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Mineral composition, omegas and lipid quality in the visceral fat residues of tambaqui (*Colossoma macropomum* Cuvier, 1818)

Composição mineral, ômegas e qualidade lipídica em resíduos de gordura visceral de tambaqui (Colossoma macropomum Cuvier, 1818)

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ABSTRACT: This study aimed to determine the mineral composition, fatty acid profile, omegas and lipid quality indexes in the visceral fat residues of tambaqui (*C. macropomum*). Three pieces of visceral fat were collected from 20 fish weighing 1.10 ± 0.10 kg, which were homogenized and sent for compositional analysis. Minerals were determined by AOAC Official method 969.23 and 968.08. The fatty acids were grouped to calculate the ∑*PUFAs*/∑*SFAs* fatty acids ratio and the proportion of polyunsaturated fatty acids ∑*PUFAs* (*n*-6/*n*-3), atherogenicity indixes (AI) were calculated, thrombogenicity (TI), and ratio between hypocholesterolemic and hypercholesterolemic fatty acids (HH). Mineral elements were found, 0.68 ± 0.015 mg/100g of total iron, 159.16 ± 14.32 mg/100g of Na^+, 63.90 ± 5.11 mg/100g of K^+, 10.28 ± 0. 62 mg/100g of Ca^{2+} and 7.31 ± 0.58 mg/100g of Mg^{2+}. As for fatty acids, 40.10% of SFAs, 38.10% of MUFAs and 21.80% of PUFAs. The calculations indicated significant values of omegas, 3, 6, 7 and *n*-7. There were ∑*PUFAs*/∑*SFAs* ratios of 1.84 and ∑*PUFAs* (*n*-6/*n*-3) of 6.22, with an AI of 0.50 and a TI of 0.93 and HH of 2.16. The 1.0 ± 0.10 kg tambaqui visceral fat residues can be evaluated as having high nutritional value, in addition to being a viable option for oil extraction and inclusion in animal feed.

KEYWORDS: Essential fatty acids; Lipid quality indexes; Omegas; juvenile tambaqui.

RESUMO: O objetivo do estudo foi determinar a composição mineral, perfil de ácidos graxos, omegas e índices de qualidade lipíca de resíduos de gordura visceral de tambaqui (*C. macropomum*). Foram três amostras de gordura visceral coletadas de 20 peixes de 1,10 ± 0,10 kg, os quais foram homogeneizados e enviados para análise composicional. Os minerais foram determinados pelo método oficial AOAC 969,23 e 968,08. Os ácidos graxos foram agrupados para calcular a proporção de ácidos graxos ∑*PUFAs*/∑*SFAs* e a proporção de ácidos graxos poli-insaturados ∑*PUFAs* (*n*-6/*n*-3), índices de aterogenicidade (IA) foram calculados, trombogenicidade (IT) e proporção entre ácidos graxos hipocolesterolêmicos e hipercolesterolêmicos (HH). Foram encontrados os elementos minerais, 0,68 ± 0,015 mg/100g de ferro total, 159,16 ± 14,32 mg/100g de Na^+, 63,90 ± 5,11 mg/100g de K^+, 10,28 ± 0,22 mg/100g de Ca^{2+} e 7,31 ± 0,58 mg/100g de Mg^{2+}. Quanto aos ácidos graxos, 40,10% de AGS, 38,10% de AGM e 21,80% de AGP. Os cálculos indicaram valores significativos de ômegas, 3, 6, 7 e *n*-7. Em relação a ∑*PUFAs*/∑*SFAs* de 1,84 e ∑PUFAs (*n*-6/*n*-3) de 6,22, com um índice de IA de 0,50 e um IT de 0,93 e HH de 2,16. O 1,0 ± 0,10 kg na gordura visceral de tambaqui pode ser avaliado como de alto valor nutricional, além de ser uma opção viável para extração do óleo e inclusão na ração animal.

PALAVRAS-CHAVE: Ácidos graxos essenciais; índices de qualidade lipídica; Omegas; Tambaqui juvenil.

