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Fatty acid profile, omegas and lipid quality in commercial cuts of pirarucu (*Arapaima gigas* Schinz, 1822) cultivated in excavated tanks

Jucilene Cavali[1], Jerônimo Vieira Dantas Filho[1,2*], Carla Taveira Nunes[2], Elvino Ferreira[2], Rute Bianchini Pontuschka[3], Renato Zanella[4] and Maria Luiza Rodrigues de Souza[5]

[1]Programa de Pós-Graduação em Sanidade e Produção Animal Sustentável na Amazônia Ocidental, Universidade Federal do Acre, Rod. BR-364, Km 4, Distrito Industrial, 69915-900, Rio Branco, Acre, Brazil. [2]Programa de Pós-Graduação em Ciências Ambientais, Universidade Federal de Rondônia, Av. Norte Sul, 7300, Nova Morada, 76940-000, Rolim de Moura, Rondônia, Brazil. [3]Departamento de Engenharia de Pesca, Universidade Federal de Rondônia, Presidente Médici, Rondônia, Brazil. [4]Programa de Pós-Graduação em Química, Universidade Federal de Santa Maria, Santa Maria, Rio Grande do Sul, Brazil. [5]Programa de Pós-Graduação em Zootecnia, Universidade Estadual de Maringá, Maringá, Paraná, Brazil. *Author for correspondence. E-mail: jeronimovdantas@gmail.com

ABSTRACT. The study aimed to determine the fatty acid profile, omegas and lipid quality indeces in commercial cuts of pirarucu (*Arapaima gigas*) of the slaughter class 11.1 to 14.0 kg. Sample collections were carried out in two fish processing industries located in Rondônia state, Brazil. The experimental design was completely randomized, with processing performed in triplicate. Data were submitted to ANOVA to assess differences between commercial cuts in chemical compositions. If ANOVA appeared statistically significant (α=0.05), the averages were compared by Tukey's test. In the composition of fatty acids, there was a difference ($p < 0.05$) between cuts. Commercial cuts that expressed the highest percentages of SFAs tail fillet 51.2%, of MUFAs fillet mignon 39.8% and of PUFAs deboned cut 20.7%. The indeces prescribed for lipid quality, ∑PUFAs/∑SFAs, ∑PUFAs (*n*-6/∑*n*-3), AI, TI and HH, indicate that commercial cuts have lipid quality. Deboned is the cut with the highest PUFA fatty acid content, with the highest values of Omega 3, 6, 7 and *n*-9 being also expressed. Nutritional information is important for the processes of conservation and processing, development of new products on the market, as well as guiding the form of preparation, thus providing commercial security for different market niches.

Keywords: Arapaimidae; essential fatty acids; fish farming; lipid quality indeces; Osteoglossiformes.

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Introduction

In recent years the demand for fish has intensified, and this is due to the transmission of information related to its nutritional value and because its consumption is added to the health benefit and promotion of the population's quality of life (Soares & Gonçalves, 2012; Tacon et al., 2020; Dantas Filho et al., 2021). The scientific researches around the world have revealed that fish consumption is associated with a low incidence of cardiovascular diseases, due to the fact that fish meat has essential fatty acids (Yehuda, Rabinovitz, Carasso, & Mostofsky, 2002; Njinkoue et al., 2016). The clinical and epidemiological studies have suggested for some time that populations that consume meat or fish oil regularly are less prone to heart disease (Job, Antai, Inyang-Etoh, Otogo, & Ezekiel, 2015; Costa et al., 2020).

The eicosapentaenoic (EPA) and docosahexaenoic (DHA) fatty acids have a strong antiarrhythmic action on the heart and a powerful antithrombotic action, especially because these acids are direct precursors of prostanoids, as well as eicosanoids, both of which play important roles in the structure of cell membranes and in metabolic processes (Duarte et al., 2020; Pino-Hernández et al., 2020). In humans, linoleic (AA) and α-linolenic acids (ALA) are necessary to maintain cell membranes, brain functions and the transmission of nerve impulses under normal conditions (Nunes et al., 2012). These fatty acids also participate in the transfer of atmospheric oxygen to blood plasma, the synthesis of hemoglobin and cell division, being called essential because they are not synthesized by the human organism although can be found in the meat and fat of tropical fish (Duarte et al., 2020).

The content and availability of fatty acids varies between fish species, depending on age and inclusion rates in diet (Parthasarathy & Joseph, 2011; Nunes et al., 2012). The pirarucu *Arapaima gigas* (Schinz, 1822) (Osteoglossiformes: Arapaimidae) is a species native to the Amazon basin of interest to fish farming in Rondônia state, Brazil. In a natural environment it can reach up to 200 kg in total weight, and its high economic importance has determined the growing interest in its commercial exploitation by fish farmers (Oliveira, Jesus, Batista, & Lessi, 2014). Rondônia state is the largest producer of native fish in Brazil, corresponding to a total of 68.8 thousand tons of fish

produced in 2019 (Peixe BR, 2021) and has *A. gigas* as one of the most cultivated fish and, together with tambaqui *Colossoma macropomum* (Schinz, 1822) (Characiformes: Serrasalmidae), represent about 85% of the fish grown in Rondônia state (Meante & Dória, 2017).

