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Minerals, omegas, and lipid quality in mechanically separated meat from *Arapaima gigas* filleting residue

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ABSTRACT: The aimed of this study was to determine mineral and lipid profile of mechanically separated meat (MSM) from filleting residue of pirarucu (*Arapaima gigas*). The data were obtained from six 4 cm^2 with 50g samples, frozen until the time of compositional analysis. MSM revealed 1.16 ± 0.18 mg $100g^{-1}$ total iron, 255.84 ± 40.93 mg $100g^{-1}$ Na^+, 298.00 ± 47.68 mg $100g^{-1}$ K^+, 16.40 ± 2.62 mg $100g^{-1}$ Ca^{2+} and 11.28 ± 1.80 mg $100g^{-1}$ Mg^{2+}, in addition to 31.9280% SFAs, 40.0456% MUFAs and 28.0264% PUFAs. Essential fatty acids stand out with 1.0009 ± 0.008% α-Linolenic acid (ALA), 4.1555 ± 0.009% Linoleic acid (AA), 6.1760 ± 0.004% Eicosapentanoic acid (EPA) and 4.4146 ± 0.003% Docosahexaenoic acid (DHA), in addition to significant values of omegas: 12.9215% n-3, 15.1049% n-6, 3.5070% n-7 and 36.0700% n-9. The indices were found 0.8780 for PUFAs/SFAs, 1.1690 for n-6/n-3, 0.3591 for IA, 0.4165 for IT and 2.4797 for h/H were found. Thus, it becomes feasible to destine pirarucu filleting residue MSM, for inclusion in food for humans and domestic and production animals.

Key words: essential fatty acids; fish farming; nutritional quality

Minerais, ômegas e qualidade lipídica em carne mecanicamente separada proveniente do resíduo da filetagem de *Arapaima gigas*

RESUMO: Esse estudo objetivou determinar o perfil mineral e lipídico da carne mecanicamente separada (CMS) do resíduo da filetagem do pirarucu (*Arapaima gigas*). Foram obtidas seis amostras de 4 cm^2 de 50g, congelados até o momento da análise de composição. A CMS apresentou 1,16 ± 0,18 mg $100g^{-1}$ de ferro total, 255,84 ± 40,93 mg $100g^{-1}$ de Na^+, 298,00 ± 47,68 mg $100g^{-1}$ de K^+, 16,40 ± 2,62 mg $100g^{-1}$ de Ca^{2+} e 11,28 ± 1,80 mg $100g^{-1}$ de Mg^{2+}, além de 31,9280% de SFAs, 40,0456% de MUFAs e 28,0264% de PUFAs. Quanto aos ácidos graxos essenciais, destacam-se 1,0009 ± 0,008% de ácido α-linolênico (ALA), 4,1555 ± 0,009% de ácido linoleico (AA), 6,1760 ± 0,004% de ácido eicosapentanoico (EPA) e 4,4146 ± 0,003% de ácido docosahexaenoico (DHA), além de valores significativos dos ômegas: 12,9215% de n-3, 15,1049% de n-6, 3,5070% de n-7 e 36,0700% de n-9. Foram encontrados os índices 0,8780 para PUFAs/SFAs, 1,1690 para n-6/n-3, 0,3591 para IA, 0,4165 para IT e 2,4797 para h/H. Deste modo, torna-se viável destinar a CMS de resíduo de filetagem de pirarucu, para inclusão na alimentação humana e de animais domésticos e de produção.

Palavras-chave: ácidos graxos essenciais; piscicultura; qualidade nutricional

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Introduction

Rondônia state is the largest producer of native fish in Brazil, corresponding to a total of 65.5 thousand tons of fish produced in year 2020 (Peixe BR, 2021), and has tambaqui (*Colossoma macropomum*) and pirarucu (*Arapaima gigas*), as a of the most commercialized fishes, corresponding to about 80% of the fish cultivated in Rondônia state (Meante & Dória, 2017). Thus, it is essential to know the composition of fish to encourage, encourage and promote consumption, factors that will allow the dissemination of fish meat as a protein of high biological value, adding commercial value and diversifying the processing of species, including those native to Amazon (Meante & Dória, 2017). The processing of new products and by-products originating from fish is essential so that different cuts/portions are available to consumer, favoring consistency in consumption (Signor et al., 2020).