INTRODUCTION

The state of Rondônia stands out as the largest producer of tambaqui *Colossoma macropomum* (CUVIER, 1818) (Characiformes: Serrasalmidae) in Brazil, producing in 2020 around 65,500 tons, while the state of Amazonas ranked fifth with only 20,500 tons (PEIXE BR, 2021). However, Amazonas state is the largest consumer market for cultivated tambaqui in Brazil, in addition, the city of Manaus is the main market for tambaqui (Gandra, 2010; Pedroza Filho et al., 2016; Peixe BR, 2021). It is noteworthy that the processing of fish produces a significant amount of residues (head, total viscera, fin, tail, spine, fin, scales, meat remains and especially visceral fat residues), generating an average of 70% of residues (VALENTE et al., 2014), in tambaqui

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the residues reaches 67% (ABREU et al., 2012). Estimates suggest that for each ton of fish processed for sale, one ton of residues is generated (AGUIAR et al., 2014), it should be noted that these percentages may vary according to species and processing (Peixe BR, 2021).

Visceral fat residues from fish tend to have high nutritional value, including minerals (THAMMAPAT et al., 2010), proteins and lipids (Nges et al., 2012; SILVA et al., 2018), essential amino acids, poly fatty acids-unsaturated, with an emphasis on *n*-3 (FELTES et al., 2010), which can that can be added to the fish meal and oil (ESTEBAN et al., 2007; Arvanitoyannis; Kassaveti, 2008; TRINDADE NETO et al., 2008; SILVA et al., 2020). Additionally, isceral fish fat residue can also be used for better use in various alternative lines such as: animal feed, organic fertilizers, chemical products, functional products, n-3 rich oil, human food (patet, mechanically separated meat and surimi), production of biodiesel and other value-added products (Boscolo; Feiden, 2007; FELTES et al., 2010; NUNES, 2011; SANTOS et al., 2017), its use is an alternative that aims to reduce the lack of products rich in protein and reduction of its volume. It is worth emphasizing other alternatives for using fish processing residues as organic fertilizers organic (López-Moesqueira et al., 2011; NUNES, 2011), silage production (Borghesi; Hisano, 2011; Oliveira et al., 2014) or hydrolysates (Dieterich, 2014), used as alternative foods in animal nutrition and also the use of fish skin in the manufacture of shoes and other leather products (Maluf; Hilbig, 2010; FRANCO, 2011). According to Sousa (2014), these residues can be used for the production of various products, bringing advantages to the fish farming sector, since it is a low-cost, high-productivity raw material, in addition to minimizing the problem of eliminating processing residues.

Furthermore, the use of these residues in animal feed appears as an option to meet the demand for fish oils for animal feed, which has been reduced due to production costs (Rombenso et al., 2016). Given the context presented, knowing the lipid composition of residues from fish processing, it is important to evaluate the mineral and fatty acid composition of visceral fat residues, including the tambaqui that can be used to meet the demands of short term and supply the scarcity of fish from the off-season market in the city of Manaus, AM - Brazil. In defluence to its shorter cultivation time, which gives off faster to supply. However, as it is a relatively new product on the market, nutritional information is scarce.

Considering the increased demand for tambaqui in the lighter weight class by the consumer market in the city of Manaus, mainly in the off-season period. As well as the residual production of fish processing and the search for alternatives that add value. This study aimed to determine the mineral composition, fatty acid profile, omegas and lipid quality indexes in the visceral fat residues of tambaqui (*C. macropomum*).

MATERIAL AND METHODS

The research was conducted by the Universidade Federal de Rondônia (UNIR) and the analyzes were carried out at the Water and Food Laboratory, Department of Chemistry, Universidade Estadual de Maringá (UEM), with the support of the Rondônia Research Support Foundation (FAPERO) and approved by the Ethics Committee on the Use of Animals (CEUA) with protocol number 02/2017. Sample collections were carried out from January to October 2018, in a fish processing unit registered in the Brazilian System of Inspection of Animal Products (SISBI-POA), located in the municipality of Vale do Paraíso, RO - Brazil. Three visceral fat residues samples were collected from 20 tambaqui (*C. macropomum*) examples weighing 1.10 ± 0.10 kg

Commercial diet

In fish farms, the tambaquis were supplied with extruded commercial feed, containing 36% crude protein at a feeding rate of 1.0% in relation to body weight. It is worth emphasizing that the feed was provided twice a day, from 10 am to 5 pm, for 130 days (Table 1). It is important to point out that it is important to present the information on the guarantee levels of the rations provided by the fish farms, the fish suppliers to the refrigeration unit. In order to demonstrate that businesses adopt a standardized diet. Therefore, there is no dietary difference to cause variations in the fatty acid profile results.

Processing, sampling and design

The first stage of processing the tambaquis was carried out with weighing and identification, the processed fish were

Table 1. Guarantee levels of the feed provided to tambaqui (*C. macropomum*).

