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Essential fatty acids in farmed tambaqui (*Colossoma macropomum*) from the Brazilian Amazon Area

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ABSTRACT. The goal of this study was to determine the essential fatty acids of the total lipids of the fillet, head and orbital cavity tissue from farmed tambaqui (*Colossoma macropomum*) fish from a Brazilian Amazon area. The tambaqui were acquired from different fish farms in the Roraima state, located at Western Brazilian Amazon. The meat, the head and the fatty tissue from orbital cavity were dissected for lipid extraction and analysis of fatty acids by gas chromatography. The fatty acids were quantified in mg g^{-1} of total lipids using C23:0 as an internal standard. The nutritional quality of the lipids was determined by using the atherogenicity and thrombogenicity indices, and also by the ratio between hypocholesterolemic / hypercholesterolemic fatty acids. The orbital cavity tissue had the higher concentration amount of linoleic and α-linolenic acid, whereas the fillet had higher docosahexaenoic acid (DHA). The eicosapentaenoic acid (EPA) concentration was: 1.28, 0.97, 1.71 mg g^{-1} of total lipids, in the filet, in head, and in orbital cavity tissue, respectively. All essential fatty acids were detected in the three parts analyzed. The nutritional quality of the total lipids from the head and from the orbital cavity tissue was similar to the fillet.

Keywords: freshwater fish; EPA; DHA; nutritional quality of lipids.

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Introduction

The world aquaculture production has increased, and in 2018 the fish production was 7.32% higher than in 2016. In 2018, the aquaculture animal production was of 82.1 million tons, of which 54.3 million tons corresponded to finfish production (Food and Agriculture Organization [FAO], 2020). In Brazil, 722.56 thousand tons of fish were produced in 2018. The highlight of this production was the tambaqui (*Colossoma macropomum*), a freshwater fish from the Amazon and Orinoco area, which corresponded to the most produced native species in the country, mainly in the Brazilian North Region (Associação Brasileira da Piscicultura, 2019).

The fish have high nutritional quality, and its lipid composition has the essential fatty acids such as the linoleic (LA, 18:2n-6), α-linolenic (LNA, 18:3n-3) and polyunsaturated fatty acids of long chain (LC-PUFA), such as eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3). The LA (omega 6) and LNA (omega 3) are considered essential fatty acids since they cannot be synthesized by mammals and must be obtained from food. These two fatty acids are necessary precursors for the synthesis of LC-PUFA, differing from the omega 9 fatty acids that can be synthesized by the organism (Food and Agriculture Organization [FAO], 2010; Spector & Kim, 2019). The LA obtained from the diet can be converted to arachidonic acid (AA, 20:4n-6), while LNA can be converted to EPA and DHA, corresponding to n-6 and n-3 of C20 and C22 LC-PUFA, respectively (FAO, 2010).

The EPA and DHA fatty acids are important for the cardiovascular system (Baum et al., 2012), and according to Amminger et al. (2010), they are also linked to the functioning of the brain. The fatty acids AA and DHA act on vision acuity (Drover et al., 2011).

The biosynthetic pathways of LC-PUFA in fish were also investigated by analyzing the effects with experimental diets. According to Tocher (2010), some freshwater fish can convert LA into AA and LNA into EPA and DHA through desaturation and chain lengthening. Ferraz et al. (2019) showed that the tambaqui fish has the necessary enzymes for this conversion.

Fish head, skin leather and viscera are among the byproducts generally processed out of fish. Some studies showed that the fish waste can be are a rich source of fatty acid compounds, since essential fatty acids were detected in freshwater fish waste. In the head from Indian carp (Rohu and Catla), a study detected 4.1% of LA and 5.7% of LNA, in addition to 2.4, 2.8 and 2.9% of AA, EPA and DHA, respectively (Murthy, Rai, & Bhaskar, 2014).

In the adipose tissue from the ocular cavity of matrinxã (*Brycon cephalus*) it was detected 9.35% of LA and 0.80% of LNA, and also 0.71% of AA, 0.13 % of EPA and 0.58% of DHA (Almeida & Franco, 2007). Meanwhile, from the same tissue of tambaqui, it was detected 103.4, 6.6, 20.0, 4.4 and 8.1 mg g^{-1} of total lipids of LA, LNA, AA, EPA and DHA, respectively (Almeida & Franco, 2006).

