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DEVELOPMENT OF SAUSAGE MADE WITH MECHANICALLY SEPARATED PIRARUCU (*ARAPAIMA GIGAS*) MEAT: NUTRITIONAL AND MICROBIOLOGICAL QUALITY

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Abstract : This study aimed to develop a sausage using mechanically separated meat (MSM) from pirarucu (*Arapaima gigas*) and to evaluate its nutritional, microbiological, and functional quality. MSM is obtained by removing meat fractions adhered to the carcass, allowing greater utilization of fish raw material and contributing to waste reduction. Although it has high market potential, studies on the application of pirarucu MSM in the development of processed products are still scarce, highlighting the relevance of this research. The methodology included proximate analyses of moisture, protein, lipids, ash, and carbohydrates, as well as determination of the fatty acid profile, mineral composition, and microbiological evaluations, conducted in accordance with Normative Instruction No. 60/2019 of the Brazilian Ministry of Agriculture, Livestock, and Supply. The results indicated that the product has a balanced nutritional composition, with a protein content of 14.12% and a high proportion of unsaturated fatty acids (72.71%), including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The presence of essential minerals such as iron, potassium, and magnesium was also observed. Microbiological analyses confirmed the product's safety, with the absence of *Salmonella* spp., *Escherichia coli*, and *Staphylococcus aureus*. It is concluded that the sausage produced with pirarucu MSM represents an innovative, safe, and nutritious alternative, with potential to add value to the Amazonian fish production chain and meet the growing demand for functional and sustainable foods.

Keywords: Fatty acids. Fish-based sausage. Sustainability.

INTRODUCTION

The Amazon region holds the largest river basin in the world and represents the main hub of continental fish production in Brazil (BRAZIL, 2021). Aquaculture and capture fisheries constitute fundamental economic and sociocultural activities in the region, accounting for a significant share of local and national protein supply. However, despite this potential, the Amazonian fish production chain still faces challenges such as lack of structural organization, inadequate management practices, insufficient standardization, and limited investment, which restrict its competitiveness and expansion (SANTOS et al., 2020; CAVALI; DANTAS FILHO, 2024).

Among the native species with the greatest potential for regional aquaculture, pirarucu (*Arapaima gigas*) stands out as one of the largest freshwater fish species in the world. Characterized by rapid growth, tolerance to farming conditions, and high meat quality, featuring boneless fillets without intramuscular bones, light color, and mild flavor, pirarucu has become a zootechnically and economically viable alternative for strengthening aquaculture in the Amazon region (NUNES et al., 2020; CAVALI et al., 2023). The increase in captive production, driven by public policies and research institutions, seeks to reconcile species conservation in the wild with the demands of a growing consumer market (LIMA et al., 2021; SILVA et al., 2025).

Nevertheless, a key challenge remains: how to add value to and diversify pirarucu production while minimizing losses and ensuring full utilization of the fish. Despite the growth of the sector, the market still lacks by-products and value-added fish products,

in stark contrast to the beef, pork, and poultry industries, which offer a wide range of processed products, including sausages. In this context, carcasses and lower-value cuts from primary processing of pirarucu can be converted into mechanically separated meat (MSM), a low-cost, high-protein raw material that is well suited for the development of new products (KUMAR et al., 2022).

Based on the preliminary development reported by Dantas Filho et al. (2022), the scientific hypothesis of this study is that pirarucu MSM is a technologically suitable and safe raw material for sausage production, capable of yielding a product with superior nutritional characteristics, given the high-quality protein and favorable lipid profile of fish, and compliant with the microbiological standards established by current legislation, thereby ensuring food safety.

The rationale for this investigation is grounded in the convergence of three main factors: the need for innovation and value addition in Amazonian aquaculture; the growing market demand for practical, healthy, and sustainable food products; and the widespread popularity of processed meat products in the Brazilian diet. The development of a pirarucu MSM sausage represents a strategic opportunity to diversify the product portfolio of regional aquaculture, reduce waste of fishery resources, and promote fish consumption, whose per capita intake in Brazil remains below the level recommended by the World Health Organization (IBGE, 2020).

In light of the above, the objective of this study was to develop a sausage using mechanically separated meat (MSM) from pirarucu (*Arapaima gigas*) and to evaluate its nutritional quality through proximate composition analysis (moisture, protein, lipids,

ash, and carbohydrates), caloric and energy value, as well as its microbiological quality by assessing the presence of *Salmonella* spp., enumeration of *Staphylococcus aureus*, and determination of total and thermotolerant coliforms.

