Research Article

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Nutritional quality in roes of tambaqui (*Colossoma macropomum*) raised in fish ponds in Rondônia state, Brazil

Abstract

Background: The roes of tambaqui (*Colossoma macropomum*) - Amazon caviar - are co-products from fish processing that have a high nutritional value and can be considered a nutritionally viable alternative for human and animal consumption, in addition to the possibility of using them for lipid extraction.

Objective: The aim of this study was to determine the nutritional quality in roes of tambaqui raised in fish ponds in Rondônia state, Brazil.

Main Body: A total of 3 samples of 20 specimens of tambaqui were collected in a fish processing unit, registered in the Brazilian System of Inspection of Products of Animal Origin (SISBI-POA), located in the municipality of Vale do Paraíso, Rondônia state, Brazil. The results obtained were proximate composition (in 100g), 1.77g of mineral matter, 17.77g of crude protein, 12.24g of total lipids and 79.94% moisture. A mineral profile (in 100g) was obtained, 6.21 mg of total iron, 49.18 mg of Na^+, 309.17 mg of K^+, 473.93 mg of Ca^{2+} and 162.6 mg of Mg^{2+}. They also contain essential fatty acids such as EPA 2 *n*-6) 1.39%, DHA (C22:6 *n*-3) 0.40%, ALA (C18:3 *n*-3) 0.53% and AA (C18 :2 *n*-6) 9.61% and high quality indices UFAs/SFAs 1.26, UFAs (*n*-6/*n*-3) 5.44, TI 0.47, AI 0.53 and h/H 1, 74. The tambaqui roes showed good nutritional parameters with a significant amount of essential fatty acids and good lipid quality indeces.

Keywords: Amazonian caviar, co-product of fish processing, essential fats, fatty acid profile, lipid quality

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Introduction

Rondônia is a Brazilian state belonging to the North region and bathed by the Amazon basin. Rondônia state the largest producer of native fish species in Brazil, the most recent estimate for year 2023 highlighted Rondônia with a fishing production of 57,200 thousand tons.[1] The tambaqui *Colossoma macropomum* (Cuvier, 1818) is the most cultivated native fish in Rondônia state and in Brazil, around 85% of the fish raised in Rondôna state is represented by this species.[2] Some researchers attribute the success of fish farming in Rondônia to environmental aspects such as super humid climatic conditions, the proximity of a large consumer market such as the city of Manaus, added to the high availability of water from the large Amazon rivers, especially the Madeira and Mamoré rivers, tributaries of the Amazon River.[2,3] Scientific research revealed that the habit of consuming fish is strongly associated with a low incidence of cardiovascular diseases, due to fish being composed of low saturation fats and essential fatty acids.[4,5]

It is known that meat is the main product of interest to the fish industry, however residues and co-products from fish farming have increased due to technologies in the industrialization of fish. There are more and more studies aimed at characterizing these residues according to their chemical composition and possible uses.[6,7] Fish viscera in general have high nutritional value, including minerals, proteins and lipids,[8,9] essential amino acids, polyfats and acids polyunsaturated, with emphasis on omega3 *n*-3,[10] which can be added to fishmeal and essential oils.[11] Furthermore, the residue from fish processing can be used for better use in several alternative lines in the consumer market, such as: pet feeds, fertilizers for agriculture and gardening, agrochemicals, immunomodulators, oil rich in *n*-3, human food (fishpâtét and mechanically separated – MSM prepared by the processing unit), including biodiesel extraction processes and other value-added products.[10,12] The optimized use of these products from the food industry is a great alternative to reduce the lack of animal products rich in proteins and at the same time composed of healthy fats.

Given the assumptions presented above, it is reasonable to consider the use and processing of residues from fish processing, such as fertilizers for agriculture and gardening,[13] silage production[14,15] or hydrolysates,[16] reused alternatives in animal nutrition and agrochemicals, as well as other benefits to the consumer market such as ecological leather from fish skin in the manufacture of shoes, bags, carpets and other leather products.[17] According to Cavali et al.[7] and Vilhena et al.,[18] the above-mentioned co-products provide interesting advantages for the fish farming sector, as they are a low-cost raw material simultaneously with high productivity, and are also capable of minimizing the problem of waste from fish processing. Given the information presented, the benefits arising from regular consumption of fish and commercial availability for consumption. The aim of this study was to determine the nutritional quality in roes of tambaqui raised in fish ponds in Rondônia state, Brazil.