A. gigas is an important source of animal protein for the Amazonian population and it is essential to know its profile of EPA and DHA polyunsaturated fatty acids, essential to health (Franco, Noleto, Santos, Bem, & Kirschnik, 2018). The meat of this fish is easily digestible due to proteins of high biological value (Batalha et al., 2017; Costa et al., 2020). Because they efficiently provide energy and essential fatty acids, lipids stored in fish are important components of the diet. Several vegetable oils are rich sources of *n*-6 series MUFAs and PUFAs fatty acids, such as olive, soy and corn, while fish oils also represent the sources of *n*-3 polyunsaturated fatty acids (Xiyang et al., 2020). Lipids have energetic, structural, hormonal, biochemical functions, among others (Costa et al., 2020). In view of the information expressed, the benefits from regular fish consumption reinforce the validity of fostering incentives through public policies to increase commercial availability for the consumption of *A. gigas* meat. In this context, fish farming emerges as a viable alternative to continue increasing supply in the coming years (Brabo, Ferreira, Santana, Campelo, & Veras, 2016; Costa et al., 2020).

Given the justified evidence, this study aimed to determine the fatty acid profile, omegas and lipid quality in commercial cuts of *A. gigas*, of the slaughter class 11.1 to 14.0 kg, cultivated in excavated tanks in Rondônia state, Western Brazilian Amazon.

Material and methods

Bioethical considerations

The study was conducted by the Universidade Federal de Rondônia (UNIR) and the analyzes were performed at the Laboratório de Água e Alimentos, Departmento de Química, Universidade Estadual de Maringá (UEM). 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 approved by the Ethics Committee on the Use of Animals (CEUA), under protocol No. 02/2017. The sample collections were carried out from May 2017 to December 2018 in two processing industries registered in the Brazilian System for the Inspection of Products of Animal Origin (SISBI-POA), located in the municipalities of Ariquemes and Vale do Paraíso, in Rondônia state, Brazil.

Commercial diet

A commercial artificial extruded feed was supplied to *A. gigas*, containing 36% crude protein at a feed rate of 1.0% of body weight. The supply of artificial feed was carried out twice a day from 10 am to 5 pm for 130 days (Table 1). It is important to present the composition of the rations provided in fish farms, in order to demonstrate that fish farming adopt a standardized diet. Therefore, there's no difference in feeding therefore feeding will not cause variation in results.

Table 1. Guarantee levels of the feed provided to *A. gigas* commercialized in Western Brazilian Amazon.

Feed composition	Content ($g\ kg^{-1}$)	Composition	Content ($g\ kg^{-1}$)
Dry matter (g)	910.0	Ethereal extract (min., g)	80.0
Crude protein (min., g)	360.0	Calcium (max., g)	35.0
Fibrous matter (máx., g)	95.0	Calcium (min., g)	20.0
Mineral matter (max., g)[1]	15.0	Phosphorus (min., g)	15.0

[1]Amount of nutrient per kg, for crude protein ration (36%). Pantothenic acid (min.) - 3.00 mg; Biotin (min.) - 50 mg; Choline (min.) - 290 mg; Vitamin A (min.) - 28,000 IU; Vitamin B_1 (min.) - 2.00 mg; Vitamin B_{12}(min.) - 4.00 mg; Vitamin B_2(min.) –3.00 mg; Vitamin B_6(min.) - 2.00 mg; Vitamin D_3(min.) –5,000 IU; Vitamin E (min.) –45.00 IU; Vitamin K_3(min.) - 2.00 mg; Vitamin C (min.) - 500 mg; Copper (min.) - 10.00 mg; Iron (min.) - 90 mg; Iodine (min.) - 0.40 mg; Niacin (min.) - 50.00 mg; Manganese (min.) - 10.00 mg; Zinc (min.) - 180 mg; Selenium (min.) - 0.60 mg.

Sampling and processing

The sampled fish come from fish farms that use a semi-intensive system in excavated tanks. There 77 specimens of the *A. gigas* with body weight in the slaughter class of 11.1 to 14.0 kg were studied and the commercial cuts of deboned, tail fillet, loin and fillet mignon of the *A. gigas* were evaluated, making 10 fish per commercial cut for analysis of lipid composition. 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 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. In definition, the loin is located in the upper part of the deboned cut, the fillet mignon is the largest meat part that covers the ribs and the tail fillet is located in the caudal portion of the deboned cut (Figure 1).

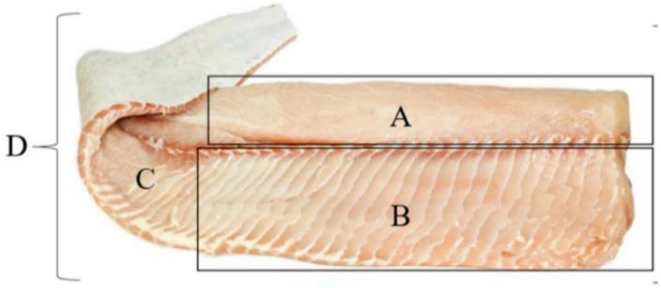

Figure 1. Representation of commercial cuts of the *A. gigas* produced in processing industries in the Western Brazilian Amazon. (A) Loin; (B) Fillet mignon; (C) Tail fillet; (D) Deboned cut.
Source: Dantas Filho et al. (2022).

