Lipid quality of Amazonian’s native fish, overview and market outlook of Brazilian fish farming

Regiane Pandolfo Marmentini*; Jerônimo Vieira Dantas Filho**; Raphael Brito dos Santos***; Carlos Andre Amaringo Cortegano****; Jucliene Cavali*****

*Mestre em Ciências Ambientais, Professora do Curso Técnico em Alimentos, Instituto Federal de Educação, Ciência e Tecnologia de Rondônia - IFRO, Jaru - RO, Brazil.
**Doutor em Sanidade e Produção Animal, Bolsista de Pós-Doutorado CNPq/FAPERJ e Docente Colaborador no Programa de Pós-Graduação em Ciências Ambientais, Universidade Federal de Rondônia - UNIR, Rolim de Moura - RO, Brazil.
***Doutor em Aquicultura, Bolsista de Pós-Doutorado da CAPES e Docente Colaborador no Programa de Pós-Graduação em Aquicultura, Universidade Nilton Lins - UNILINS, Manaus - AM, Brazil.
****Mestrado em Aquicultura, Professor do Instituto Veterinario de Investigaciones Tropicales y de Altura, Universidad Nacional Mayor de San Marcos, Ucayali, Peru.
*****Doutora em Zootecnia, Professora do Departamento de Engenharia de Pesca, Universidade Federal de Rondônia – UNIR, Presidente Médici – RO, Brazil.

*Autor para correspondência e-mail: jeronimovdantas@gmail.com

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Harmless food

PALAVRAS-CHAVE
Alimentação saudável
Peixes nativos do Brasil
Alimento inócuo

Resumo: The aimed of this study was to carry out a bibliometric survey on the lipid composition Amazonian’s native fish and the international aquaculture overview, Brazilian aquaculture overview, native farmed fish production, characteristics of Brazilian fish meat, nutritional aspects and benefits of native fish consumption and market outlook of Brazilian fish farming. This is a data collection study that is characterized as being of an exploratory descriptive, with a qualitative character, aiming to analyze, systematize, compare and cross data between different scientific literatures related to the theme. The searches in Web, storage and data analysis were carried out from March to August 2021. The bibliographic bases for carrying out the searches were Scopus, Web Science, Elsevier, Hindawi, Scielo, Wiley, CAPES/Brasil Journals and institutional repositories. Searched for descriptors in Portuguese and English language, with words and terms separated by the Boolean operators 'AND' and 'OR'. In addition to being sustainable, consuming native farmed fish is a healthy choice from a nutritional point of view, because they contain monounsaturated and polyunsaturated fatty acids that are related to an anti-inflammatory effect and a lower propensity for cardiovascular diseases in consumers. Regarding the production chain problems, market studies must be carried out for each region of Brazil. In addition, more investment in integrated crop systems is needed. In other words, quality certification is needed to universalize native Brazilian fish. Therefore, the future of Brazilian fish will depend on better dissemination to attract different market niches.

Qualidade Lipídica de Peixes Nativos da Amazônia, Panorama e Perspectivas de Mercado da Piscicultura Brasileira

Abstract: O objetivo deste estudo foi realizar um levantamento bibliométrico sobre a composição lipídica de peixes nativos da Amazônia e o panorama da aquicultura internacional, panorama da aquicultura brasileira, produção de pescado nativo, características da carne do pescado brasileiro, aspectos nutricionais e benefícios do consumo e mercado do pescado nativo, assim como perspectivas da piscicultura brasileira. Trata-se de um estudo de levantamento de dados que se caracteriza como exploratório descritivo, de caráter qualitativo, objetivando analisar, sistematizar, comparar e cruzar dados entre diferentes literaturas científicas relacionadas ao tema. As buscas na Web, armazenamento e análise dos dados foram realizadas no período de março a agosto de 2021. As bases bibliográficas para realização das buscas foram Scopus, Web Science, Elsevier, Hindawi, Scielo, Wiley, Periódicos CAPES/Brasil e repositórios institucionais. As pesquisas buscaram descritores nos idiomas português e inglês, com palavras e termos separados pelos operadores booleanos ‘AND’ e ‘OR’. Além de ser sustentável, o consumo de peixes cultivados nativos é uma escolha saudável do ponto de vista nutricional, pois contém ácidos graxos monoinsaturados e poli-insaturados que estão relacionados ao efeito anti-inflamatório e à menor propensão a doenças cardiovasculares nos consumidores. Em relação aos problemas da cadeia produtiva, estudos de mercado devem ser realizados para cada região do Brasil. Além disso, é necessário mais investimento em sistemas integrados de cultivo, ou seja, a certificação de qualidade é necessária para universalizar o consumo de peixes nativos brasileiros. Portanto, o futuro do mercado de peixes nativos dependerá de uma melhor divulgação, para atrair diferentes nichos de mercado.
Introduction