Feed composition[1]	Content (g/kg)	Feed composition[1]	Content (g/kg)
Calcium (min.g)	10.0	Vitamin B_{12} (mg)	4.2
Calcium (max. g)	40.0	Vitamin B_2 (mg)	3.5
Ethereal extract (g)	25.0	Vitamin B_6 (mg)	2.0
Phosphorus (g)	6.0	Vitamin D_3 (mg)	4.200.0
Crude protein (g)	90.0	Vitamin E (UI)	52.0
Mineral matter (g)	150.0	Vitamin K_3 (mg)	2.1
Crude protein (g)	280.0	Vitamin C (mg)	300.0
Moisture (g)	90.0	Copper (mg)	5.0
Pantothenic acid (mg)	3.5	Iron (mg)	30
Biotin (mg)	0.05	Iodine (mg)	0.2
BHT (mg)	70.0	Niacin (mg)	10.5
Choline (mg)	290.0	Manganese (mg)	6.0
Vitamin A (UI)	14.000	Zinc (mg)	17.0
Vitamin B_1(mg)	2.0	Selenium (mg)	0.06

[1]Percentage of dry matter.

kept in boxes with the waste and the flat cut until the end of the production line. The second stage was performed on the evisceration table, with the procedure of removing the head by section at the level of the junction with the spine, desquamation and removal of the viscera and weighing the flat cut (Figure 1 A). Finally, after completing the flat cut, the visceral fat residues was collected, separated and weighed, considered by the industry as a by-product of slaughter. This fat was homogenized and, finally, three simple 50g samples were collected and sent for analysis of nutritional composition (Figure 1 B).

Mineral composition assessment

For the quantification of the macrominerals, an extract was obtained from the complete digestion of the sample in sulfuric 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 spectrometer 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 et al. (2020).

Fatty acid profile assessment

Total lipids were extracted by the method of Bligh and Dyer (1959) and fatty acid methyl esters were prepared by methylation of triacylglycerols, as described in method 5509 of the International Organization for Standardization (ISO, 1978). The fatty acid methyl esters were analyzed using a 14-A gas chromatograph (Shimadzu, Japan), equipped with a flame ionization detector and a fused silica capillary column (50 m long, 0.25 mm internal diameter and 0 .20 µm Carbowax 20M).

Figure 1. Processing, sampling and design, (A) exemplary of tambaqui (*C. macropomum*) to 1.10 ± 0.10 kg in "flatted cut", made in Rondônia state - Brazil. (a) Example of unheaded cut, (b) cut longitudinally in two united bands up to the caudal fin, (c) with removal of the spinal column; (B) visceral fat residues was collected, separated and weighed. Then, it was homogenized and then samples were collected and sent for analysis.

The fluxes of ultrapure gases (White Martins) were 1.2 mL/min for carrier gas (H_2); 30 mL/min for the auxiliary gas (make-up) (N_2); 30 and 300 mL/min for the flame gases, H_2 and synthetic air, respectively. The sample split ratio (split) was 1/100 (Justi et al., 2005). Column temperature was programmed at a rate of 2º C/min, from 150 to 240º C. Injector and detector temperatures were 220 and 245º C, respectively. Just as, justi et al. (2005), the peak areas were determined by means of the CG-300 Integrator-Processor (CG scientific instruments) and the identification of the peaks was performed by comparison with the retention times of patterns (Sigma, USA).

Lipid quality indices

The fatty acid profile data were grouped to calculate the ∑*PUFAs*/∑*SFAs* ratio and the ratio ∑*PUFAs* (*n*-6/*n*-3) following the guidelines of the World Health Organization (WHO, 2005). The nutritional quality of the lipid fraction was also calculated from the fatty acid profile through the indices of atherogenicity index (AI) = [(12:0 + 4 x 14:0+ 16:0)]/Σ*MUFAs* + Σ*n*-6+Σ*n*-3, thrombogenicity index (TI) = (14:0 + 16:0 + 18:0)/[(0,5 x Σ*MUFAs*)+(0,5 x Σ*n*-6)+(3 x Σ*n*-3)+(Σ*n*-3/*n*-6)] (Ulbricht; Southgate, 1991) and the ratio between hypocholesterolemic and hypercholesterolemic fatty acids (HH) = (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*-6)/(14:0 + 16:0) (SANTOS-SILVA et al., 2002).