Of the total of 77 fishes, they were distributed in the seven body weight classes. For chemical composition analyses, five fish per weight class were sampled. Concerning the details of samples preparation, the commercial cuts of the same fish were only filet mignon and tail fillet, on the left side of the animals. While the deboned cut was obtained from the right side of the fish. From these sampling points, 1 cm strips of three points were collected from the respective commercial cuts, the samples were homogenized and frozen. however, for the loin, three fishes sectioned samples of 2 cm thick were used in the dorsal region at the height of the tail fin (Dantas Filho et al., 2021).

Samples of the commercial cuts destined to the analysis of the lipid composition were obtained from the homogenization of three points of the commercial cut in order to obtain greater representativeness. The deboned cuts were sampled by removing 4 cm from the right side of the carcasses, and 3 cm of samples were removed for analysis. The samples were properly identified and stored at -18°C for further processing and analysis of the lipid composition. They were left labeled and frozen in a freezer at -18ºC until the moment of analysis of chemical composition. To carry out lipid assessments, three simple 50 g samples were collected from each commercial cut of *A. gigas* (fillet mignon, tail fillet, loin and deboned) in the weight class of 11.1 to 14.0 kg, categorized as classes of ideal slaughter weight according to the classification system proposed by Dantas Filho et al. (2021).

Assessment of the fatty acid profile

The total lipids were extracted by the method of Bligh and Dyer (1959) and the methyl esters of fatty acids were prepared by methylation of the triacylglycerols, as described in method 5509 of International Organization for Standardization (ISO, 1978). Regarding the fatty acid methyl esters were analyzed using a gas chromatograph 14-A (Shimadzu, Japan), equipped with a flame ionization detector and fused silica capillary column (50 m in length, 0.25 mm in internal diameter and 0, 20 µm Carbowax film thickness 20M). The flow rates of ultra-pure gases (White Martins) were 1.2 mL $min.^{-1}$ for carrier gas (H_2); 30 mL $min.^{-1}$ for auxiliary gas (make-up) (N_2); 30 and 300 mL $min.^{-1}$. And, for H_2 flame gases and synthetic air, respectively.

The injection volume was in µL and the sample split ratio was 1: 100 (Cavali et al., 2022). The column temperature was programmed at a rate of 2ºC $min.^{-1}$, from 150 to 240ºC. The injector and detector temperatures were 220 and 245ºC, respectively. Just as Coutinho et al. (2019), the peak areas were determined using the Integrator-Processor CG-300 (CG scientific instruments) and the identification of the peaks was performed by comparison with the pattern retention times (Sigma, USA).

Lipid quality indeces

Fatty acid profile data were grouped to calculate the ratio of polyunsaturated per saturated fatty acids ∑PUFAs/∑SFAs and the proportion of polyunsaturated fatty acids ∑PUFAs (*n*-6/*n*-3), following the guidelines of the WHO. The data found were compared with compositions of other animal species processed and evaluated in different regions of Brazil and the world.

Lipid quality of the calculated from the fatty acid profile through the atherogenicity (AI), thrombogenicity (TI) indeces (Ulbricht & Southgate, 1991) and the ratio between hypocholesterolemic and hypercholesterolemic fatty acids (HH) (Santos-Silva, Bessa, Santos-Silva, & 2002). For this evaluation, the following calculations were used: a) Atherogenicity Index (AI) = [(C12:0 + 4 x C14:0 + C16:0)]/ΣMUFAs + Σ*n*-6+Σ*n*-3; b) Thrombogenicity Index (TI) = (C14:0 + C16:0 + C18:0)/[(0,5 x ΣMUFAs) + (0,5 x Σ *n*-6) + (3 x Σ *n*-3) + (Σ *n*-3/*n*-6)]; c) Reasons between hypocholesterolemic and hypercholesterolemic fatty acids; (HH) = (C18:1 *n*-9 + C18:2 *n*-6 + C20:4 *n*-6 + C18:3 *n*-3+C20:5 *n*-3+C22:5 *n*-3+C22:6 *n*-6)/(C14:0 + C16:0).

Statistical design and analysis

The experimental design was completely randomized with four commercial cuts for the industrial processing of *A. gigas*, and the processing was carried out in triplicate. Data were submitted to analysis of variance (ANOVA) to assess differences between commercial cuts in chemical compositions. If ANOVA appeared statistically significant (α=0.05), the averages were compared by Tukey's test. The software used to carry out the statistical analyzes was the Genes Program made available by the Universidade Federal de Viçosa (UFV), version 13.3 (Cruz, 2013).

Results

Fatty acid composition showed a statistical difference ($p < 0.05$) between commercial cuts, with the exception of Heneicosanoic acid (21:00), which did not shown a difference ($p > 0.05$). There was also a statistical difference ($p < 0.05$) between the totals of polyunsaturated fatty acids, in omegas 3, 6, 7 and *n*-9 (Table 2).

Table 2. Fatty acid profile (%) in commercial cuts of the *A. gigas* cultivated in excavated tanks in Rondônia state, Western Amazon.