MATERIAL AND METHODS

This study was conducted by Afya Centro Universitário de Ji-Paraná, and the analyses were performed at the Water and Food Laboratory, Department of Chemistry, at the Universidade Estadual de Maringá (UEM), with financial support from the Research Support Foundation of Rondônia (FAPERO). The study was approved by the Institutional Animal Care and Use Committee under protocol number 18/2025/CEUA/UNIR.

Sample collection was carried out from May to December 2024 at a fish processing facility registered with the Brazilian System of Inspection of Products of Animal Origin (SISBI-POA), located in the municipality of Vale do Paraíso, Rondônia, Brazil.

Samples of mechanically separated meat (MSM) were obtained from the filleting of pirarucu (*Arapaima gigas*) sourced from fish farms operating semi-intensive systems in excavated fishponds. During the sampling period, 30 pirarucu specimens were filleted, with body weights ranging from 11.1 to 14.0 kg.

The sampled fish were selected from previously characterized fish farms, excluding batches from production systems with reported parasitic infestations, mortality due to high stocking densities, undernutrition, cultivation in cage or lined tanks, among other issues. Fish were removed from the

ponds using fishing nets and subsequently subjected to stunning by cerebral concussion, followed by euthanasia through exsanguination via sectioning of the carotid veins, in accordance with the procedures adopted by the processing facility.

At the processing unit, fish were washed, eviscerated, and processed into commercial cuts according to market demand. The initial stage of pirarucu processing was carried out on the evisceration table, involving the removal of the skin with scales, head, and viscera, with the remaining steps described in Section 2.2.

Sausage development

The production method followed the guidelines described by Dantas Filho et al. (2022); however, a new formulation was developed with the addition of other ingredients, and the entire processing procedure was carried out in the meat processing laboratory of the National Service for Industrial Training of Mato Grosso (SENAI-MT). At the end of the previously described processing steps, the final product was obtained (Figure 1).



Figure 1 - Final product of the sausage developed with pirarucu MSM (*Arapaima gigas*).

The ingredients used in the new formulation consisted of mechanically separated meat (MSM) totaling 5,400 g, followed by chilled water and vegetable fat, both at 325 g. Seasonings included refined salt (100g), granulated dehydrated garlic (50g), fresh aromatic chili pepper (50g), black pepper (10g), as well as oregano, parsley, bay leaf powder, and coriander powder, each at 5g. This formulation was designed to ensure flavor, texture, and overall quality of the final product, while maintaining appropriate proportions for fresh sausage processing.

After the production of the pirarucu MSM sausage, 30 samples were allocated for nutritional and microbiological analyses. Samples weighing 50g were hermetically packaged in transparent plastic zip-lock bags. Samples intended for microbiological analyses were packaged in sterile bags and subsequently froze until analysis.

Nutritional composition analyses

Among the commercial cuts previously mentioned, the processing facility produced MSM from residues generated during the processing of pirarucu tenderloin and tail fillets, with residues from 30 fillets being sampled. After completion of the MSM and sausage production steps, six random sausage samples measuring 4 cm² and weighing 50g were collected. These samples were properly identified, stored at -8 °C in a cooler, and sent to a specialized laboratory at the UEM, Maringá city, Brazil. At the laboratory, the samples were cut into 1 cm² pieces, weighed, identified, placed in aluminum containers, and frozen at -20 °C for 48 hours.

The containers containing the samples were labeled and stored in a freezer at -18

°C until proximate composition analysis. To avoid outliers in lipid composition data, the sampled fish (represented by their residues used for MSM and sausage production) were selected from fish farms previously characterized by the processing facility. Additionally, it should be noted that the stunning, slaughtering, use of filleting residues, and MSM production procedures were all carried out by the fish processing unit.

For macromineral quantification, extracts were obtained through complete digestion of the samples in sulfuric acid at high temperature (350–375 °C). Microminerals were analyzed from acid digestion extracts under controlled temperatures using nitric acid (120 °C) and perchloric acid (180–190 °C), for the determination of total iron (Fe²⁺ + Fe³⁺) (RUIZ-DE-CENZANO et al., 2013).

Measurements were performed using an atomic absorption spectrometer (model AA 12/1475). Sodium (Na⁺) and potassium (K⁺) were determined according to AOAC official method 969.23, while total iron, calcium (Ca²⁺), and magnesium (Mg²⁺) were determined following AOAC official method 968.08 (COOK, 1997).

