 156, p. 113008, 2022.

PULGARÍN, O.; LARREA-WACHTENDORFF, D.; FERRARI, G. Effects of the amylose/amylopectin content and storage conditions on corn starch hydrogels produced by high-pressure processing (HPP). *Gels*, v. 9, n. 2, p. 87, 2023.

RAÚL, L. J.; ARAÚJO, I. B. D.; BARBOSA, R. C.; MACIEL, M. I. S.; SHINOHARA, N. K. S.; CAMPAGNOLI DE OLIVEIRA FILHO, P. R. Manufacture of biquara (*Haemulon Plumierii*-Lacepède, 1801) fishburger with addition of wheat bran. *Journal of Aquatic Food Product Technology*, v. 27, n. 5, p. 544-556, 2018.

REKOLA, S. M.; KÅRLUND, A.; MIKKONEN, S.; KOLEHMAINEN, M.; POMPONIO, L.; SOZER, N. Structure, texture and protein digestibility of high moisture extruded meat alternatives enriched with cereal brands. *Applied Food Research*, v. 3, n. 1, p. 100262, 2023.

SÁNCHEZ-ALONSO, I.; HAJI-MALEKI, R.; BORDERIAS, A. J. Wheat fiber as a functional ingredient in restructured fish products. *Food Chemistry*, v. 100, n. 3, p. 1037-1043, 2007.

REVISTA DESAFIOS ISSN 2359-3652

SIGNOR, F. R. P.; SIMÕES, G. S.; COLDEBELLA, P. F.; SIGNOR, A. A.; BOSCOLO, W. R. Effect of the addition of pregelatinized starch and dextrin in the formulation of tilapia mechanically separated meat patties. *Boletim do Instituto de Pesca*, v. 45, n. 4, 2019.

SILVA, M. A. P.; VIEIRA, P. H. S.; OLIVEIRA FILHO, P. R. C. Elaboração de fishburger de saramunete (*Pseudupeneus maculatos*) utilizando diferentes tipos de farinhas vegetais. *Revista Brasileira de Engenharia de Pesca*, v. 9, n. 2, p. 36-51, 2016.

VELOSO, R. R.; DOS ANJOS, B. W.; MACIEL, M. I. S.; SHINOHARA, N. K. S.; ANDRADE, H. A. Development and evaluation of fresh sausage type of marine catfish [*Sciades herzbergii* (Bloch. 1794)] stored under low temperatures. *International Food Research Journal*, v. 26, n. 2, 2019.

VYNCKE, W. Direct determination of the thiobarbituric acid value in trichloracetic acid extracts of fish as a measure of oxidative rancidity. *Fette, Seifen, Anstrichmittel*, v. 72, n.12, p.1084-1087, 1970.

ZIM, A. F. M. I. U.; AKTER, A.; ALI, M. S.; ANIK, W. A.; AHMED, S.; ZAMRI, A. I. B. Proximate composition, texture analysis and sensory evaluation of *keropok lekor* formulated with herbs and spices. *Food Research*, v. 3, p. 635-639, 2019.