MSM from fish filleting residue, also called minced fish, fish pulp or comminuted, mechanically deboned fish meat, among others, is the fish pulp separated from the skin and bones, in a deboning machine (Matiucci et al., 2021). The *Codex Alimentarius* defines MSM as a product obtained from a single species, or mixture of fish species with similar sensory characteristics, through mechanized processing of the edible belly, generating portions of skeletal muscle free of viscera, scales, bones, and skin (Signor et al., 2020). It is important to mention that the MSM is prepared by passing the gutted and headless fish or its residues through a meat and bone separator machine, which may or may not washed with water, drained, adjusted to moisture, packed in blocks and frozen in a quick freezer (Leonel et al., 2019).

Fish species that present complex processing and low acceptability, as well as the trimmings resulting from industrial fish filleting and ridges, normally showed as discarded residue, could used as food using this technology (Leonel et al., 2019). The use of such technology can rescue a portion of the fish normally destined for the production of flour for animal feed, adding value to a depreciated part of the catches (Guimarães et al., 2017). Environmental problems and the crisis of available food resources signal the need for research that focuses on the development and/or introduction of new technologies for food production, considering food safety, both in relation to a better use of the different raw materials, as in relation to food safety (Honma et al., 2020). Faced with this overview the fish industry has shown continuous development to meet the growing market demand and, at the same time, the amount of residue discarded due to processing has increased (Bernardo et al., 2020). However, the MSM was created for various uses, underused species of low commercial value, accompanying fauna, in addition to other niches (Guimarães et al., 2017).

In response to the overview mentioned, this study aimed to use the residue from filleting of pirarucu (*Arapaima gigas*), a high-value fish in the Rondônia state, Western Amazon.

Materials and Methods

This study was conducted by Universidade Federal de Rondônia (UNIR) and the analyzes were carried out at Laboratório de Águas e Alimentos, Departamento de Química, at Universidade Estadual de Maringá (UEM), receiving support from Fundação de Amparo à Pesquisa de Rondônia (FAPERO), and was approved by Ethics Committee on the Use of Animals, under protocol number 012/2021/CEUA/UNIR. Sample collections were carried out from May 2019 to December 2020 in a fish slaughter unit, registered in the Brazilian System of Inspection of Products of Animal Origin (SISBI-POA), located in the Vale do Paraíso municipality, RO, Brazil.

The sampled fish come from fish farms that use a semi-intensive system in excavated tanks. In the sampling period, 70 specimens of pirarucu (*Arapaima gigas*) were filleted with body weight 11.1 to 14.0 kg. The sampled fish were selected from fish farms previously characterized, excluding lots of production systems that adopted production management that differed from that adopted in fish farms, such as reports of parasite infestations, deaths from high stocking densities, undernutrition, cultivation in canvas or net tanks, among others.

The fish were removed from the tanks by averages of a fishing net, and then they went through the process of stunning by brain concussion, then they were euthanized by exsanguination by section of the carotid veins, according to procedures adopted by the slaughterhouses. In the processing industry the fish were washed, gutted and processed in commercial cuts according to market demand. The initial stage of processing the *A. gigas* was performed on the evisceration table, with the procedure of removing the skin with scales, removing the head and the viscera.

Among the commercial cuts, the slaughter unit prepared MSM from the residues of the processing in fillet mignon and tail fillet, which of the 70 filleted fish were sampled residues of 30 fillets. After the processing unit concluded the MSM production steps of *A. gigas* filleting residues (Figure 1A), six random samples of 4 cm^2 with 50g were obtained (Figure 1B). These samples were properly identified and stored at -8° C in a cooler and sent to a specialized laboratory (Figure 1C), where they were cut into 1 cm^2 pieces, weighed, identified, and placed in aluminum containers, being frozen at -20° C for 48 hours. The containers with the samples were labeled and frozen in a freezer at -18° C until the moment of composition analysis.

To avoid outliers to lipid composition data, the sampled fish (represented by their residues in MSM) were selected from fish farms previously characterized by slaughter unit. In addition, it is worth emphasizing that the methods of stunning, slaughter, use of filleting residues and MSM elaboration were carried out by fish slaughter unit.