	Commercial cuts			
Fatty acids	Fillet mignon	Tail fillet	Loin	Deboned
SFAs				
12:00	3.071 ± 0.002^{a}	1.964 ± 0.004^{b}	2.963 ± 0.002^{a}	2.03 6± 0.001^{b}
13:00	0.284 ± 0.004^{b}	0.704 ± 0.002^{a}	0.228 ± 0.002^{b}	0.288 ± 0.001^{b}
14:00	1.390 ± 0.010^{a}	1.311 ± 0.001^{a}	1.529 ± 0.001^{a}	0.606 ± 0.001^{b}
15:00	0.109 ± 0.001^{b}	0.159 ± 0.005^{a}	0.125 ± 0.005^{b}	0.096 ± 0.006^{b}
16:00	32.803 ± 0.001^{a}	26.14 ± 0.001^{ab}	25.182 ± 0.004^{ab}	20.817 ± 0.001^{b}
17:00	0.335 ± 0.015^{ab}	1.847 ± 0.001^{a}	0.321 ± 0.002^{ab}	0.172 ± 0.001^{b}
18:00	8.176 ± 0.003^{b}	13.333 ± 0.002^{a}	12.822 ± 0.004^{a}	12.338 ± 0.004^{a}
20:00	0.248 ± 0.002^{ab}	0.287 ± 0.001^{ab}	0.227 ± 0.003^{b}	0.347 ± 0.001^{a}
21:00	0.480 ± 0.001^{a}	0.504 ± 0.001^{a}	0.499 ± 0.002^{a}	0.531 ± 0.002^{a}
22:00	0.820 ± 0.002^{a}	0.540 ± 0.001^{b}	0.914 ± 0.002^{a}	0.750 ± 0.001^{b}
24:00	0.325 ± 0.003^{b}	0.385 ± 0.005^{b}	0.365 ± 0.005^{b}	0.587 ± 0.004^{a}
∑*SFAs*	48.041	47.174	45.175	38.568
MUFAs				
16:1 *n*-7	3.036 ± 0.002^{a}	0.595 ± 0.001^{b}	3.635 ± 0.004^{a}	3.191 ± 0.002^{a}
16:1 *n*-9	0.327 ± 0.001^{b}	3.951 ± 0.001^{a}	0.390 ± 0.001^{b}	0.340 ± 0.002^{b}
17:1	0.660 ± 0.002^{a}	0.482 ± 0.001^{b}	0.784 ± 0.004^{a}	0.486 ± 0.001^{b}
18:1 *n*-7	2.397 ± 0.002^{b}	4.461 ± 0.001^{a}	2.455 ± 0.015^{b}	2.084 ± 0.001^{b}
18:1 *n* -9	31.558 ± 0.002^{a}	21.748 ± 0.004^{b}	31.192 ± 0.002^{a}	29.139 ± 0.003^{a}
20:1 *n* -9	0.120 ± 0.002^{b}	0.185 ± 0.005^{a}	0.170 ± 0.001^{a}	0.150 ± 0.001^{ab}
22:1 *n* -9	0.274 ± 0.002^{b}	1.529 ± 0.004^{a}	0.265 ± 0.001^{b}	0.278 ± 0.002^{ab}
24:1 *n* -9	0.500 ± 0.004^{b}	1.159 ± 0.002^{a}	0.520 ± 0.010^{b}	0.650 ± 0.010^{ab}
∑*MUFAs*	38.872	34.110	39.411	36.318
PUFAs				
18:2 *n*-6	6.418 ± 0.001^{ab}	5.899 ± 0.009^{b}	10.040 ± 0.001^{ab}	15.230 ± 0.001^{a}
18:3 *n*-3 (ALA)	0.686 ± 0.004^{ab}	3.430 ± 0.001^{a}	0.571 ± 0.001^{b}	0.597 ± 0.001^{ab}
18:3 *n*-6	0.262 ± 0.012^{b}	0.533 ± 0.001^{a}	0.330 ± 0.025^{b}	0.485 ± 0.003^{b}
20:2 *n*-6	1.214 ± 0.001^{a}	0.342 ± 0.003^{b}	1.655 ± 0.005^{a}	1.097 ± 0.002^{a}
20:3 *n*-3	1.039 ± 0.005^{a}	0.344 ± 0.002^{b}	0.617 ± 0.001^{b}	1.615 ± 0.002^{a}
20:3 *n*-6	0.205 ± 0.005^{b}	2.736 ± 0.004^{a}	0.711 ± 0.004^{ab}	0.310 ± 0.001^{ab}
20:4 *n* -6 (AA)	0.181 ± 0.001^{b}	0.327 ± 0.001^{a}	0.108 ± 0.001^{b}	0.206 ± 0.001^{ab}
20:5 *n*-3 (EPA)	0.687 ± 0.002^{ab}	0.394 ± 0.001^{b}	0.615 ± 0.005^{ab}	1.050 ± 0.001^{a}
22:2 *n*-6	0.574 ± 0.002^{a}	0.499 ± 0.002^{a}	0.545 ± 0.015^{a}	0.425 ± 0.002^{b}
22:6 *n*-3 (DHA)	0.416 ± 0.001^{b}	2.303 ± 0.002^{a}	0.416 ± 0.001^{b}	2.195 ± 0.003^{a}
∑*PUFAs*	11.682	16.807	15.608	23.210

Saturation: saturated fatty acids (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs); If there are averages followed by different letters in the columns (^{a,b}), they are different from each other by Tukey's test ($p < 0.05$).

The fillet mignon showed the percentage of SFAs 50.04%, MUFAs 39.8% and PUFAs 10.16%. In the tail fillet, the percentage of PUFAs 51.2%, MUFAs 34.11% and PUFAs 14.69%. The percentage of SFAs 48.6%, MUFAs 39.0% and PUFAs 12.4% was found in the loin. Finally, the deboned expressed the percentage of SFAs 39.98%, MUFAs 39.32% and PUFAs 20.7% fatty acids. It is worth noting that the deboned was the commercial cut that showed a balance between saturated and monounsaturated fatty acids and a higher polyunsaturated content (Table 2).