Lipid composition was evaluated after freeze-drying the samples for 44 hours using a LIOTOP L101 lyophilized. Total lipids were extracted using the Bligh and Dyer method, and fatty acid methyl esters (FAMES) were prepared by methylation of triacylglycerols, according to ISO 5509 (ISO, 1978). FAMES were analyzed using a Shimadzu 14-A gas chromatograph (Japan), equipped with a flame ionization detector and a fused silica capillary column (50 m length, 0.25 mm internal diameter, and 0.20 µm Carbowax 20M film thickness).

The flow rates of ultrapure gases (White Martins) were 1.2 mL min⁻¹ for the carrier gas (H₂), 30 mL min⁻¹ for the make-up gas (N₂), and 30 and 300 mL min⁻¹ for flame gases (H₂ and synthetic air), respectively. The injection volume was 1 µL, and the split ratio was set at 1:100 (SANTOS et al., 2017). Column temperature was programmed at a rate of 2 °C min⁻¹, from 150 °C to 240 °C. Injector and detector temperatures were set at 220 °C and 245 °C, respectively. As described by Santos et al. (2017), peak areas were determined using a CG-300 Integrator-Processor (CG Scientific Instruments), and peak identification was carried out by comparison with standard retention times (Sigma, USA).

Fatty acid profile data were grouped to calculate the polyunsaturated-to-saturated fatty acid ratio (PUFAs/SFAs) and the *n-6/n-3* ratio, following World Health Organization recommendations. Other lipid quality indices were compared with values reported in the literature, including Hernández-Martínez et al. (2016), Passos et al. (2016), Rodrigues et al. (2017), and Souza and Tobal (2021). The nutritional quality of the lipid fraction was also assessed based on the fatty acid profile using the atherogenicity index (AI), thrombogenicity index (TI), and the hypocholesterolemic/hypercholesterolemic fatty acid ratio (h/H) (RODRIGUES et al., 2017), calculated as follows:

$$\text{I) Atherogenicity Index (AI)} = [(12:0 + 4 \times 14:0 + 16:0)] / (\Sigma\text{MUFA} + \Sigma n-6 + \Sigma n-3);$$

$$\text{II) Thrombogenicity Index (TI)} = (14:0 + 16:0 + 18:0) / [(0.5 \times \Sigma\text{MUFA}) + (0.5 \times \Sigma n-6) + (3 \times \Sigma n-3) + (\Sigma n-3 / n-6)];$$

$$\text{III) Hypocholesterolemic/Hypercholesterolemic Ratio (h/H)} = (18:1 \ n-9 + 18:2 \ n-6 + 20:4 \ n-6 + 18:3 \ n-3 + 20:5 \ n-3 + 22:5 \ n-3 + 22:6 \ n-3) / (14:0 + 16:0).$$

Microbiological analyses

Analyses for the detection of *Salmonella* spp. were performed using ISO method 6579:2007, while *Staphylococcus aureus* was assessed by direct plate count. Total coliforms at 35 °C, thermotolerant coliforms at 45 °C, and *Escherichia coli* were quantified using the Most Probable Number (MPN) method, following APHA procedures.

These analyses aimed to assess hygiene and sanitary conditions and to verify compliance with quality standards established by current legislation. All procedures were conducted in accordance with the microbiological criteria defined by Normative Instruction No. 60/2019 of the Brazilian Ministry of Agriculture, Livestock, and Supply (MAPA).

Statistical analysis

Statistical analyses were performed using RStudio with descriptive statistics, and results were expressed as mean and standard deviation to evaluate data dispersion and homogeneity. Mean comparisons were conducted using analysis of variance (ANOVA), followed by Tukey's test, adopting a significance level of 5% ($p < 0.05$).

RESULTS

The sausage developed from pirarucu mechanically separated meat (MSM) showed a balanced nutritional composition and complied with the limits established by Brazilian legislation (Normative Instruction

No. 04/2000) (Table 1). The sodium chloride content was 1.93%, well below the maximum permitted level of 4%, while moisture was 60.70%, also within the 65% limit. Ash (2.55%) and lipid (9.0%) contents complied with the maximum limits of 2.5% and 30%, respectively. Notably, the protein content averaged 14.12%, exceeding the minimum required level of 12%, indicating good nutritional value. The pH (6.26) and water activity ($A_w = 0.95$) do not have legally established limits but fall within typical ranges for meat products. Carbohydrate content was 17.42%, and the caloric value reached 217.16 kcal per 100g, equivalent to 908.60 kJ, suggesting an energy-dense and nutritious product (Table 1). These results indicate that sausage is suitable for consumption and has potential as an alternative food product.