RESULTS

The visceral fat residues of tambaqui (*C. macropomum*) of 1.10 ± 0.10 kg is composed of the mineral elements, 0.68 ± 0.015 mg/100g of Total Iron, 159.16 ± 14.32 mg/100g of Na^+, 63.90 ± 5.11 mg/100g of K^+, 10.28 ± 0.62 mg/100g of Ca^{2+} and 7.31 ± 0.58 mg/100g of Mg^{2+}.

Were found in the lipid composition 40.10% of saturated fatty acids (SFAs), 38.10% of monounsaturated fatty acids (MUFAs) and 21.80% of polyunsaturated fatty acids (PUFAs). Highlight the detection of fatty acids, 0.848 ± 0.004 of 18:3 *n*-3 (ALA), 1,255 ± 0.009 of 20:4 *n*-6 (AA), 0.214 ± 0.004 of 20:5 *n*-3 (EPA) and 0.760 ± 0.010 of 22:6 *n*-3 (DHA) (Table 2).

Sums of omegas were found, 3,014 ∑*PUFAs* (*n*-3), 18,770 ∑*PUFAs* (*n*-6), 2,898 ∑*PUFAs* (*n*-7) and 34,737 ∑*PUFAs* (*n*-9). It also presented ∑*PUFAs*/∑*SFAs* ratios of 1.84 and ∑*PUFAs* (*n*-6/*n*-3) of 6.22. As well as a ratio of atherogenicity index (AI) of 0.50 and thrombogenicity index (TI) of 0.93 and ratios between hypocholesterolemic and hypercholesterolemic fatty acids (HH) of 2.16 (Table 3).

DISCUSSION

Fish meat has considerable amounts of the mineral elements calcium, phosphorus, sodium, potassium, manganese, copper, cobalt, zinc, iron and iodine, such minerals have primary functions in the metabolism of fish and their absence in both the diet and water can cause biological dysfunctions and reflect its content in muscle (LIMA et al., 2012; DUARTE et al., 2021). Regarding the mineral composition of fish residues, there are studies in the literature that present oscillations in the mineral concentration in different species, Murueta et al. (2007) obtained for residues of nine fish species, different mineral contents ranging from 8.15% to 20.27%, Chen and Jaczynski (2007), for trout by-products they found 1.61% of minerals, Taskaya et al. (2009), in carp (*Cyprinus carpio*) they obtained a concentration of 3.80% of minerals and Tavakolipour (2011) found 2.2% in silver carp residues. These variations in mineral concentrations may be related to the chemical composition of the by-products, as they are different species and because they are processing residues, it is extremely difficult to standardize it for comparison purposes (SILVA et al., 2020).

Fish can accumulate high amounts of minerals from culture water through gill filtration, through consumption of food and sediments, accumulating in tissues (Yilmaz et al., 2010), it should be noted that this accumulation varies according to the mineral concentration in the water and exposure time (Yilmaz; Yilmaz, 2007). Thus, it is inferred that the mineral contents may be due to factors resulting from the bioavailability of these mineral elements for the use of fish, contributing to a greater or lesser content in their meat and fats (DUARTE et al., 2021). Research has shown that diets rich in lipids affect mineral concentrations in the fish body, causing less absorption of minerals such as calcium, resulting in greater renal and/or fecal excretion (Corwin, 2003; Morais; Burgos, 2007). The induction of urinary calcium excretion when there are high concentrations of free fatty acids in plasma (BONJOUR, 2005), considering such premises, a negative interaction between lipids and mineral deposition in muscle tissue is considered (DUARTE et al., 2021).

Duarte et al. (2017), mentions that the ingested amount of an element and the mineral versus mineral interactions that occur when they compete for the same absorption site because they have physicochemical similarities, and the excess of one will harm the use of the other. Burkert et al. (2008), found in the residues of cultivated Amazonian catfish (*Pseudoplatystoma fasciatum*) mineral values below those obtained in this research. Likewise, Fallah et al. (2011), in visceral fat residues of trout (*Oncorhynchus mykiss*) found mineral matter values lower than visceral fat of tambaqui, 0.39mg/100g of Total iron, 88.0 mg/100g Na^+, 33.68 mg/100g of K^+ and 5.89mg/100g of Ca^{2+}. However, Njinkoue et al. (2016) in *Pseudotolithus typus* and *Pseudotolithus elongatus*, marine fish species, found 0.19 mg/100g of Total iron and 13.9 mg/100g of K^+, values lower than tambaqui visceral fat residues, however, they presented Ca^{2+} values to 19.0mg/100g and Mg^{2+} to 12.0mg/100g higher. Parthasarathy and Joseph (2011), in the visceral fat residues of Mozambican tilapia (*Oreochromis mossambicus*), found higher values of 175.5mg/100g of Na^+ and 67.5 mg/100g of K^+, but lower values of 3.88 mg /100g of Ca^{2+} and 5.4mg/100g of Mg^{2+} . However, Job et al. (2015), in the visceral fat residues of Nile tilapia (*Oreochromis niloticus*), found values of 1.51 mg/100g Total iron, 28.3 mg/100g of Ca^{2+} and 11.9 mg/100g of Mg^{2+}, higher than visceral fat residues of tambaqui, however, found much lower values of 17.1 mg/100g of K^+ and 130.0 mg/100g of Na^+.