The ALA was found at the highest value in the tail fillet 3.430 ± 0.001. In relation to AA, the cut that expressed the highest value was tail fillet 0.327 ± 0.001. However, EPA was found to have a higher value in deboned cut 1,050 ± 0.001. The DHA was found at the highest value in tail fillet 2,303 ± 0.002 and deboned cut 2,195 ± 0.003. Therefore, ALA, AA and EPA showed statistical differences ($p < 0.05$) between the commercial cuts (Table 2).

The highest total value of ∑ (*n*-3) was found in 6.471 tail fillet and 5.457 deboned cut. Although the highest total value of ∑ (*n*-6) was found in deboned cut 17,753. Concerning the highest total value of ∑ (*n*-7) was found in filet mignon 5.433 and loin 6.090. As well, the highest total value of ∑ (*n*-9) was found in filet mignon 32,779 and loin 32,537. For all total values of omegas there was a difference statistics ($p < 0.05$) between the commercial cuts (Table 3).

Regarding the lipid quality indeces prescribed by the WHO, commercial cuts of *A. gigas* showed a ratio of ∑UFAs/∑SFAs with a difference ($p < 0.05$) between commercial cuts, fillet mignon 0.20, tail fillet 0.29, loin 0.26 and deboned cut 0.52. And the proportion of polyunsaturated fatty acids (∑UFAs *n*-6/*n*-3) with difference ($p < 0.05$) between commercial cuts, fillet mignon 3.69, tail fillet 1.46, loin 5.14 and deboned cut 7.53 (Table 3).

The Atherogenicity Index (AI) with difference ($p < 0.05$) between commercial cuts, expressed fillet mignon 3.13, tail fillet 4.46, loin 2.67 and deboned cut 1.69. Regarding the Thrombogenicity Index (TI) with difference ($p < 0.05$) between commercial cuts expressed fillet mignon 1.57, tail fillet 1.12, loin 1.52 and deboned cut 1.08. However, between Hypocholesterolemic and hypercholesterolemic (HH) fatty acids with difference ($p < 0.05$) between commercial cuts expressed fillet mignon 1.18, tail fillet 1.31, loin 1.38 and deboned cut 2.16 (Table 3).

Table 3. Omegas and lipid quality indeces in commercial cuts of the *A. gigas* cultivated in excavated tanks in Rondônia state, Western Amazon.

	Commercial cuts			
	Fillet mignon	Tail fillet	Loin	Deboned
Omegas				
∑*PUFAs* (*n*-3)	2.828^{b}	6.471^{a}	2.219^{b}	5.457^{a}
∑*PUFAs* (*n*-6)	8.854^{b}	10.336^{ab}	13.389^{ab}	17.753^{a}
∑*PUFAs* (*n*-7)	5.433^{a}	5.056^{b}	6.090^{a}	5.275^{b}
∑*PUFAs* (*n*-9)	32.779^{a}	28.572^{b}	32.537^{a}	30.557^{b}
	Lipid quality indeces			
∑*PUFAs*/∑*SFAs*	0.243^{b}	0.356^{b}	0.346^{b}	0.602^{a}
∑*PUFAs* (*n*-6/*n*-3)	3.131^{ab}	1.597^{b}	6.034^{a}	3.253^{ab}
AI	0.820^{a}	0.655^{ab}	0.623^{ab}	0.425^{b}
TI	1.297^{a}	0.965^{ab}	1.190^{a}	0.772^{b}
HH	1.168^{b}	1.242^{b}	1.608^{ab}	2.260^{a}

Saturation: saturated fatty acids (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs); Atherogenicity Index (AI); Thrombogenicity Index (TI); Ratios between hypocholesterolemic and hypercholesterolemic (HH) fatty acids; If there are averages followed by different letters in columns (^{a,b}) they are different from each other by Tukey's Test ($p < 0.05$).

Discussion

Comparing the percentage of fatty acids SFAs, MUFAs and PUFAs (Martino, Cyrino, Portz, & Trugo, 2002; Wing-Keong, Phaik, & Peng, 2003; Orban et al., 2008; Tanamati et al., 2009; Chaijan, Jongjareonrak, Phatcharat, Benjakul, & Rawdkuen, 2010), when evaluating the fatty acid profile of spotted fillets (*Pseudoplatystoma corruscans*), African catfish (*Clarias gariepinus*), panga (*Pangasius hypophthalmus*), pacu (*Piaractus mesopotamicus*) and pangasius (*Pangasius boccourti*) 18,10; 20.50, 12.45, 18.00 and 14.80, respectively, found lower percentages of PUFAs than the *A. gigas* deboned and higher than the fillet mignon, tail fillet and loin. *A. gigas* cuts showed a higher percentage of SFAs than the averages obtained by Hautrive, Marques, and Kubota (2012) and Navarro et al. (2012) for pork 28%, beef 32.26%, ostrich 27.3% and chicken 19.73%. With the exception of the tail fillet 34.11%, they expressed a higher percentage of MUFAs than the average fat of chicken MUFAs 37.0%. However, they expressed lower levels of MUFAs in relation to ostrich meat 45.7%, pork 52.2% and bovine 61.0%. Although the fillet mignon, tail fillet and loin express a lower percentage of PUFAs than swine fat 20.26%, the deboned expressed higher PUFAs contents in relation to meat bovine 5.9%.