Material and methods

This research was carried out by the Universidade Federal de Rondônia (UNIR) and the analyzes were carried out at the Laboratório de Águas e Alimentos, Chemistry Department, at the Universidade Estadual de Maringá (UEM), Maringá city, Paraná state, Brazil. The research was supported by the Fundação Rondônia de Amparo ao Desenvolvimento das Ações Científicas e Tecnológicas e à Pesquisa do Estado de Rondônia (FAPERO), and the current study were approved by the Ethics Committee on the Use of Animals (CEUA/UNIR) with protocol No. 012/2021/UNIR. Sample collections were carried out from January to October 2022, in a fish processing unit, registered with the Sistema Brasileiro de Inspeção de Produtos de Origem Animal (SISBI-POA), located in the municipality of Vale do Paraíso, Rondônia state.

Sampling procedures

A total of 3 roe samples (triplicates) were taken from 20 specimens of tambaqui (*Colossoma macropomum*), totaling 60 samples analyzed. The processed fish were in the ideal weight category for slaughter/commercialization, from 2.41 to 3.50 kg.[19] It is worth noting that the fish sampled were selected from previously characterized fish ponds, not considering batches from production systems that adopt management discrepant production to that employed in fish ponds. Examples include reports of parasite infestations, deaths due to high stocking densities, malnutrition, among others.[20]

The fish were removed from the ponds using a fishing net, and then went through the pre-slaughter stunning process by thermonarcosis. The tambaquis captured and stunned were euthanized using the exsanguination method, through the section of the carotid gills, in accordance with the procedures adopted by fish processing units in the state of Rondônia.[21] In the processing unit, the fish were washed, eviscerated and processed into commercial cuts according to market demand. Finally, the roe samples were destined for analysis, which were obtained from the homogenization of three points of the roe, in order to obtain greater representativeness.

Assessment of proximate composition and energy value

Roe samples were first lyophilized, to later obtain the content of dry matter, ash which will be referred to with mineral matter, crude protein and total lipids.[22] Concerning the lipids assesment, a total fo 3.5g of the lyophilized sample were used and the lipids were extracted with ethanol and chloroform.[23] Regarding the macrominerals assessment, an extract was obtained from complete digestion of the sample in Sulfuric acid at high temperature (350-375°C). Regarding the microminerals analyzed from extracts of acid digestion samples under controlled temperatures, with Nitric acid (120°C) and Perchloric acid (180-190°C).[22]

To quantify the minerals in the tambaqui roe samples, an Atomic Absorption Spectrometer (model AA 12/1475, USA) was then used. The results were obtained from ash, here called mineral matter, concerning the minerals sodium (Na^+), potassium (K^+), total iron (Fe^{2+}+ Fe^{3+}), calcium (Ca^{2+}), and magnesium (Mg^{2+}) were determined by the AOAC Official method 969.23 and 968.08.[24] Based on data on proteins, lipids and carbohydrates, the values in calories (kcal) per 100g of tambaqui roe were obtained. Once this theoretical calculation was completed, the data was converted into an energy value (KJ 100g^{-1}).[24]

Assessment of mineral profile and average percentage daily supply

When quantifying macrominerals, an extract was obtained from complete digestion of the sample in Sulfuric acid and high temperature (350 - 375°C). Microminerals were analyzed from extracts of acid digestion samples under controlled temperatures, with Nitric acid (120° C) and Perchloric acid (180 - 190° C), total iron (Fe^{2+}+ Fe^{3+}).[25] To carry out the measurements, it was An Atomic Absorption Spectrometer (model AA 12/1475, USA) 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.[24]

Based on the results of tambaqui roe mineral profile, they will be contrasted with the minimum daily mineral supply values (men and women adults).[26,27] The comparative analysis will be carried out by calculating the daily supply (Vdsm %) to recommendations for daily consumption (mg day^{-1}) of minerals (recommended by the WHO).[27] For this, the calculation showed in Equation (1) was carried out.