For the quantification of macrominerals, an extract was obtained from the complete digestion of the sample in Sulfuric

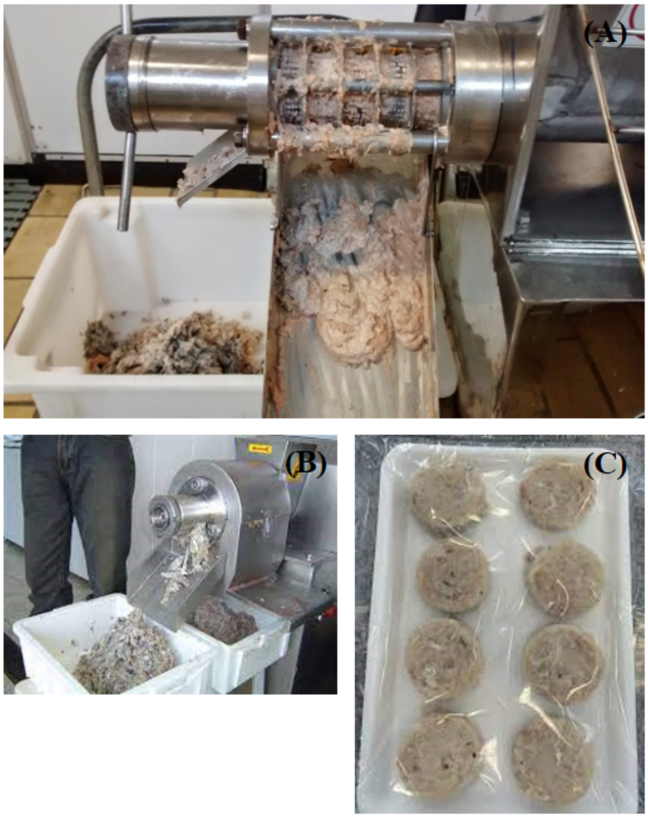

Figure 1. Production of MSM from pirarucu (*Arapaima gigas*) filleting residues. (A) Product from elaboration of MSM from filleting; (B) Collection of MSM samples in plastic containers; (C) MSM samples stored in cooler.

acid and high temperature (350 - 375° C). The microminerals were analyzed from extracts from samples of acid digestions under controlled temperatures, with Nitric acid (120° C) and Perchloric acid (180 - 190° C), Total iron (Fe^{2+} + Fe^{3+}) (Ruiz-de-Cenzano et al., 2013). To perform the measurements, a model AA 12/1475 atomic absorption spectrom-eter was used. The minerals Na^{+} and K^{+} were determined by the AOAC Official method 969.23 and the minerals Total iron, Ca^{2+} and Mg^{2+} were determined by the AOAC Official method 968.08 according to the methodology described by Cook (1997).

To evaluate the lipid composition, a lyophilizer LIOTOP L101 was used for 44 hours. Total lipids were extracted by method of Bligh & Dyer and methyl esters of fatty acids were prepared by methylation of triacylglycerols, as described in ISO method 5509 (ISO, 1978). Fatty acid methyl esters were analyzed using a 14-A gas chromatograph (Shimadzu, Japan), equipped with a flame ionization detector and fused silica capillary column (50 m long, 0.25 mm internal diameter and 0.20 µm Carbowax 20M film thickness). The flows of ultrapure gases (White Martins) were 1.2 mL min^{-1} for the carrier gas (H_2); 30 mL min^{-1} for make-up gas (N_2); 30- and 300-mL min^{-1}, and for flame gases H_2 and synthetic air, respectively.

The injection volume was in µL and sample split ratio was 1:100 (Santos et al., 2017). The column temperature was programmed at a rate of 2° C min^{-1}, from 150° to 240° C. The inlet and detector temperatures were 220° and 245° C, respectively. As well as Santos et al. (2017), peak areas were determined using the Integrator-Processor CG-300 (CG scientific instruments) and peak identification was performed by comparison with the retention times of the standard (Sigma, USA).