The lipid percentage of the *A. gigas* cuts showed values equivalent to those of other freshwater fish species such as *Brycon orbignyanus*, *Brycon microlepsis* and *Brycon cephalus* (Martins, Martins, & Pena, 2017). However, *A. gigas* has in its meat an essential percentage of PUFAs from groups 3, 6, 7 and *n*-9 (1376.1 mg $100g^{-1}$ of fresh muscle), such as C18:3 (ALA), C20:5 (EPA) and C22:6 (DHA), essential for human health (Martins et al., 2017). With regard to the content of essential fatty acids EPA and DHA found (Orban et al., 2008, Tanamati et al., 2009; Dang et al., 2018) when evaluating the fatty acid profile of pangasius fillets (*Pangasius hypophthalmus*) EPA 0.19 and DHA 0.083, American catfish (*Ictalurus punctatus*) DHA 0.75 and pacu (*Piaractus mesopotamicus*) DHA 1.90 found lower percentages of EPA and DHA than the *A. gigas* commercial cuts. Additionally, Martino et al. (2002) and Wing-Keong et al. (2003) when evaluating the fillets of African catfish (*Clarias gariepinus*) DHA 2.00 and Amazon catfish (*Pseduplatystoma corruscans*) DHA 2.20 found lower percentages than the fillet of the *A. gigas* tail.

Very long-chain PUFAs are derived from linolenic fatty acid (C18:3 *n*-3 AA) with priority to EPA and DHA by stretching and desaturation, and are able to modulate inflammatory processes competing with polyunsaturated fatty acids *n*-6 derivatives of Linoleic acid such as docosatetranoic (C22:4 DTA) by the deposition of membrane phospholipids in the cells of the immune system (Antonelo et al., 2020). According to Harris et al. (2009), it is recommended to consume between 250 to 500mg of EPA + DHA per day. And, according to Helenius, Budge, Nadeau, and Johnson (2020) the conversion of linolenic to fatty acids EPA and DHA is limited and the efficiency in the transfer of linolenic to EPA and from EPA to DHA *n*-3 in adult humans is about 0.2 and 0.05%, respectively. Generally, eicosanoids produced from *n*-3 fatty acids, mainly EPA and DHA, are reported as essential fatty acids due to inhibition of stearic metabolism to inflammatory eicosanoids, since they increase anti-inflammatory mediators, vasodilation and also inhibit platelet aggregation compares those produced in the *n*-6 series of eicosanoids (Antonelo et al., 2020). That is, the enzymatic action of these polyunsaturated fatty acids in modulating the lipid profile from unsaturated to saturated during metabolism changes the efficiency of the diet consumed and the ingested profile making the meat healthier (Vieira et al., 2015).

Fallah, Siavash-Saei-Dehkordi, and Nematollahi (2011) determined the fatty acid profile of rainbow trout (*Oncorhynchus mykiss*) in Northern Iran, and found PUFAs percentages higher 25% than *A. gigas* commercial cuts, although with a lower percentage of MUFAs fatty acids 28%. However, Njimkoue et al. (2016) compared the fatty acid profiles of the meat of *Pseudotolithus typus* and *Pseudotolithus elongatus*, two species of marine fish widely consumed on the West coast of Africa, and obtained a higher percentage of PUFAs 50.93% compared to *A. gigas* commercial cuts, and a percentage lower than MUFAs 33.4%.

Commercial cuts tend to differ quantitatively and qualitatively in terms of lipid content and profile. Regions more prone to lipid deposition, such as the ventral region, tend to form adipocyte clusters and deposit triacylglycerols more quickly compared to leaner cuts (Sharma et al., 2010) such as loin of *A. gigas*. The lipid profile of triglycerides tends to have a shorter chain and saturated fatty acid profile when compared to more unsaturated membrane lipids (Rigano, Oteri, Russo, Dugo, & Mondello, 2018). This lipid deposition profile added to the fatty acid profile of the diet at different life stages influence the lipid quality of the different commercial cuts.

The characteristic of lower fat deposition, as in the loin of *A. gigas* and of more fat as in the filet mignon and tail fillet of *A. gigas*, has a positive nutritional appeal since it favors the ratio of membrane phospholipids *vs* neutral lipids, due to the lower deposition of triglycerides in adipocytes (M'Barek et al., 2017), it favors the acid profile due to the greater deposition of essential fatty acids PUFAs, especially long-chain fatty acids. These fatty acids participate in several metabolic processes beneficial to human health, especially the omega-3 isomers (Benjamin & Spener, 2009).

Concerning the lipid quality indices, a method prescribed by WHO to assess lipid quality is based on the ∑UFAs/∑SFAs fatty acid ratio, with values below 0.45 being considered unhealthy. *A. gigas* commercial cuts expressed ∑UFAs/∑SFAs fillet mignon 0.20, tail fillet 0.29, loin 0.26 and deboned cut 0.52. According to the fatty acid composition determinations obtained by Navarro et al. (2012), it can be seen that although the *A. gigas* commercial cuts have a lower percentage of PUFAs than salmon (47.3%), they have percentages of higher PUFAs than sardines (*Triportheus angulatus*) 19.8%, sea bass 18.7% and xareu (*Caranx hippos*) 20.08%, and have a higher ∑PUFAs/∑MUFAs ratio than these species, with the exception of salmon (ratio of 1.5). The lipids of ruminant meat are characterized by having high proportions of SFAs and low ∑UFAs/∑SFAs ratio (Duarte et al., 2020). The SFAs are considered hypercholesterolemic and the most worrying for cardiovascular health, in this sense, are Myristic, Lauric and Palmitic acids (Nunes et al., 2012).