Vdsm= Vmf/Vmr x 100.[26] (1)

Where: Vdsm = Percentage of the daily value of the mineral supply; mineral value found (in 100g); minimum mineral value for daily consumption (recommended by WHO).[27]

Assessment of fatty acid profile and lipid quality indices

The method of Bligh and Dyer[28] was adopted for lipid extraction and the International Organization for Standardization (ISO 550929) was adopted for the extraction of methyl esters from fatty acids, through the methylation of triacylglycerols. Then, a 14-A Gas chromatograph (Shimadzu, Japan) was used to analyze the methyl esters of fatty acids. This chromatograph had a flame ionization detector and fused silica capillary column (50 m long, 0.25 mm internal diameter and 0.20 µm Carbowax 20M).

Ultrapure gas flows (White Martins) were 1.2 mL min^{-1} for carrier gas (H_2); 30 mL min^{-1} for the auxiliary gas (makeup) (N_2); 30 and 300 mL min^{-1} for flame gases, H_2 and synthetic air, respectively. The sample division ratio (split) was 1/100.[29] The column temperature was programmed at a rate of 2º C min^{-1}, from 150 to 240º C. The injector and detector temperatures were 220 and 245º C, respectively. Like Justi et al.,[29] the peak areas were determined using the CG-300 Integrator-Processor (CG scientific instruments) and the peaks were identified by comparison with the retention times of the standards (Sigma, USA).

Finally, based on the fatty acid profile in tambaqui roe, lipid quality indices were calculated. Firstly, the UFAs/SFAs and *n*-6/*n*-3 relationships were found following WHO guidelines.[26,27] Based on the results of these relationships and the values in omegas 3,6,7 and *n*-9, then the indices were calculated Atherogenicity (Equation 2), Thrombogenicity (Equation 3) and the ratio between hypocholesterolemic and hypercholesterolemic fatty acids (Equation 4) were calculated.

$$AI = [(12{:}0 + 4 \times 14{:}0 + 16{:}0)] / \Sigma MUFAs + \Sigma n\text{-}6 + \Sigma n\text{-}3 \quad (2)$$
[30]

$$TI = (14{:}0 + 16{:}0 + 18{:}0) / [(0.5 \times \Sigma MUFAs) + (0.5 \times \Sigma n\text{-}6) + (3 \times \Sigma n\text{-}3) + (\Sigma n\text{-}3/n\text{-}6)] \quad (3)$$
[30]

$$h/H = (18{:}1\ n\text{-}9 + 18{:}2\ n\text{-}6 + 20{:}4\ n\text{-}6 + 18{:}3\ n\text{-}3 + 20{:}5\ n\text{-}3 + 22{:}5\ n\text{-}3 + 22{:}6\ n\text{-}6)/(14{:}0 + 16{:}0). \quad (4)$$
[31]

Results

Tambaqui roe is composed of 1.77g $100g^{-1}$ of mineral matter, 17.77g $100g^{-1}$ of crude protein, 12.24g $100g^{-1}$ of total lipids and 79.94% moisture. The caloric value found was 181.24 kcal $100g^{-1}$, corresponding to 758.31 KJ $100g^{-1}$ of energy value. As for the mineral profile, 6.21 mg $100g^{-1}$ of total iron, 49.18 mg $100g^{-1}$ of Na^+, 309.17 mg $100g^{-1}$ of K^+, 473.93 mg $100g^{-1}$ of Ca^{2+} and 162, 6 mg $100g^{-1}$ of Mg^{2+}.

According to the minimum daily mineral supply values recommended by the WHO[27], total iron 8.0mg day^{-1} for men and 18mg day^{-1} for women, Na^+ 2,000mg day^{-1}, K^+ 3,510mg day^{-1}, Ca^{2+} 1,000 mg day^{-1} and Mg^{2+} 400mg day^{-1}. Using these parameters, the results were that 100g of tambaqui roe supplies 77.63% of the daily value Vdsm of total iron recommended for men and 34.50% for women. And, 100g of tambaqui roe supplies 2.46% of the Vdsm for Na^+, 8.81% of the Vdsm for K^+, 47.39% of the Vdsm for Ca^{2+} and 40.65% of the Vdsm for Mg^{2+} (Table 1).