Fatty acid profile data were pooled to calculate the ratio of polyunsaturated fatty acids to saturated fatty acids PUFAS/SFAs, ratio of n-6/n-3 omegas, following WHO prescriptions. The other data found by lipid quality indices were compared with indices recommended in the Literature, as main examples Hernández-Martínez et al. (2016), Passos et al. (2016), Rodrigues et al. (2017), and Souza & Tobal (2021).

The nutritional quality of lipid fraction was also calculated from fatty acid profile through the atherogenicity (AI), thrombogenicity (TI) indices and the ratio between hypocholesterolemic and hypercholesterolemic fatty acids (h/H) (Rodrigues et al., 2017). For these evaluations, the following mathematical formulas were used: a) Atherogenicity Index (AI) = [(12:0 + 4 x 14:0 + 16:0)]/ΣMUFAs + Σn-6 + Σn-3; b) Thrombogenicity Index (TI) = (14:0 + 16:0 + 18:0)/[(0.5 x ΣMUFAs) + (0.5 x Σn-6) + (3 x Σn-3) + (Σn-3/n-6)]; c) Ratios between hypocholesterolemic and hypercholesterolemic fatty acids (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).

Results

MSM from *A. gigas* filleting residue is composed of the mineral elements, 1.16 ± 0.18 mg $100g^{-1}$ of total iron, 255.84 ± 40.93 mg $100g^{-1}$ of Na^{+}, 298.00 ± 47.68 mg $100g^{-1}$ of K^{+}, 16.40 ± 2.62 mg $100g^{-1}$ of Ca^{2+} and 11.28 ± 1.80 mg $100g^{-1}$ of Mg^{2+} (Table 1).

In the lipid composition, 31.9280% saturated fatty acids (SFAs), 40.0456% monounsaturated fatty acids (MUFAs) and 28.0264% polyunsaturated fatty acids (PUFAs) were found. Among these values, the percentages of essential fatty acids stand out, 1.0009 ± 0.008% of α-Linolenic acid (ALA), 4.1555 ± 0.009% of Linoleic acid (AA), 6.1760 ± 0.004% of Eicosapentaenoic acid (EPA) and 4.4146 ± 0.003% Docosahexaenoic acid (DHA) (Table 2).

From fatty acid profile data, 12.9215% of n-3, 15.1049% of n-6, 3.5070% of n-7 and 36.0700% of n-9 were found. Regarding the lipid quality indices, 0.8780 were found for PUFAs/SFAs, 1.1690 for n-6/n-3, 0.3591 for AI, 0.4165 for TI and 2.4797 for h/H (Table 3).

Table 1. Mineral profile (mg $100g^{-1}$) of MSM from pirarucu (*Arapaima gigas*) filleting residue.

Mineral profile	
Mineral elements	**Values (mg $100g^{-1}$)**
Total iron[1]	1.16 ± 0.18
Sodium (Na^{+})	255.84 ± 40.93
Potassium (K^{+})	298.00 ± 47.68
Calcium (Ca^{2+})	16.40 ± 2.62
Magnesium (Mg^{2+})	11.28 ± 1.80

[1]Total iron = Fe^{2+} + Fe^{3+}.

Table 2. Fatty acid profile (%) of MSM from pirarucu (*Arapaima gigas*) filleting residue.