The results of the fatty acid profile measured in Table 1 show that *∑SFAs* had a high concentration, providing visceral fat residues with a healthy and nutritional connotation, and can be used in animal feed as a source of fatty acids. Among the polyunsaturated fatty acids, octadecadienoic, eicosatetraenoic, eicosatrienoic, which are indicators of lipid quality, are highlighted, as well as being related to the acceleration of the healing process and renewal of erythrocytes and

Table 2. Fatty acid profile (%), omegas and lipid quality indexes in the visceral fat residues of tambaqui (*C. macropomum*) to 1.10 ± 0.10 kg (*n*=20).

Fatty acids	IUPAC Nomenclature	Values (%)
SFAs		
12:00	Dodecanoic acid	2.365 ± 0.001
13:00	Tridecanoic acid	0.359 ± 0.001
14:00	Tetradecanoic acid	1.757 ± 0.001
15:00	Pentadecanoic acid	0.112 ± 0.003
16:00	Hexadecanoic acid	20.829 ± 0.001
17:00	Heptadecanoic acid	0.285 ± 0.003
18:00	Octadecanoic acid	12.410 ± 0.001
20:00	Eicosanoic acid	0.375 ± 0.004
21:00	Heneicosanoic acid	0.731 ± 0.003
22:0	Docosanoic acid	0.371 ± 0.002
24:0	Tetracosanoic acid	0.562 ± 0.013
	∑SFAs	40.100
MUFAs		
16:1 *n*-7	9-Hexadecenoic acid	0.420 ± 0.010
16:1 *n*-9	7-Hexadecenoic acid	3.606 ± 0.014
17:1	8-Heptadecenoic acid	0.422 ± 0.001
18:1 *n*-7	11-Octadecenoic acid	2.478 ± 0.009
18:1 *n*-9	9-Octadecenoic acid	30.060 ± 0.002
20:1 *n*-9	11-Eicosenoic acid	0.138 ± 0.001
22:1 *n*-9	13-Docosenoic acid	0.299 ± 0.002
24:1 *n*-9	15-Tetracosenoic acid	0.634 ± 0.003
	∑MUFAs	38.100
PUFAs		
18:2 *n*-6	9,12-Octadecadienoic acid	15.754 ± 0.003
18:3 *n*-6	6,9,12-Octadecatrienoic acid	0.578 ± 0.001
18:3 *n*-3 (ALA)	(α-) Linolenic acid	0.848 ± 0.004
20:2 *n*-6	11,14-Eicosadienoic acid	0.217 ± 0.002
20:4 *n*-6 (AA)	5,8,11,14-Eicosatetraenoic acid	1.255 ± 0.009
20:3 *n*-6	8,11,14-Eicosatrienoic acid	0.441 ± 0.004
20:5 *n*-3 (EPA)	5,8,11,14,17-Eicosapentaenoic acid	0.214 ± 0.004
20:3 *n*-3	11,14,17-Eicosatrienoic acid	1.192 ± 0.003
22:2 *n*-6	13,16-Docosadienoic acid	0.525 ± 0.005
22:6 *n*-3 (DHA)	4,7,10,13,16,19-Docosahexaenoic acid	0.760 ± 0.010
	∑PUFAs	21.800

Results expressed as percentage (%) of total fatty acids. Saturation: saturated fatty acids (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs).

Table 3. Omegas and lipid quality indexes in the visceral fat residues of tambaqui (*C. macropomum*) to 1.10 ± 0.10 kg (n=20).