The quantification of essential fatty acids (EFAs) in the edible portion and waste of freshwater fish is important, since wastes such as the head and adipose tissue of the ocular cavity can be low-cost sources of omega 3 fatty acids for human and animal feed.

The objectives of the present study were to quantify EFAs of the total lipids of the fillet, head and orbital cavity tissue, and to compare the EFAs of the total lipids between the different parts of the fish (filet, head and adipose tissue of the ocular cavity).

Materials and methods

Sampling

The tambaqui (n = 9) were acquired dead from different fish farms in the Roraima state (2 ° 03 'N, 61 ° 24' O), from Western Brazilian Amazon, in April 2018. The fish had an average weight of 2.71 ± 0.15 kg and length of 44.83 ± 0.60 cm. The fish were frozen after capture, and kept on ice during transport from Roraima to Paraiba state, Brazil, in polystyrene boxes protected with a thermal blanket for preservation.

The meat, the head and the fatty orbital cavity tissue were dissected out, freeze-dried, frozen at -18°C under N_2 atmosphere and then transported by air to the Food Chemistry Laboratory /FEA/UNICAMP (Campinas, São Paulo, Brazil) for lipid extraction and fatty acid analysis.

Moisture and lipid methodology

The fish meat, head and orbital cavity tissue were freeze-dried. The moisture content was determined according to Pitombo (1989), and total lipid extraction was conducted according to Folch, Less and Stanley (1957), with subsequent quantification by gravimetry. All samples were analyzed in triplicate.

Gas chromatographic analysis

The derivatization of the fatty acids was accomplished according to Joseph and Ackman (1992). The FAME were separated using gas chromatograph (Shimadzu 2010 system, Shimadzu Corporation, Kyoto, Japan) with a flame ionization detector (FID). The separation was accomplished with a fused silica capillary column (100 m x 0.25 m (i.d.), of 0.20 µm thickness of stationary phase) (CP-SIL 88, Chromopack, Middleburg, The Netherlands). The column temperature was programmed to start at 120°C for 8 min., increasing to 160 at 20°C $min.^{-1}$, and from 160 to 195°C at 3°C $min.^{-1}$, remaining at 195°C for 10 min., then increasing from 195 to 210°C at 3°C $min.^{-1}$, and from 210 to 220°C at 35°C min^{-1}. After 3 min. at 220°C, the temperature rose to 240°C at 20°C $min.^{-1}$, where it remained for 5 min., with a final holding time of 45 min. (Costa & Bragagnolo, 2017). Hydrogen was used as carrier gas at 20 cm s^{-1} with an oxygen filter coupled to the line; nitrogen was used as make-up gas at 30 mL $min.^{-1}$, and synthetic air was used at 30 mL $min.^{-1}$ and 300 mL $min.^{-1}$ for the detector. The injection was in split mode, using 1 µL of sample, at 1:100 ratio with the injector at 250°C and the detector at 260°C. All stages, from the transesterification to the final injection, were carried out under nitrogen.

Identification and quantification of the fatty acids

For identification, the retention times of the studied fatty acids were compared to those of standard methyl esters (Supelco 37 FAME Mix C4-C24, Sigma, Bellefonte, PA, USA), and the co-chromatography used the software GC Solution (Shimadzu Corporation, Kyoto, Japan). The quantification (in mg g^{-1} of total lipids) was carried out against a C23:0 internal standard, from Sigma (Sigma, Bellefonte, PA, USA), using the Equation 1 (Visentainer, 2012):

$$Mx = \frac{Ms \times Ax \times TCF}{As \times Sm \times \text{EACF}} \quad (1)$$

Where: Mx = mass of fatty acid X in mg g^{-1} of oil or fat; Ms = mass of internal standard in mg; Ax = area of fatty acid methyl ester X; TCF = theoretical correction factor; As = area internal standard; Sm = sample mass (oil or fat) in g; EACF = methyl ester to fatty acid conversion factor.

Nutritional quality indices of lipids

The nutritional quality of the lipid was determined in fatty acids by using the composition data from two indices, atherogenicity (AI), thrombogenicity (TI) and to the hypocholesterolemic/hypercholesterolemic ratio (HH).

The atherogenicity and thrombogenicity indices were calculated according to Ulbricht and Southgate (1991), and the ratio between hypocholesterolemic/hypercholesterolemic fatty acids according to Santos-Silva, Bessa and Santos-Silva (2002).