Usual nomenclature / symbology	Values in fatty acids (%)
Lauric acid[1]/ C12:0	1.4200 ± 0.010
Myristic acid [1]/ C14:0	0.4845 ± 0.003
Pentadecylic acid[1]/ C15:0	0.0815 ± 0.001
Palmitic acid[1]/ C16:0	21.0900 ± 0.100
Margaric acid[1]/ C17:0	0.2850 ± 0.003
Stearic acid[1]/ C18:0	6.4100 ± 0.100
Arachidic acid[1]/ C20:0	0.3770 ± 0.001
Behenic acid[1]/ C22:0	0.3320 ± 0.004
Lignoceric acid[1]/ C24:0	0.5900 ± 0.015
Palmitoleic acid[2]/ C16:1 *n*-7	0.4060 ± 0.008
Cis-10-heptadecenoic acid[2]/ C17:1	0.4606 ± 0.0+03
Oleic acid[2]/ C18:1 *n*-9	30.988 ± 0.023
Vaccenic acid[2]/ C18:1 *n*-7	3.1010 ± 0.011
Gondoic acid[2]/ C20:1 *n*-9	0.2030 ± 0.001
Erucic acid[2]/ C22:1 *n*-9	0.3130 ± 0.002
α-Linolenic acid (ALA)[2]/ C18:3 *n*-3	1.0009 ± 0.008
Dihomo-α-linolenic acid[2]/ C20:3 *n*-3	1.3300 ± 0.005
Eicosapentaenoic acid (EPA)[2]/ C20:5 *n*-3	6.1760 ± 0.004
Linoleic acid (AA)[2]/ C18:2 *n*-6	2.0505 ± 0.008
Gamma linolenic acid (GLA)[2]/ C18:3 *n*-6	0.5080 ± 0.004
Eicosadienoic acid[2]/ C20:2 *n*-6	0.2120 ± 0.002
Dihomo-Gamma-linolenic acid (DGLA)[2]/ C20:3 *n*-6	0.5050 ± 0.004
Arachidonic acid[2]/ C20:4 *n*-6	4.1555 ± 0.009
Docosahexaenoic acid (DHA)[2]/ C22:6 *n*-3	4.4146 ± 0.003
Others*	
Summation (∑)	
Saturated fatty acids (SFAs)	31.9280
Monounsaturated fatty acids (MUFAs)	40.0456
Unsaturated fatty acids (UFAs)	68.0720
Polyunsaturated fatty acids (PUFAs)	28.0264

*Other fatty acids that appeared in minimal amounts, when evaluated individually; Saturation: [1]saturated fat; [2]unsaturated fat; or saturated fatty acids (SFAs), ymonounsaturated (MUFAs) and zpolyunsaturated fatty acids (PUFAs).

Table 3. Omegas and MSM lipid quality indices from pirarucu (*Arapaima gigas*) filleting residue.

Variables		Values (%)[1]
Omegas	∑PUFAs (*n*-3)	12.9215
	∑PUFAs (*n*-6)	15.1049
	∑PUFAs (*n*-7)	3.5070
	∑PUFAs (*n*-9)	36.0700
Lipid quality indices	UFAs/SFAs	2.1320
	PUFAs (*n*-6/*n*-3)	1.1690
	AI[2]	0.3591
	TI[3]	0.4165
	h/H[4]	2.4797

Results expressed as percentage (%) of total fatty acids. Saturation: saturated (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs) fatty acids; [1]Percentage of total fatty acids; [2]Atherogenicity Index (AI); [3]Thrombogenicity Index (TI); [4]Ratio between hypocholesterolemic and hypercholesterolemic fatty acids (h/H).

Discussion

Large-scale production of MSM is difficult, and even more complex in native fish. However, when transformed into simpler products, it allows the production of high added value products. This meets the societal need for premium quality animal protein (Sozo et al., 2017). The trend of full use of fish, as in other sectors, poultry and beef, means that it can fully exploited, generating new products that are more accessible to consumers (Zamorano et al., 2019). The elaboration of fish MSM is advantageous, when it is related to greater profitability of the fish industry. Its use has been a practice widely used in the fish processing industries, because it achieves a greater yield of the meat and its use in the elaboration of a wide range of fish products, such as hamburgers, sausages, breaded, meatballs, pâtés, canned goods and others (Guimarães et al., 2017). Souza & Tobal (2021), obtained a MSM protein concentrate *Pseudoplatystoma corruscans* from fish farming. The authors used the chemical method of washing pH basified and centrifuged, and found a product with 74.54% moisture, 46.26 lipids and 41.23% crude proteins. While Matiucci et al. (2021) elaborated formulations of MSM pâté *Brycon amazonicus* from fish farming and characterized regarding yield of the species, the physicochemical parameters of the raw material and the final product and its sensorial characterization. The values found for the final products for formulation with 100% MSM were 61.65% of moisture, 10.35% of proteins, 24.40% of lipids, 1.85% of minerals and 1.75% of carbohydrates. As for the sensorial analysis, the pâté formulation with 100% of cooked *B. amazonicus* MSM obtained better averages, 94 and 86%, for acceptability and consumption attitude, respectively.