Indexes	Formulas	Values
Omegas	ΣPUFAs (n-3)	3.014%
	ΣPUFAs (n-6)	18.770%
	ΣPUFAs (n-7)	2.898%
	ΣPUFAs (n-9)	34.737%
	ΣPUFAs/ΣSFAs	1.84
	ΣPUFAs (n-6/n-3)	6.22
Lipid quality	AI	0.50
	TI	0.93
	HH	2.16

Saturation: saturated fatty acids (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs); Atherogenicity index (AI), Thrombogenicity index (TI) and ratio between hypocholesterolemic and hypercholesterolemic fatty acids (HH).

leukocytes (MANHEZI et al., 2008; NUNES et al., 2008; NUNES et al., 2012), the observation of essential fatty acids such as alpha-linolenic (ALA), linoleic, oleic, arachidonic, docosahexaenoic (DHA), eicosapentaenoic (EPA) and palmitoleic acid, especially n-3, associated with prevention and treatment of many chronic diseases such as neurological ones, cancers, inflammatory diseases, obesity and diabetes mellitus (SANTOS et al., 2019).

Sousa (2014), evaluating the lipid composition of tambaqui residues, among the fatty acids found, those with the highest proportions were oleic, palmitic, linoleic and stearic acids. Lu et al. (2003), in tambaqui residues, observed more expressive values of glutamic acid, aspartic acid and among the essential amino acids that showed higher concentrations are lysine and leucine, standing out as a great potential to participate in the preparation of fish feed.

Crexi et al. (2009) found in the oil of carp (*Cyprinus carpio*) viscera, considerable amounts of fatty acids, with greater amounts for oleic, palmitic, palmitoleic, linoleic and linolenic acid. Menegazzo et al. (2014), found high concentrations of oleic, palmitic, linoleic, docosahexaenoic, linoleic acid in Nile tilapia and hybrid Amazonian catfish residue oils, Francisco et al. (2019) in Nile tilapia visceral oil revealed a large presence of oleic, palmitic, linoleic, palmitoleic, stearic, myristic, linolenic, arachidic, erucic, lauric, behenic and erucic acid.

Oils from rainbow trout residues have lower concentrations of SFAs and higher levels of MUFAs ones, while PUFAs ones have intermediate levels, being a good source of eicosapentaenoic (EPA) and docosahexaenoic (DHA) (GOOSEN et al., 2014). Souza et al. (2020), found in curimbatá viscera higher levels of eicosapentaenoic, docosahexaenoic and arachidonic acids and a lower n-6/n-3 ratio, therefore of better nutritional quality. However, Souza et al (2020), in Amazonian curimba residues (*Prochilodus lineatus*), found expressive concentrations of n-3 and n-6 fatty acids, the authors emphasize that the use of fish processing residues is both economically profitable with tendencies to reduce cost, as nutritional seen its composition in essential fatty acids.

It is noteworthy that the lipid concentration can be directly influenced by the diet to which the fish is submitted (Grigorakis, 2007), and the lipid pattern of the diet tends to change the fatty acid composition of wild marine or freshwater fish (LIE, 2001; Grigorakis, 2007). Duarte et al. (2021), using fish residues oil in Nile tilapia feed, found in its meat 34 different fatty acids with a predominance of oleic, palmitic, linoleic and stearic acids. It is noteworthy that the difference in the yield of extracted lipids can be influenced by the amount of fat stored in residues, which in turn can be influenced by the type of diet (SOUZA et al., 2020).

An example of a successful experiment was the inclusion of visceral fish fat waste oils in the Nile tilapia (*O. niloticus*) feed. The inclusion contributed to the nutritional enrichment of the chemical composition of the meat. To incorporate of n-3 fatty acids and the presence and high concentrations of EPA and DHA in oil residues was essential to provide improve PUFAs/SFAs and PUFAs n-6/n-3, are nutritionally essentials (BERY et al. , 2012; SOUZA et al., 2020; DUARTE et al., 2021).

Tambaqui visceral fat residues had a higher percentage of MUFAs (38.1%) than chicken fat (37%) and lower than ostrich fat (45.7%), pork (52.2%) and bovine beef (61%), referring to PUFAs (21.8%), tambaqui visceral fat residues had higher levels than pork fat (20.26%) and bovine fat (5.9%) (HAUTRIVE et al., 2012; LEITE et al. al., 2015). Fallah et al. (2011) determined the fatty acid profile of the fat of trout (*Oncorhynchus mykiss*) and found a higher percentage of PUFAs (25%) than the results of the present research, and a lower percentage of MUFAs (28%). However, Njinkoue et al. (2016) compared the fatty acid profiles of the fat from *Pseudotolithus typus* and *Pseudotolithus elongatus*, two species of marine fish widely consumed off the coast of West Africa. They found a higher percentage of PUFAs (50.93%) than the visceral fat residues of tambaqui and a lower percentage of MUFAs (33.4%).