The sausage prepared with pirarucu MSM shows a mineral composition that contributes positively to the nutritional value of the product (Table 2). The total iron content ($Fe^{2+} + Fe^{3+}$) was 1.22 mg/100 g, which is relevant for the prevention of anemia and for oxygen transport in the body. Sodium, at 280 mg/100 g, is present in a moderate amount, consistent with processed meat products, while potassium reached 300 mg/100 g, a mineral essential for electrolyte balance and muscle function. Calcium (14.40 mg/100 g) and magnesium (12.30 mg/100 g) were found at lower concentrations but still contribute to bone health and energy metabolism (Table 2). These data indicate that, in addition to being flavorful, pirarucu sausage may serve as an interesting source of important dietary minerals.

Table 3 presents the results for the sausage prepared from pirarucu mechanically

separated meat (MSM), which showed a lipid profile characterized by a predominance of unsaturated fatty acids (72.71%), with emphasis on monounsaturated fatty acids (41.25%), particularly oleic acid (36.44%). Among the polyunsaturated fatty acids (31.46%), eicosapentaenoic acid (EPA, 8.62%), docosahexaenoic acid (DHA, 6.98%), and arachidonic acid (6.77%) stood out, evidencing a significant presence of nutritionally important omega-3 and omega-6 fatty acids. Saturated fatty acids accounted for 27.29% of the total, with palmitic acid (18.34%) and stearic acid (5.58%) being the most abundant. This profile suggests a product with potential functional value due to the high proportion of unsaturated fatty acids, especially long-chain fatty acids associated with cardiovascular and anti-inflammatory benefits.

Table 4 shows the omega fatty acid values and lipid quality indices of the sausage developed from MSM of pirarucu (*Arapaima gigas*). The lipid profile of the product is characterized by a high content of polyunsaturated fatty acids (PUFAs), with a predominance of omega-9 fatty acids (37.02%), followed by omega-3 (23.12%), omega-6 (8.11%), and omega-7 (3.95%). The expressive contribution of omega-3 highlights the nutritional potential of the product, especially considering the health benefits associated with cardiovascular protection.

Regarding lipid quality indices, the ratio of unsaturated to saturated fatty acids (UFAs/SFAs) was 2.66, indicating a predominance of unsaturated lipids, which is considered desirable from a nutritional standpoint. The PUFA $n-6/n-3$ ratio was 0.35, a favorable value, as lower ratios are associated with a reduced risk of inflammatory and cardiovascular diseases.

Parameters	Sample Means	Legislation (IN no. 04/2000)
Sodium chloride (NaCl) (%)	1.93 ± 0.01	—
pH	6.26 ± 0.01	—
Aw	0.95 ± 0.02	—
Moisture (%)	60.70 ± 8.91	Max. 70%
Ash (%)	2.55 ± 0.52	—
Crude protein (%)	14.12 ± 0.08	Min. 12%
Lipids (%)	9.0 ± 2.50	Max. 30%
Carbohydrates (%)***	17.42 ± 1.67	—
Calories (kcal/100g)***	217.16	—
Energy value (kJ/100g)	908.60	—

Results expressed as mean ± standard deviation of three replicates.

** Coefficient of variation.

*** Results derived from calculations according to Brazil (2003) and Brazil (2001), not allowing for statistically significant analysis.

**** Brazil (2000).

Table 1 - Proximate composition, caloric value, and energy content of the sausage developed from mechanically separated meat (MSM) of pirarucu (*Arapaima gigas*).

Minerals	Values (mg/100g)
Total Iron	1.22 ± 0.18
Sodium (Na ⁺)	280.00 ± 20.00
Potassium (K ⁺)	300.00 ± 50.00
Calcium (Ca ²⁺)	14.40 ± 2.25
Magnesium (Mg ²⁺)	12.30 ± 2.70

¹ Ferro total = Fe²⁺ + Fe³⁺

Table 2 - Mineral composition of the sausage developed from mechanically separated meat (MSM) of pirarucu (*Arapaima gigas*).

The atherogenic index (AI = 0.293) and the thrombogenic index (TI = 0.279) showed low values, suggesting a reduced potential for the development of atherosclerosis and thrombosis. Additionally, the hypocholesterolemic/hypercholesterolemic ratio (h/H = 3.441) further reinforces the good nutritional quality of the lipid fraction of the sausage, indicating a balanced lipid profile that is beneficial to human health.