Table 1 Daily supply (%) in roes of tambaqui (*Colossoma macropomum*) depending on the recommendations for average daily consumption (mg day^{-1}) of the minerals iron, sodium, potassium, calcium and magnesium for adults (men and women)

Minerals	Daily supply (DS%)[1]
Ferro total	77.63[#] – 34.50[*]
Sodium (Na+)	2.46
Potassium (K+)	8.81
Calcium (Ca2+)	47.39
Magnesium (Mg2+)	40.65

[1]DS (supply in 100g of tambaqui roe. (for men[#]–women[*] adults).

Regarding the profile of fatty acids found in tambaqui roe, 43.76% saturated fatty acids (SFAs), 55.32% unsaturated fatty acids (UFAs), which corresponded to 49.69% polyunsaturated fatty acids (PUFAs). Stearic acid (C18:0) represented 13.53%, the highest percentage among SFAs. While Oleic acid (C18:1 *n*-9) represented 35.19%, Linoleic acid (AA C18:2 *n*-6) represented 9.61%, Palmitoleic acid (C16:1 *n*-7) represented 3.07% and Vaccenic acid (C18:1 *n*-7) represented 2.03% of UFAs. Essential fatty acids were found, EPA (C20:2 *n*-6) 1.39%, DHA (C22:6 *n*-3) 0.40%, ALA (C18:3 *n*-3) 0.53% and AA (C18:2 *n*-6) 9.61% (Table 2).

A total of *n*-3 1.97%, *n*-6 10.71%, *n*-7 5.10% and *n*-9 36.11% were found. Concerning the lipid quality indices, 1.26 were found for UFAs/SFAs, 1.26 were found for UFAs/SFAs, 5.44 for *n*-6/*n*-3 (Table 3).

Table 2 Fatty acid profile (%) in roles of tambaqui (*Colossoma macropomum*)

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

Usual nomenclature/symbols	Average values (%)
Lauric acid[1]/ C12:0	1.24
n-Tridecylic acid[1]/C13:0	0.24
Myristic acid[1]/ C14:0	0.7
Pentacylic acid[1]/ C15:0	0.09
Palmitic acid[1]/ C16:0	25.84
Margaric acid[1]/ C17:0	0.25
Stearic acid[1]/ C18:0	13.53
Arachidic acid[1]/ C20:0	0.31
n-Heneicosoic acid[1]/ C21:0	0.34
Behenic acid[1]/ C22:0	0.84
Lignoceric acid[1]/ C24:0	0.38
Palmitoleic acid[2]/ C16:1 n-7	3.07
cis-10-Heptadecenoic acid[2]/ C17:1	0.53
Oleic acid[2]/ C18:1 n-9	35.19
Vacenic acid/[2]/ C18:1 n-7	2.03
Gondoic acid[2]/ C20:1 n-9	0.19
Erucic acid[2]/ C22:1 n-9	0.24
α-Linolenic acid (ALA)[2]/ C18:3 n-3	0.53
Dihomo-α-linolenic acid[2]/ C20:3 n-3	0.43
Eicosapentaenoic acid (EPA)[2]/ C20:5 n-3	0.61
Linoleic acid (AA)[2]/ C18:2 n-6	9.61
y-Linolenic acid (GLA)[2]/ C18:3 n-6	0.2
Eicosapentaenoic (thymnodonic) acid (EPA)[2]/ C20:2 n-6	1.39
Dihomo-gamma-linolenic acid dihomo-y-linolenic acid (DGLA)[2]/ C20:3 n-6	0.17
Arachidonic acid[2]/ C20:4 n-6	0.24
Docosahexanoic (cervonic) acid (DHA)[2]/ C22:6 n-3	0.4
Nervonic acid[2]/ C24:1 n-9	0.49
Others*	2.83
Sum (∑)	
SFAs	43.76
MUFAs	5.63
UFAs	55.32
PUFAs	49.69

Table 3 Omegas and lipid quality indices in roles of tambaqui (*Colossoma macropomum*)

Variables		Values (%)1
Omegas	n-3	1.97
	n-6	10.71
	n-7	5.1
	n-9	36.11
	UFAs/SFAs	1.26
Indices	n-6/n-3	5.44
	AI	0.53
	TI	0.47
	h/H	1.74

Results expressed as percentage (%) of total fatty acids. Saturation: saturated fatty acids (SFAs), unsaturated fatty acids (UFAs); Percentage of total fatty acids; Atherogenicity index (AI); Thrombogenicity index (TI); Ratio between hypocholesterolemic and hypercholesterolemic fatty acids (h/H).