Regarding the PUFAs/SFAs ratio, this is related to the nutritional quality of fatty acids in the food, values below 0.45 are undesirable because they increase blood cholesterol (Wood; Enser, 1997; WHO, 2005). The result of the present study was 1.84, confirming that it is healthier than beef, pork, chicken and ostrich fat, which presented values below 0.45 (HAUTRIVE et al., 2012). However, Rodrigues et al. (2017), studying five species of Brazilian freshwater fish found values for PUFAs/SFAs of 2.23 and n-6/n-3 ratio of 0.98, the authors also point out that the Department of Health and Social Security of the United Kingdom recommends PUFAs/SFAs ratios above 0.45 and n-3/n-6 below 4:1 as good nutritional quality.

The ratio of PUFAs n-6/n-3 has also been used as a criterion to assess the quality of fat, which should be less than 4:1 (WHO, 2005). The visceral fat residues of tambaqui had an PUFAs *n*-6/*n*-3 ratio of 6.22, while beef fat had an average ratio of 2.44 and chicken ratio of 19.99 (HAUTRIVE et al., 2012). However, an excess of linoleic acid prevents the transformation of ALA its derivatives EPA and DHA, the same happens otherwise, with a lower consumption of linoleic acid there will be a reduction in arachidonic acid activation, since the enzyme Δ-6-desaturase has affinity for both fatty acids (Jankowska et al., 2010; SIQUEIRA et al., 2018).

Regarding the nutritional quality of the lipid profile, visceral fat had an atherogenicity index (AI) of 0.50 and a thrombogenicity index (TI) of 0.93, these indices are used to assess the inhibitory potential for the onset of coronary artery disease (Ulbricht; Southgate, 1991 ; SANTOS et al., 2002; RODRIGUES et al., 2017; ZHANG et al., 2020), are related to pro and antiatherogenic acids, which assess fatty acids and their effects on lipoprotein metabolism, however, there are no recommended values for these indices (RAMOS FILHO et al., 2008; NOZAKI et al., 2012), thus, the lower the AI and TI values, the higher the ratio of fatty acids that are more beneficial to health (TURAN et al., 2007; TONIAL et al., 2010), demonstrating the potential for using tambaqui visceral fat residues of 1.0 ± 0.10 kg in animal feed (BARROS et al., 2013).

Ramos-Filho et al. (2008), obtained AI and TI in filet of Amazonian triped catfish (*Pseudoplatystoma fasciatum*) of 0.54 and 0.59, Amazonian catfish (*Pseudoplatystoma corruscans*) of 0.49 and 0.33, yellow pacu (*Piaractus mesopotamicus*) of 0.86 and 1.16 and freshwater catfish (*Salminus brasiliensis*) of 0.70 and 0.35, superior results those obtained by Senso et al. (2007) in the marine species golden-headed sea bream (*Sparus aurata*) ranging from 0.21 to 0.29 and Gonçalves et al. (2012) in residual oils in Nile tilapia and salmon, with AI values 0.45 and 0.35; TI 0.74 and 0.20 respectively. The lipid profile of visceral fat has ratios between HH of 2.16, expressing values considered to be of high lipid quality, the ratio HH is a supplementary analysis used to assess the nutritional quality of lipids, since which is related to the effect of individual fatty acids on cholesterol metabolismo (SANTOS et al., 2002). Bentes et al. (2009), emphasizes that nutritionally higher values of HH are more recommended to provide benefits to human health. Testi et al. (2006), studying European sea bass (*Dicentrarchus labrax*), golden-headed sea bream (*Sparus aurata*) and trout (*Oncorhynchus mykiss*) found HH ratios ranging from 2.03 to 2.46, Ramos-Filho et al. (2008) found in Amazonian striped catfish (1.75), Amazonian catfsih (1.84), yellow pacu (1.66) and freshwater catfish (1.49), Gonçalves et al. (2012) obtained for residual oils in Nile tilapia (0.06) and salmon (1.52).