Statistical analysis

The data were submitted to analysis of variance complemented by the Tukey test at 5% significance level using the SAS system, version 9.2 (Statistical Analyses System Institute, Cary, NC, USA), Licensed by the Federal University of Paraiba.

Results and discussion

In this study, all results for mean and standard deviation were calculated from repetitions of analyzes (n=3).

For moisture content, the fillet showed a significant difference ($p < 0.05$) in relation to the fish's head and orbital cavity tissue (Table 1). The orbital cavity tissue presented the highest content of total lipids (18.44%).

Table 1. Moisture and total lipid content of the fillet, head and orbital cavity tissue from farmed tambaqui in the Brazilian Amazonian.

Fish portion	Moisture (%)	Total lipids (%)
Fillet	73.35 ± 1.53^{a}	4.99 ± 1.51^{b}
Head	56.38 ± 7.01^{b}	6.88 ± 0.58^{b}
Orbital cavity tissue	55.63 ± 0.47^{b}	18.44 ± 2.18^{a}

Values are mean ± standard deviation of three replicates. Means followed by different letters in the same column differ significantly at a level of 5% (Tukey's test).

In the head and fillet, the total lipids represented 6.88 and 4.99%, respectively. The content of total lipids in farmed tambaqui meat was 4.8% in study of Almeida and Franco (2006). In fish, lipid variation can occur between the same species or between different tissues, due to the diverse fat distribution in the animal's body (Ordóñes et al., 2005).

Essential fatty acids are the ones that cannot be synthesized by the body. The long-chain omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) can be synthesized from LNA (Spector & Kim, 2019), but due to low conversion efficiency, they must be supplied from foods rich in EPA and DHA (Gerster, 1998).

There are few studies about the fatty acids' composition of farmed freshwater tambaqui (*Colossoma macropomum*) from Brazilian Amazon Area. Almeida and Franco (2006) studied the fatty acids' composition of tambaqui from the aquiculture and captured in the Brazilian Amazonian Area in two different seasons. Another study on five native Amazonian fish aimed to assess seasonal variations in lipid content, fatty acid composition and nutritional profiles (Petenuci et al., 2016).

The Table 2 shows the fatty acid contents of LA, LNA, AA, EPA, DHA, total omega-6 fatty acids, total omega-3 fatty acids and ratio of total fatty acids n-6 and n-3 in mg g^{-1} of total lipids in the farmed tambaqui acquired from the Amazon area in the Roraima State, Brazil.

Table 2. Essential fatty acids contents (mg g^{-1} of total lipids) in the fillet, head and orbital cavity tissue in the farmed tambaqui from the Brazilian Amazonian.

Fish portion	LA	LNA	AA	EPA	DHA
Fillet	53.45 ± 6.12^{b}	4.14 ± 0.76^{b}	5.80 ± 0.82^{a}	1.28 ± 0.12^{a}	4.41 ± 0.34^{a}
Head	67.36 ± 8.86^{ab}	5.82 ± 1.71^{b}	3.04 ± 0.18^{b}	0.97 ± 0.23^{a}	1.92 ± 0.68^{b}
Orbital cavity tissue	77.61 ± 5.69^{a}	12.55 ± 2.19^{a}	2.80 ± 0.32^{b}	1.71 ± 0.60^{a}	2.75 ± 0.25^{b}
	n-6	n-3	n-6/n-3		
Fillet	66.13 ± 7.68^{b}	10.11 ± 0.63^{b}	6.53 ± 0.34^{ab}		
Head	77.35 ± 9.44^{ab}	9.08 ± 2.52^{b}	8.79 ± 1.79^{a}		
Orbital cavity tissue	88.71 ± 4.97^{a}	16.11 ± 2.74^{a}	5.63 ± 1.14^{b}		

Values are mean ± standard deviation of three replicates. Means followed by different letters in the same column differ significantly at a level of 5% (Tukey's test). LA linoleic acid, LNA α-linolenic acid, AA arachidonic acid, EPA eicosapentaenoic acid, DHA docosahexaenoic acid, n-6 total omega-6 fatty acids, n-3 total omega-3 fatty acids, n-6/n-3 ratio of total fatty acids n-6 and n-3.