The microbiological analysis of the sausage produced with pirarucu MSM revealed satisfactory results and compliance with the standards established by Normative Instruction No. 60/2019 of MAPA (Table 5), indicating a product safe for consumption. *Staphylococcus Coagulase-positive* were not detected, for which the maximum permitted level is 5×10^3 CFU/g, nor was *Salmonella* spp. detected, whose absence is mandatory in 25 g of sample. Coliforms at 45°C showed counts below 3 MPN/g, well below the limit of 5×10^2 MPN/g. Total coliforms were also below 3 MPN/g, and there is no legal specification for this parameter in the table. The absence of *Escherichia coli* was recorded, although there is no direct normative reference for this microorganism. These data demonstrate that the product meets hygienic and sanitary requirements, reinforcing its microbiological quality.

DISCUSSION

The present study successfully demonstrates the potential of mechanically separated meat (MSM) from pirarucu as a viable raw material for the development of a processed meat product, specifically a sausage, with high nutritional and microbiological quality. The results are consistent with the global trend toward full utilization

of fish, adding value to filleting by-products and promoting sustainability in the production chain (GUIMARÃES et al., 2017).

The proximate composition of the developed sausage revealed a nutritionally balanced product, fully meeting the parameters established by Normative Instruction No. 04/2000. The protein content of 14.12% exceeds the minimum requirement of 12%, confirming the high protein value inherent to pirarucu (MARTINS et al., 2017) and highlighting MSM as an excellent source of this macronutrient. The low sodium content (1.93% NaCl) is a positive attribute, considering contemporary concerns related to cardiovascular health. The lipid profile, with 9.0% total lipids, is favorable; however, the true nutritional distinction lies in the quality of this fat.

The fatty acid profile was noteworthy, characterized by a predominance of unsaturated fatty acids (72.71%), particularly polyunsaturated fatty acids (31.46%). The significant presence of long-chain *n*-3 fatty acids, such as EPA (8.62%) and DHA (6.98%), confers considerable functional potential to the product, being associated with cardiovascular, anti-inflammatory, and cognitive benefits (SCHERR et al., 2015). The omega-6/omega-3 fatty acid ratio (0.35) is considered excellent, remaining well below values typically found in Western diets, which is highly desirable. The presence of *n*-7 fatty acids, such as palmitoleic acid, also deserves mention due to their emerging role in modulating insulin sensitivity and anti-inflammatory processes (FRIGOLET; GUTIÉRREZ-ANGULAR, 2017). The calculated lipid quality indices (AI, TI, and h/H ratio), although not presented in the table, would be expected to be favorable given the high degree of unsaturation and spe-

Common Nomenclature / Symbol	Values (%)
Lauric acid ¹ / C12:0	1.23 ± 0.10
Myristic acid ¹ / C14:0	0.42 ± 0.03
Pentadecylic acid ¹ / C15:0	0.084 ± 0.01
Palmitic acid ¹ / C16:0	18.34 ± 1.00
Margaric acid ¹ / C17:0	0.29 ± 0.00
Stearic acid ¹ / C18:0	5.58 ± 0.62
Arachidic acid ¹ / C20:0	0.44 ± 0.01
Behenic acid ¹ / C22:0	0.37 ± 0.04
Lignoceric acid ¹ / C24:0	0.54 ± 0.02
Palmitoleic acid ² / C16:1 n-7	0.62 ± 0.01
Cis-10-heptadecenoic acid ² / C17:1	0.50 ± 0.03
Oleic acid ² / C18:1 n-9	36.44 ± 0.06
Vaccenic acid ² / C18:1 n-7	3.33 ± 0.01
Gondoic acid ² / C20:1 n-9	0.22 ± 0.00
Erucic acid ² / C22:1 n-9	0.36 ± 0.00
α-Linolenic acid (ALA) ² / C18:3 n-3	2.30 ± 0.04
Dihomo-α-linolenic acid ² / C20:3 n-3	1.78 ± 0.01
Eicosapentaenoic acid (EPA) ² / C20:5 n-3	8.62 ± 0.04
Linoleic acid (LA) ² / C18:2 n-6	3.44 ± 0.07
Gamma-linolenic acid (GLA) ² / C18:3 n-6	0.57 ± 0.00
Eicosadienoic acid ² / C20:2 n-6	0.23 ± 0.00
Dihomo-gamma-linolenic acid (DGLA) ² / C20:3 n-6	0.54 ± 0.00
Arachidonic acid ² / C20:4 n-6	6.77 ± 0.09
Docosahexaenoic acid (DHA) ² / C22:6 n-3	6.98 ± 0.02
Other*	—
Saturated fatty acids (SFAs)	27.29
Monounsaturated fatty acids (MUFAs)	41.25
Unsaturated fatty acids (UFAs)	72.71
Polyunsaturated fatty acids (PUFAs)	31.46

¹Saturated fatty acids. ²Unsaturated fatty acids.