Discussion

Guimarães et al.[32] found in tambaqui residues weighing 500 to 800g, they found 75.67% moisture, 7.08% protein, 8.83% lipids, 3.81% minerals, 4.61% carbohydrates and caloric value of 126.3 kcal $100g^{-1}$. It is noteworthy that tambaqui roe can be considered a rich source of iron for men, a mineral that is responsible for transporting oxygen in the human body, essential for the correct development of the most diverse physiological functions and a good source for women.[33]

Furthermore, we can consider roe as a co-product of fish processing, and is a good source and supply of calcium and magnesium, Mg^{2+} is important in the performance of muscle contraction and nervous transmission, in turn, Ca^{2+} has an indispensable function to maintain healthy bones and teeth, in addition to enabling muscle contraction and relaxation.[34] The fatty acids found, namely EPA (20:5 *n*-3) and DHA (22:6 *n*-3) are those most associated with the benefits to human health, because there is an association between a lower propensity for cardiovascular diseases.[35] The consumption of fish, a healthy food, also promotes the health and quality of life of those who consume it.[26,27]

It is possible to extract lipids from fish residues for use in the production of biofuels.[35,36] Cavali et al.,[7] when carrying out a study on lipid quality in the residues of tambaqui visceral fat, obtained different relationships for fatty acids, a similar percentage only for SFAs (40.10%), MUFAs (38.10%), and PUFAs (21.80%), resulting in tambaqui visceral fat weighing 1.0 ± 0.10 kg, its nutritional quality was proven, in addition to being a viable alternative for oil extraction and inclusion in pet feeds., in the current study has higher results for polyunsaturated ones (49.69%). However, some authors found nutritional values in fish roe considered low for AI 0.53 and TI 0.47, when found high, these have the potential to stimulate platelet aggregation, leading to the formation of thrombi and atheromas in the cardiovascular system.[37] Gonçalves et al.[38] found AI values of 0.45 and 0.35 in residual tilapia and salmon oils; TI 0.74 and 0.20 respectively. A study carried out with tambaqui viscera showed an AI ratio of 0.50 and results greater than the study for a TI of 0.93.[39] Rocha et al.[19] determined the profile of fatty acids, omegas and optimal lipid quality indices in loins of different weight classes of pirarucu (*Arapaima gigas*), the authors found high values in omegas 3, 6, 7 and *n*-9, optimal AI values between 0 .33 and 0.66, TI values between 15.52 and 47.77, and h/H values between 1.83 and 2.31. Dantas-Filho et al.[40] when developing a study with mechanically separated meat (MSM) from pirarucu (*Arapaima gigas*) filleting residue from fish ponds in Rondônia state, h/H 2.47 higher compared to the current study. The result for the h/H ratio obtained was 1.74, expressing values considered to be of high lipid quality.

By-products and co-products from fish processing can become alternative sources of EPA and DHA. However, due to the high enzymatic activity in these biological reproductive tissues such as roe, special care must be taken to avoid oxidation and lipid hydrolysis. Various methodologies involving food grade solvents were verified to assess their suitability for extracting lipids from dry by-products, with Soxhlet extraction with *n*-hexane identified as the most suitable process in terms of extraction yield and EPA/DHA values, while at analyzes of the lipid composition of tropical fish viscera showed that the internal organs with the highest lipid quality are the liver and roe.[41–43]

Conclusion

Tambaqui roe (*Colossoma macropomum*) - Amazon caviar - is composed of a significant amount of MUFAs and PUFAs, has essential fatty acids, EPA, DHA, AA and ALA, and suply the minerals daily. Significant values of omegas, 3, 6, 7 and *n*-7 and excellent lipid quality indices, PUFAs/SFAs, *n*-6/n-3, AI, TI and h/H were found. Therefore, the roe of tambaqui has such nutritional quality that we authors consider this co-product to be a nutritionally viable alternative for oil extraction and inclusion in animal (pet feeds) and human foods.

Conflicts of interest

The authors declare that there is no conflicts of interest.

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