It is inferred that it can be used as a raw material in animal feed, and can be considered as an alternative for incorporation into feed (PINTO et. al. 2017; MACEDO et al., 2020), being a low-cost substitute for conventional fish oil, as it is derived from fish processing residues, it has the additional advantage of not increasing the catch of wild fish (GOOSEN et al., 2014). However, their inclusion in fish feed should be improved and studied at different concentrations, since excess lipids can harm animal health, affect carcass composition by increasing lipids, impair growth and decrease body weight of the animal fish or affect your appetite (DUARTE et al., 2021).

To add more technical and scientific information, the inclusion of fish processing residues in animal feed has shown promising results. Researches demonstrate the potential of its use in the formulation of feeds, for example, the research by Batalha et al. (2019), and Brelaz et al. (2021), studying the use of fish residues oil in the feeding of laying hens, concluded that it can be used as an additive in rations at a level of 1.5%, and can be used as an alternative feed, reducing production costs. Stoneham et al. (2018), found that tilapia fed with rations enriched with *n*-3 from fish oil showed a high concentration of *n*-3 in their meat and rapid growth, demonstrating that it is possible and viable to use and produce by-products with added value of the visceral fat residues.

Goosen et al. (2014), demonstrated that the inclusion of trout residues oil in the feeding of Mozambican Tilapia was a good source of PUFAs, with antimicrobial properties, concluding that the residues oil successfully replaced the commercial oil without negative effects on production parameters and improving cellular immunity. Silva et al. (2014), stated that the use of tilapia processing residues can serve as a good source of amino acids, with potential for use in fish feed. Gonçalves et al. (2012), emphasize that fish fed with salmon residues oil contain high concentrations of *n*-3 fatty acids and better ∑PUFAs (*n*-3/*n*-6) ratio in their meat, reaching the conclusion that fish residues oils can be used in replacement of soy oil without causing a drop in production performance. Nascimento (2013), describes that the residues of *Branchy platystoma vaillant* contain high levels of proteins (45.82 to 60.72%), Santos et al. (2017) also describe high levels of protein in Nile tilapia residues (41.4%), confirming that fish residues are potential sources for protein enrichment in feeds.

Guimarães et al. (2021), in tambaqui residues from 500 to 800 g, found 75.67% moisture, 7.08% protein, 8.83% lipids, 3.81% minerals, 4.61% carbohydrates and caloric value of 126.3 kcal. Fish residues has high concentrations of protein, lipids and minerals, and its use is a profitable alternative for the fishing industry, as it is a quality raw material, developing products with high added value of nutrients for use in animal feed (GUIMARÃES et al., 2021). Milles and Chapman (2015), highlight that fat represents around 4 to 20% of the fish's total weight. In this context, Almeida and Carvalho (2012), obtained 146.0 g of visceral fat residues in a 2.48 kg tambaqui, which represents 6% of the total weight and Signor et al. (2010), in pacus with an average weight of 834.7 g and average fat percentage of 6.82 g. Research has shown that visceral fat tends to fluctuate as the fish grows, due to a reduction in protein metabolism and a change in the direction of dietary energy, and that it may be related to the growing environment, with restricted movement in captivity. It causes greater accumulation of visceral fat due to the decrease in energy expenditure for movement (Aarbeláez-Rojas et al., 2002). Another relevant factor to be highlighted is the lipid concentration in fish residues, which can reach up to 45% (SANTOS et al., 2010; SOUZA et al, 2020). Macedo et al. (2020), found a lipid concentration of 23.10% in Nile tilapia filleting residues.

These results are important due to the search for foods of good nutritional quality that can minimize the costs of feeding in fish farming, as well as the use of residues rich in proteins and lipids that until then would have been residuesd, its proper use can minimize production costs, since food has become the most expensive item in fish farming (BATALHA et al., 2017). Its use in fish feeding tends to provide nutritional and economic advantages, especially in Brazilian regions that suffer from logistical limitations for grains and high-value raw materials (CRUZ et al., 2016).

CONCLUSIONS

Visceral fat residues of tambaqui (*C. macropomum*) to 1.10 ± 0.10 kg is composed of important minerals, total iron, Na^+, K^+, Ca^{2+} e Mg^{2+}. It is also composed of polyunsaturated essential fatty acids, as examples MUFAs and PUFAs. The calculations indicated significant values of omegas, 3, 6, 7 and *n*-7. Therefore, presenting high nutritional value and can be considered a nutritional viable option for oil extraction and inclusion in animal feed, since it presented considerable lipid content, which can be used to add value, enabling reuse and inclusion in animal feed as a source of lipids and minerals, in addition to that, it is an option to minimize the incorrect disposal of residues from fish processing, as well, tends to have economic and nutritional advantages.

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