The highest amount of LA was gotten in the orbital cavity tissue of tambaqui (77.61 mg g^{-1} of total lipids). There was a significant difference ($p < 0.05$) between the orbital cavity tissue and the fillet (53.45 mg g^{-1} of total lipids). Almeida and Franco (2006) showed higher values of LA from orbital cavity and fillet of farmed tambaqui, corresponding to 103.4 and 208.0 mg g^{-1}, respectively.

The concentrations of fatty acids in meat and orbital cavity tissue in fish are probably related to the fish feeding. Satar, Uysal, Ünlü, Başhan and Satar (2012) suggest that high levels of LA and LNA are due to good fish feeding conditions.

The orbital cavity tissue had the highest content of LNA. In this tissue, the LNA content was 12.55 mg g^{-1} of total lipids, whereas in the fillet was 4.14 mg g^{-1} of total lipids. There was no significant difference ($p > 0.05$) between the fillet and head for the LNA content.

In farmed tambaqui cultivated in Manaus, in the State of Amazonas, the LNA content was 12.4 mg g^{-1} of total lipids in the meat and 6.6 mg/g in the orbital cavity (Almeida & Franco, 2006). In tambaqui captured in the wild in Roraima state, located in the Western Amazon, the LNA content was 9.34 and 12.92 mg g^{-1} of total lipids in fillet from fish captured in the dry season and in the flood season, respectively (Petenuci et al., 2016).

In human diet, the consumption of LA is higher than LNA. Linoleic acid is the most common and it is found abundantly in nature in the seeds of many vegetables. The linolenic acid is present in the chloroplast of green leafy vegetables. The linoleic acid is considered essential in the diet of animals, as it is the precursor of a family of other fatty acids, which are produced by desaturation and chain elongation. In humans, the LA can be converted to AA, and the LNA to EPA and DHA, through Δ6, Δ5 and Δ4-desaturase enzymes. The levels of n-6 LC-PUFA derived from LA in plasma can be higher than the levels of n-3 LC-PUFA (FAO, 2010).

In this study, the AA and DHA presented a higher content in the tambaqui fillet and showed a significant difference ($p < 0.05$) between the head and the orbital cavity tissue. When working with farmed tambaqui, Almeida and Franco (2006) showed the higher value of DHA in the fillet.

In this research, the high value to the DHA (4.41 mg g^{-1}) was in fillet, in spite of several authors who claim that the highest content of DHA in fish is concentrated in the retina and brain (Mourente & Tocher, 1992; Nieminen, Westenius, Halonen, & Mustonen, 2014). Probably related to muscle tissue supply as a buffer against changes in the composition of fatty acids of tissues more specialized in response to alterations in the environmental and physiological conditions of the fish (Mjaavatten, Levings, & Poon, 1998). The DHA is important for brain development and proper functioning of the nervous system (Liu, Green, Mann, Rapoport, & Sublette, 2015; Spector & Kim, 2019). The DHA is a key component of all cell membranes and is found in abundance in the brain and retina (Krauss-Etschmann et al., 2007).

There was no significant difference ($p > 0.05$) between the meat, head and the orbital cavity tissue of the farmed fish with respect to the contents of EPA, with the highest value in the orbital cavity tissue (1.71 mg g^{-1} of total lipids). Almeida and Franco (2006) showed values of EPA in farmed tambaqui of 5.0 mg g^{-1} in the meat and 4.4 mg g^{-1} no orbital cavity.

EPA consumption prevents platelet aggregation through the synthesis of prostaglandins with antithrombotic effect, therefore acting in the prevention of thrombosis and atherosclerosis (Spector & Kim, 2019). EPA and DHA are important for the prevention of cardiovascular diseases (Baum et al., 2012), they can act in prevention of diabetes (Djoussé et al., 2011), and can also be helpful to treat diseases such as arthritis (Calder, 2008), depression (Wani, Bhat, & Ara, 2015) and cancer (Van der Meij et al., 2012).

In this work, the n-6 fatty acids showed higher values than the n-3 group in fillet, head and orbital cavity tissue. The fillet presented a sum of n-6 and n-3 of 66.13 and 10.11 mg g^{-1} of total lipids, respectively. The head values for n-6 were 77.35 mg g^{-1} of total lipids, and 9.08 mg g^{-1} for n-3. Orbital cavity tissue had the highest values of n-6 and n-3, with 88.71 and 16.11 mg g^{-1} of total lipids, respectively.