PUFAs increase the level of blood cholesterol by reducing the activity of the LDL-cholesterol receptor and reducing the free space of LDL in the bloodstream (Grundy & Denke, 1990). The palmitic SFAs is the most harmful to cardiac functions and is the most found in bovine and porcine fats (Hautrive et al., 2012). However, Myristic, Lauric and Palmitic SFAs were not found among the lipid contents of the *A. gigas* commercial cuts (Table 2). According to some

studies (Martino et al., 2002; Lu, Takeuchi, & Ogawa, 2003; Orban et al., 2008; Tanamati et al., 2009), when studying the composition of Amazon catfish fillets (*Pseudoplatystoma corruscans*), pangasius (*Pangasius hypophthalmus*), Nile tilapia (*Oreochromis niloticus*) and pacu (*Piaractus mesopotamicus*) ∑PUFAs/∑SFAs 0.44, 0.26, 0.53 and 0.35, respectively, found lower rates of ∑UFAs/∑SFAs fatty acids than the *A. gigas* deboned and higher than the fillet mignon, tail fillet and *A. gigas* loin. In addition, Amazon catfish, panga and pacu do not have lipid quality according to WHO prescriptions.

The proportion of ∑UFAs (*n*-6/*n*-3) has also been used as a criterion to assess the quality of lipids, by the WHO. An excess of Linoleic acid (AA) prevents the transformation of α-Linolenic acid (ALA) into its EPA and DHA derivatives, the same happens in the opposite case, with less consumption of Linoleic acid, there will be a reduction in arachidonic acid activation, because the enzyme Δ-6-desaturase has the purpose for both fatty acids (Martins et al., 2017). However, the enzyme is more specific for *n*-3 and will require lower percentages of these acids than *n*-6 fatty acids to produce the same percentage of PUFAs (Gomes et al., 2016). That is, there must be a higher proportion of AA than ALA. Therefore, a balance is needed between the supply of the two fatty acids through the diet. And, the proportion of polyunsaturated fatty acids ∑PUFAs (*n*-6/*n*-3) found in the present work was, fillet mignon 3.69, fillet of the tail 1.46, loin 5.14 and deboned cut 7.53 (Table 3).

According to Hautrive et al. (2012) and Navarro et al. (2012), bovine fat showed a positive average 2.44 and chicken 19.99. According to Souza et al. (2017), PUFAs have fundamental action in the body, of the *n*-6 group are pro-inflammatory. They increase the production of cytokines with vasoconstrictor action and that promote platelet aggregation (Gomes et al., 2016). It is related to the occurrence of cardiovascular, autoimmune and inflammatory diseases such as arthritis, asthma, psoriasis, lupus and ulcerative colitis. Although the *n*-3 group are anti-inflammatory. Unlike *n*-6, they promote vasodilation and inhibition of platelet aggregation and are related to the prevention of hypertension, atherosclerosis, hypercholesterolemia, arthritis and other autoimmune and inflammatory diseases, as well as the most diverse cancers (Souza et al., 2017).

The Western diet, rich in industrialized products, cheese and fried foods and low in fish, fruits, vegetables and legumes, contributes to the ∑PUFAs (*n*-6/*n*-3) ratio being approximately 20:1, when WHO recommends about 5:1 (Kratz et al., 2014; Souza et al., 2017). The evidence points to the importance of increasing the consumption of ∑PUFAs (*n*-6/*n*-3) to the most physiological possible and for that, some changes in diet should be made, such as the consumption of tropical fish (Passos et al., 2016). According to the lipid quality data tabulated by some studies (Passos et al., 2016; Rodrigues et al., 2017; Souza et al., 2017; Xiyang et al., 2020), the results of the Atherogenicity Index (AI), Thrombogenicity Index (TI) and the ratios between hypocholesterolemic and hypercholesterolemic fatty acids (HH) expressed in Table 3 express high lipid quality, especially the results of the deboned and loin. It is noteworthy that MUFAs fats have been linked to a decrease in total cholesterol and LDL-cholesterol, also increasing plasma HDL-cholesterol levels. The PUFAs of the *n*-3 and *n*-9 group found in fish also have a positive effect on total cholesterol, LDL-cholesterol and triglycerides (Kratz et al., 2014; Passos et al., 2016; Mahan & Escott-Stump, 2018; Rodrigues et al., 2020).

TI and AI are related to the potential to stimulate platelet aggregation. Therefore, values lower than those found in this research indicate a high amount of anti-atherogenic acids in a given fat or oil, with a correspondingly increased potential to prevent the emergence of coronary heart disease (Mahan & Escott-Stump, 2018). In contrast, a higher proportion of HH found in this research indicates greater nutritional adequacy (oil or fat) for human consumption because this index is related to cholesterol metabolism (Xiyang et al., 2020).