Still comparing the results of this study with Matiucci et al. (2021) elaborated pâtés from residue from fish processing [Nile tilapia (*Oreochromis niloticus*) + natives' fish from Brazil)] with the inclusion of smoked fish meal and evaluated the sensory, microbiological, physicochemical and shelf-life characteristics. Including the fish meal produced in the diet of dogs and cats, they obtained an 67% acceptance. In another study, Costa et al. (2016) conducted a flour elaboration processing from Nile tilapia MSM and evaluated its mineral composition, amino acids and fatty acids, as well as mathematical models to represent drying curves and sorption isotherms. The researchers found flour high in n-3 fatty acids and the minerals magnesium, potassium, phosphorus, total iron and calcium. The results suggested that the flour obtained under these conditions can destined for human consumption, proving to a viable alternative for the use of residue from filleting process.

In a longer study compared to the current research, Bernardo et al. (2020) developed a fish-based biscuit (Nile tilapia + natives' fish from Brazil) with high nutritional value that could stored at room temperature for 180 days. MSM produced expressed low economic value and was the raw material used to produce two types of fish cookie: the traditional cookie (keropok), which is expanded by frying in oil, and a microwave-expanded cookie, with low lipid content. Protein content was high at 10.86 and 14.70%, respectively. Both cookies had essential amino acid levels above the FAO recommended for adults, with lysine content higher than recommended for children. The sensory analysis performed by adult tasters showed a high level of acceptance of the cookies, 90 and 97%, respectively. Storage in vacuum packaging allowed the product to maintain its microbiological quality and physicochemical properties for 180 days at room temperature.

When studying sausage products from Nile tilapia filleting, Costa et al. (2016) developed a hamburger with MSM from carcass and fillet of Nile tilapia, without the use of additives. The effects of washing on chemical stability during freezing storage, chemical composition, and colorimetry of MSM were first investigated. The product showed itself with high nutritional quality (proteins, minerals, and healthy fats) but with low acceptance by the animals. In this way, the formulation of hamburgers with lower amounts of washed MSM from the carcass, or added with a greater amount of seasonings, can result in an improvement in sensory acceptance and feasibility of application. Meantime, Matiucci et al. (2021), technology for the use of clean residue from industrialization of Nile tilapia, using MSM from Nile tilapia filleting, in order to prepare creamy and pasty pâté, and investigated the physicochemical, microbiological and sensory characteristics. In its composition, 58.03% of moisture, 3.26% of minerals, 3.01% of proteins, 9.69% of lipids and 3.83% of carbohydrates were found. The pâté formulations developed met microbiological standards and identity and quality standards for fish-based products. In the sensory evaluation, greater acceptability was observed for the creamy pâté.

Comparing the current study with the percentage of fatty acids SFAs, MUFAs and PUFAs of the Scherr et al. (2015), and Souza & Tobal (2021), when evaluating the fatty acid profile in frozen whole cuts of *Pseudoplatystoma corruscans*, *Clarias gariepinus*, *Pangasius hypophthalmus*, *Piaractus mesopotamicus* and *Pangasius boccourti*, respectively, found percentages of PUFAs lower than the 28% obtained in MSM from *A. gigas* filleting residue, which were 18.10; 20.50, 12.45, 18.00 and 14.80, respectively (Table 2). Althoughin, the MSM from pirarucu filleting residue, PUFAs were found at values equivalent (between 15 and 22%) to those of other freshwater fish species, such as *Brycon orbignyanus*, *B. microlepsis* and *B. cephalus*. However, MSM from A. gigas filleting residue is composed of higher percentages of omegas 3, 6, 7 and n-9, such as C18:3 (ALA), C20:5 (EPA) and C22:6 (DHA), essential for the human health (Martins et al., 2017). Regarding the EPA and DHA content found (Scherr et al., 2015) when evaluating the fatty acid profile of *Pangasius hypophthalmus* fillets EPA 0.19 and DHA 0.083, *Ictalurus punctatus* DHA 0.75 and *Piaractus mesopotamicus* DHA 1.90 found lower percentages of EPA and DHA compared to MSM *A. gigas* residue. Furthermore, Ng et al. (2003) when evaluating fillets of *Clarias gariepinus* DHA 2.00 and *Pseduplatystoma corruscans* DHA 2.20 found lower percentages in relation to MSM from *A. gigas* filleting residue, with values above 4.1.