For most adults, a minimum of 15% of the total energy consumed should come from fat, until a maximum of 30-35%. Of this percentage, 0.5-2% of the energy consumed by individuals must consist of n-3 fatty acids, and 2.5-9% of n-6 fatty acids. These recommendations are important to avoid deficiency of fatty acids and fat-soluble vitamins needed by the human body (FAO, 2010).

In the n-6/n-3 ratio, the values in the fillet, head and orbital cavity tissue were 6.53, 8.79 and 5.63, respectively. There was a significant difference ($p < 0.05$) between the head and the ocular cavity tissue. The orbital cavity tissue had the lowest n-6/n-3 ratio. Simopoulos (2008) states that a value of 4.0 presented for the n-6/n-3 ratio is associated with a 70% decrease in deaths from coronary heart disease, and that a smaller proportion, between 2.0 and 3.0, fights the inflammation caused by rheumatoid arthritis.

The fatty acids n-3 PUFAs produce anti-inflammatory eicosanoids that inhibit the formation of eicosanoids derived from n-6 PUFAs. The increase in the proportion of n-3 PUFAs in the diet, mainly by EPA and DHA, through fish consumption or fish oil supplementation can reduce, for example, cardiovascular disease, inflammatory bowel disease, rheumatoid arthritis and degenerative diseases (Wall, Ross, Fitzgerald, & Stanton, 2010).

Regarding the recommendations about the LC-PUFA ingestion, the concentrations of EPA and DHA (in mg 100 g^{-1} of meat) were calculated (hypothetically) based on the data for the farmed tambaqui. The base for the reasoning calculation was the percentage of total lipids (Table 1) and the concentration of each fatty acid in mg g^{-1} of total lipids (Table 2). We also estimated the quantity of tambaqui meat that a person should eat daily, based on the recommendation by the Food and Agriculture Organization of the United Nations (FAO) in order to ensure the ingestion of 250 mg d^{-1} of EPA and DHA for adults (FAO, 2010).

The calculation result for tambaqui fish fillet was 6.39 and 22.01 mg 100 g^{-1} for EPA and DHA, respectively. For the head was 6.67 and 31.53, and 13.21 and 50.71 mg 100 g^{-1} for orbital cavity tissue, to EPA and DHA respectively.

According to these results and assuming EPA and DHA as the the only source of n-3 LC-PUFA, it was estimated that a person would need to eat 880.50 g of farmed fish meat daily, in order to ensure the ingestion of 250 mg d^{-1} of EPA and DHA. Regarding the consumption of tambaqui orbital cavity tissue and head, it would be necessary 303.98 e 1257.34 g d^{-1}, respectively. These results can encourage the use of head and orbital cavity tissue by the fish oil processing industry.

Considering the total lipids and the EPA and DHA concentrations of the results presented by Almeida and Franco (2006), in a study with tambaqui farmed in the State of Amazonas, and by Petenuci et al. (2016), for tambaqui caught in the wild in two different seasons (rainy and dry) in the State of Roraima, it was possible to calculate the amount of EPA and DHA in mg per 100 g of meat, and also to calculate how much a person should ingest these acids. fats daily. In the study of the Almeida and Franco (2006), the sum of EPA and DHA was higher for cultivated tambaqui due to the DHA content, which was 25.1 mg g^{-1}, and also to the percentage of total lipids, of 4.8%. Assuming EPA and DHA as the only source of n-3 LC-PUFA, a person would have to eat 172.50 g d^{-1} of farmed fish meat (Almeida & Franco, 2006). In tambaqui caught in the dry season, the concentration (in the meat) of EPA was 84.08 and of DHA was 153.21 mg 100 g^{-1}. For the rainy season, the results were 83.76 and 197.54 mg 100 g^{-1}, for EPA and DHA, respectively. Assuming that EPA and DHA as the only source of n-3 LC-PUFA, a person would have to eat 105.35 g/d of tambaqui meat caught in the dry season, or 88.87 g d^{-1} of those caught in the wet season (Petenuci et al., 2016).