The cholesterol is a major cause of coronary heart disease, about 40% of Brazilians have high cholesterol, and among young people, 12 to 17 years old, the rate is 20% (Lotufo et al., 2017). It is a type of fat produced in the human body and has the function of keeping cells functioning, producing hormones and vitamin D. However, 30% of cholesterol is added by the diet, and its excessive consumption, especially LDL-cholesterol in the blood can increase the risk of heart disease (Grundy & Denke, 1990; Siqueira et al., 2018). LDL cholesterol is known as bad cholesterol, it is a low density lipoprotein, it can accumulate in arteries and coronaries and can lead to the formation of atherosclerosis plaques that can interrupt blood flow to organs such as the heart and brain, increasing the risk of infarction (Jankowska, Zakes, Zmijewski, & Szczepkowski, 2010). However, there is another fraction of PUFAs, category 3, 6 and *n*-9, present for example in the *A. gigas* commercial cuts, the good HDL-cholesterol, whose function is to remove the bad LDL-cholesterol from the bloodstream and take it to be metabolized in the liver (Leite et al., 2015). The tropical fish like *A. gigas* are excellent suppliers of PUFAs *n*-3 and *n*-6, which are polyunsaturated lipids, so bromatological studies indicate the consumption of cooked fish to lower LDL-cholesterol by maintaining the presence of HDL-cholesterol in bloodstream (Martins & Oetterer, 2011; Hautrive et al., 2012; Franco et al., 2018; Siqueira et al., 2018).

It is worth emphasizing the finding of ∑PUFAs (*n*-7) found in the *A. gigas* commercial cuts, a nutrient responsible for the increase in insulin sensitivity, preventing type 2 diabetes. Reducing inflammatory processes and LDL-cholesterol levels, in addition to improving the elasticity of arteries. In summary, it helps in the treatment of metabolic syndromes (Passos et al., 2016). The palmitoleic acid is a *n*-7 fatty acid, which has gained prominence in scientific publications for being considered a potent anti-inflammatory. As a mechanism, it is suggested that this PUFAs increases the gene expression of PPAR-α, an inhibitor of nuclear factor kappa B (NFkB), recognized for increasing cellular inflammation (Souza et al., 2017). In addition, Palmitoleic acid acts as an important signal for metabolic reactions in adipocytes (Passos et al., 2016). Thus, some studies propose its consumption to reduce the risk of inflammatory and metabolic diseases (Frigolet & Gutiérrez-Angular, 2017). Likewise, research carried out in obese rats showed that the administration of Palmitoleic acid ∑PUFAs (*n*-7), for 12 weeks, promoted an improvement in insulin sensitivity, since this fatty acid regulates the phosphorylating cascade mediated by the hormone in question (Souza et al., 2017). It is worth mentioning that this benefit was also verified in a clinical way. A study carried out with 17 individuals was found to be positive in correlating plasma concentrations of palmitoleic acid and improving insulin sensitivity. Thus, the consumption of *n*-7 is suggested to reduce this trigger related to diabetes and other metabolic diseases (Kratz et al., 2014).

Another study was conducted with 20 patients diagnosed with ulcerative colitis and indicated that supplementation of Palmitoleic acid ∑UFAs (*n*-7) for 8 weeks was responsible for a significant reduction in Interleukin-6 (cytokine related to the inflammatory condition of the disease). In addition, the authors observed an increase in the gene expression of HNF4-g (hepatocyte nuclear factor 4 gamma) and HNF-a (hepatocyte alpha nuclear factor), proteins that are also involved in the immune response of this condition (Bueno-Hernandez, Sixto-Alonso, & Milke, 2017). Furthermore, ∑UFAs (*n*-7) can be found in some oilseeds - such as macadamia - and in some tropical fish (Passos et al., 2016). In a balanced way, these fatty acids can be part of the diet, promoting their benefits in our organic balance (Jankowska et al., 2010; Almeida & Silva, 2016; Bueno-Hernandez et al., 2017).

Given the difference found in this study, on the content of saturated and polyunsaturated fatty acids in different commercial cuts. What will be the most suitable destination for processing? According to the variation of the proximate composition, they demand specific forms of processing and preparation, allowing the exploration of new market niches (Cortegano et al., 2017; Pontuschka et al., 2022). The processing of fatter cuts requires more carcass cleaning with the removal of excess residual fat, such as the deboned cut, filet mignon and loin of *A. gigas*, they will be better destined to the preparation of portions of baked cookies (Dantas Filho et al., 2022). However, lean cuts, such as the loin of *A. gigas*, generate less waste in the industry and are recommended for more humid dishes such as Amazonian moqueca and stews or even grilled in the lighter food option (less caloric) (Bombardelli, Syperrech, & Sanches, 2005).

Conclusion

The lipid composition in commercial cuts of *A. gigas*, of 11.1 to 14.0 kg, have fatty acids essential to health, including EPA, DHA, AA and ALA related to a lower propensity to cardiovascular diseases. Regarding the deboned is the commercial cut with the highest content of PUFAs fatty acids, and also expressed the highest values of Omegas 3, 6, 7 and *n*-9. In relation to the lipid quality indeces prescribed by WHO, ∑PUFAs/∑SFAs, ∑PUFAs (*n*-6/∑*n*-3), AI, TI and HH, all indicated that *A. gigas* has lipid quality. Therefore, nutritional information is important for the processes of conservation and processing, development of new products on the market, as well as guiding the form of preparation, thus providing commercial security for different market niches.

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