Table 3 - Fatty acid profile of the sausage developed from mechanically separated meat (MSM) of pirarucu (*Arapaima gigas*).

Variables	Parameters	Values (%) ¹
Omegas	ΣPUFAs (n-3)	23.12
	ΣPUFAs (n-6)	8.11
	ΣPUFAs (n-7)	3.95
	ΣPUFAs (n-9)	37.02
Lipid quality indices	UFAs/SFAs	2.66
	PUFAs (n-6/n-3)	0.35
	AI ²	0.293
	TI ³	0.279
	h/H	3.441

¹Values expressed as percentage of total fatty acids. ²AI = Atherogenic Index. ³TI = Thrombogenic Index.

Table 4 - Omega fatty acid values and lipid quality indices of the sausage developed from mechanically separated meat (MSM) of pirarucu (*Arapaima gigas*).

Parameters	Results	IN No. 60/2019 – MAPA
<i>Staphylococcus Coagulase-positive</i> (CFU/g)	Absent	5 x 10 ³ (CFU/g)
<i>Salmonella sp. in 25 g</i>	Absent	Absent in 25 g
Coliforms at 45°C (MPN/g)	< 3	5 x 10 ³ (MPN/g)
Coliforms at 35°C (MPN/g)	< 3	—
<i>Escherichia coli</i> (MPN/g)	Absent	—

MPN = Most Probable Number; CFU = Colony Forming Units.

Table 5 – Microbiological analyses of the sausage developed from mechanically separated meat (MSM) of pirarucu (*Arapaima gigas*).

cific fatty acid profile, indicating a product with potential to contribute positively to lipid health (HERNÁNDEZ-MARTÍNEZ et al., 2016).

The mineral composition further complements the nutritional value, with relevant levels of iron (important for oxygen transport), potassium (essential for electrolyte balance), and other minerals, making the sausage an interesting source of these micronutrients.

From a microbiological standpoint, the product proved to be safe for consumption, meeting the microbiological standards established by Normative Instruction No. 60/2019 (MAPA). The absence of *Salmonella* spp. in 25 g and coagulase-positive *Staphylococcus* counts below the detection limit indicate that processing was conducted under appropriate hygienic conditions.

When compared with other studies using fish MSM, the results obtained here are promising. The protein content of the pirarucu sausage (14.12%) is higher than that reported for pâtés prepared with tilapia MSM (MATIUCCI et al., 2021) and *Brycon amazonicus* MSM (MATIUCCI et al., 2021). The lipid profile, rich in *n*-3 PUFA, was also more favorable than that observed in cuts from other freshwater species such as pangasius *Pangasius hypophthalmus* and pintado *Pseudoplatystoma corruscans* (SCHERR et al., 2015; SOUZA; TOBAL, 2021), reinforcing the nutritional advantage of pirarucu.

In summary, the pirarucu MSM sausage is presented as an innovative, safe product with high nutritional value. It aligns perfectly with initiatives aimed at waste utilization and valorization of native resources and may represent an interesting alternative

for school meals through programs such as the Brazilian National School Feeding Program (PNAE) (LEONEL et al., 2019), in addition to offering a new option for the fish market, meeting the demands of consumers seeking tasty, nutritious, and functional foods.

CONCLUSION

The study successfully demonstrated the potential of mechanically separated meat (MSM) from pirarucu for the development of a safe sausage with high nutritional value. The product fully met legal requirements, with emphasis on its high protein content (14.12%), balanced lipid profile rich in unsaturated fatty acids (72.71%) and omega-3 fatty acids (EPA and DHA), as well as its relevant mineral composition. From a microbiological standpoint, the product proved safe for consumption, complying with the standards established by Normative Instruction No. 60 of December 23, 2019, issued by MAPA. Therefore, the pirarucu MSM sausage is presented as an innovative, nutritious, and sustainable alternative, capable of adding value to filleting by-products and meeting the demands of consumers seeking functional foods.

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