The tambaqui can be considered as a good source of LC- PUFA, however, farmed tambaqui from Roraima showed lower results for essential fatty acids when compared to farmed tambaqui from Manaus, Amazon state (Almeida & Franco, 2006). The results were also lower for the tambaqui captured during the dry and flooded season in a Roraima river (Petenuci et al., 2016). These results indicates that the fish farming industry in the state of Roraima could improve the feed administered to tambaqui, aiming to obtain a better content of essential fatty acids in the final product so that they can reach the same nutritional quality as the fish farmed in Manaus, in the state of Amazonas, and wild fish caught in the dry and rainy seasons in the State of Roraima.

The thrombogenicity index (TI) and atherogenicity index (AI) were proposed by Ulbricht and Southgate (1991), as the authors decided to consider not only the family of fatty acids, but also their biological effect. Thus so, TI is related to the content of saturated fatty acids 14:0, 16:0 and 18:0, since these three fatty acids are considered prothrombotic. The monounsaturated and polyunsaturated fatty acids n-3 and n-6 are considered antithrombotic, and such data demonstrate how the food may have impact in the formation of clots in the blood vessels (Senso, Suárez, Ruiz-Cara, & García-Gallego, 2007). The AI is based on the effect that several fatty acids have on the plasmatic cholesterol, specifically in the formation of Low-Density Lipoproteins (LDL) and High-Density Lipoproteins (HDL).

There was no significant difference ($p > 0.05$) among the fillet, head and orbital cavity tissue of the fish for the atherogenicity index (AI), thrombogenicity index (TI), and for the ratio between hypocholesterolemic and hypercholesterolemic fatty acids (HH) (Table 3). The fillet had an AI of 0.74 and an TI of 1.61. In the head, the AI was 0.75 and TI 1.66. In the orbital cavity tissue, the indices were 0.76 to AI and 1.47 to TI. Petenuci et al. (2016) showed AI of 0.42 and TI of 0.65 for fillet from tambaqui captured in the dry season, and 0.36 for AI and 0.51 for TI from the flood period.

Table 3. Total lipid nutritional quality indexes from the fillet, head and orbital cavity tissue in the farmed tambaqui from the Brazilian Amazonian.

Fish portion	AI	TI	HH
Fillet	0.74 ± 0.03[a]	1.6 1 ± 0.05[a]	1.33 ± 0.06[a]
Head	0.75 ± 0.03[a]	1.66 ± 0.14[a]	1.30 ± 0.06[a]
Orbital cavity tissue	0.76 ± 0.02[a]	1.47 ± 0.01[a]	1.29 ± 0.04[a]

Values are mean ± standard deviation of three replicates. Means followed by different letters in the same column differ significantly at a level of 5% (Tukey's test). AI Atherogenicity Index, TI Thrombogenicity Index, HH ratio between hypocholesterolemic and hypercholesterolemic fatty acids.

Ulbricht and Southgate (1991) affirmed that, the lower the value of AI and TI, the better the quality of the food's lipids. These two indexes indicate the potential to stimulate platelet aggregation. The scientific community affirm that the greater the amount and concentration of antiatherogenic fatty acids, and the lower the amount of atherogenic fatty acids present in the lipids, consequently the better the potential for preventing coronary heart disease.

For the HH ratio in this study, the tambaqui fillet showed a value of 1.33, the head 1.30, and the orbital cavity tissue 1.29. Petenuci et al. (2016) showed a value of 2.24 in tambaqui from dry season, and 2.66 from wet season. These values are higher than the ones obtained from the tambaqui from Roraima, in the Brazilian Amazon area. Santos-Silva et al. (2002) state that the higher the HH ratio the more ideal is the fat for human consumption, and that for meat products it is recommended a value close to 2.00. The HH ratio is related to the potential to prevent increased serum cholesterol and reduce the risk of cardiovascular disease (Ascherio & Willett, 1995).

The indices of nutritional quality of lipids (AI, TI) and ratio (HH) from fish farmed in the State of Roraima were lower than the results shown by Petenuci et al. (2016) for fish caught in the wild. In accordance with our results, we recommend to fish farmers in Roraima to improve the quality of the food given to farmed fish.

Conclusion

All essential fatty acids, linoleic acid and α-linolenic acid, arachidonic acid, eicosapentaenoic acid and docosahexaenoic acid were detected in the tambaqui's fillet, head and ocular cavity tissue. The nutritional quality of the total lipids from the head and ocular cavity tissue is similar to the fillet's.

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