It is important to emphasize the presence of n-7 in this study (Table 2), because it is a nutrient responsible for increasing insulin sensitivity, preventing type 2 diabetes. It reduces inflammatory processes and LDL levels-cholesterol, in addition to improving the elasticity of the arteries. In summary, it helps in the treatment of metabolic syndromes (Passos et al., 2016). Palmitoleic acid is an n-7 series fatty acid, which has been gaining prominence in scientific publications because it is considered a potent anti-inflammatory. Therefore, some studies propose its consumption to reduce the risk of inflammatory and metabolic diseases (Frigolet & Gutiérrez-Angular, 2017). Thus, n-7 consumption is suggested to reduce this trigger related to diabetes and other metabolic diseases (Bernardo et al., 2020).

Regarding nutritional quality indices, a method prescribed by the WHO to assess lipid quality is based on the ratio of UFAs/SFAs fatty acids, with values below 0.45 being considered unhealthy. MSM from *A. gigas* filleting residue expressed a value of 2.132 (Table 3). This average high lipid quality for this index, expressing a much higher proportion of UFAs in relation to SFAs. According to lipid quality data tabulated by some studies (Passos et al., 2016; Rodrigues et al., 2017; Xiyang et al., 2020; Souza & Tobal, 2021), the results of the Atherogenicity Index (AI), the Thrombogenicity Index (TI) and the ratio between hypocholesterolemic and hypercholesterolemic (h/H) fatty acids expressed in Table 3 express high lipid quality. More specifically, the values found were 0.3591 for AI, 0.4165 for TI and 2.4797 for h/H (Table 3). TI and AI indices are related to potential to stimulate platelet aggregation. Therefore, values lower than those found in this research indicate a high amount of antiatherogenic acids in a given fat or oil, with a correspondingly increased potential to prevent the onset of coronary heart disease (Martins et al., 2017). On the other hand, a higher proportion of h/H obtained in the MSM from *A. gigas* filleting residue, indicates greater nutritional adequacy (oil or fat) for human consumption and animal feed, because this index is related to cholesterol metabolism (Xiyang et al., 2020).

Finally, Leonel et al. (2019) and Cavenaghi-Altemio et al. (2021) cite several studies that recommend the inclusion of MSM from *A. gigas* filleting residues in the production of cookies, snacks and kibbehs to offered in high school lunches, carried out through the Programa Nacional de Alimentação Escolar (PNAE), more specifically by the Programa de Aquisição de Alimentos (PAA). In this way, it is a strategy that can used to promote food security and a diet with nutritional quality for young people and children, in the public education network, at the same time promoting rural development. This program also encourages improvements in the quality of rural production and, in addition, encourages the diversification of the family farming production matrix.

Conclusion

Elaboration of MSM from pirarucu (*Arapaima gigas*) filleting residues, generates a product of nutritional quality, due to presence of essential fatty acids, α-Linolenic acid, Linoleic acid, Eicosapentanoic acid and Docosahexaenoic acid, in addition to omegas -3, -6, -7 and n-9, and excellent indices of lipid quality, PUFAs/SFAs, n-6/n-3, AI, TI and h/H. Based on the results, it is nutritionally feasible to allocate *A. gigas* filleting residue to MSM for inclusion in the food for humans and domestic and production animals. It is suggested the development of studies on the acceptability of this product included in the composition of rations, in addition to market studies to verify the economic viability.

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Compliance with Ethical Standards

Author contributions: Conceptualization: JVDF, JC; Data curation: JVDF, JC; Investigation: JVDF, GBS, SVS, ABM; Methodology: JVDF, GBS, SVS, ABM; Project administration: JVDF, JC; Resources: JVDF, GBS, SVS, ABM; Supervision: SVS, FBH, JC; Validation: SVS, FBH, JC; Visualization: JVDF, GBS, SVS, ABM; Writing - original draft: JVDF, GBS, ABM; Writing - review & editing: SVS, FBH.

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