Fish, whether from farming and/or capture, is the most produced and consumed animal protein in the world. Its demand is expanding due to the increase in global population, which currently stands at around 7.6 billion inhabitants with per capita consumption 20.5 kg per year (VALENTI et al., 2021), as well as the increase in food demand nutritious products that additionally have functional components favoring the health of the consumer, and fish meat meets these characteristics (DANTAS FILHO et al., 2022). Therefore, the world population will tend to diversify meat consumption, not only increasing the frequency of fish consumption, although also replacing the consumption of red meat with poultry and fish (DANTAS FILHO et al., 2022). In this sense, both aquaculture and fisheries are important as activities that provide protein to population. Fishing today is stagnant with a projection of an increase in its production of only 1% until year 2025, while aquaculture is animal production activity with the highest growth in the last three decades and a projected growth 5.4% annually, which makes that this activity is considered key for the supply of protein in present and in future (PONTUSCHKA et al., 2022).

Fish is a food of good nutritional quality, due to the presence of essential amino acids, minerals, vitamins and polyunsaturated fatty acids (PUFAs), including those of long chain (highly unsaturated fatty acids (MUFAs), such as Eicosapentaenoic acid (EPA; 20:5 n-3) and Docosahexaenoic acid (DHA; 22:6 n-3) (CORTEGANO et al., 2017). These MUFAs, when found in meat, increase the nutraceutical value of fish, since their consumption is related to prevention of heart disease, autoimmune diseases, arrhythmias, reduction of plasma triglyceride levels and blood pressure (PAL et al., 2018). In addition, they support proper brain and vision function in the human body, promote the prevention of mental and visual illnesses, and provide protection against various psychological disorders, in particular depression and attention deficit disorder (CAYGILL et al., 1995; SINN, 2007). The quality of lipids in flesh of fish is a function of contents and composition of dietary lipids (NRC, 2011). The natural food is determinant for fatty acid profile in captured fish. Fish from marine environment are generally rich in PUFAs due to the phytoplankton’s fatty acid composition, fish from freshwater environment are rich in Conjugated linoleic acid (CLA) and/or α-Linolenic acid (LNA) reflecting the phytoplankton fatty acid content (GONÇALVES et al., 2021). Similarly, it happens in aquaculture systems where the dietary lipids influence the flesh composition. Fish fed aquafeeds formulated with fish flours and/or fish oil are rich in n-3 fatty acids, especially EPA and DHA, while fish fed plant-based diets are generally rich in CLA and LNA (CORTEGANO et al., 2017; GONÇALVES et al., 2021; RIBEIRO et al., 2022).

Knowledge of the nutritional values of fish can generate tools to improve nutrient conservation through processing and transformation processes. Therefore, the aimed of this manuscript was to carry out a bibliometric survey on the lipid composition Amazonian’s native fish and the international aquaculture overview, Brazilian aquaculture overview, native farmed fish production, characteristics of Brazilian fish meat, nutritional aspects and benefits of native fish consumption and market outlook of Brazilian fish farming.

Methodology

A metodología This is a data survey study that is characterized as being of an exploratory descriptive, with a qualitative character, aiming to analyze, systematize, compare and cross data between different scientific literatures related to the theme. The searches in Web, storage and data analysis were carried out from March to August 2021.

In the study, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used to identify, screen, and analyze the published documents on Scopus, Web Science, Elsevier, Hindawi Scielo, Wiley, CAPES/Brasil Journals and institutional repositories from Brazil. The criteria adopted for the searches were Journals that had a focus and scope related to the theme, were linked to a higher education institution (University) and had a Qualis concept Capes/Brasil (2013-2016), at least B1, in Environmental Sciences and Food Technology or impact factor above 1.5.

The descriptors used were fisheries, aquaculture, fish farming, commercial fish, native farmed fish, fish meat and fatty acid profile; in Portuguese and English language, with words and terms separated by the Boolean operators ‘AND’ and ‘OR’ according to the search objectives in each topic of this review article, (i) International aquaculture overview, (ii) Brazilian aquaculture overview, (iii) Fish meat characteristics, (iv), Nutritional aspects and benefits of native farmed fish consumption and (v) Market outlook.
Lastly, the bibliometric analysis of research was performed to divulge the lipid quality of Amazonian’s native fish, aquaculture overviews and market outlook of Brazilian fish farming. The program used for data storage was Dropbox™ (version 3.3, 2019). The stored data, after being transformed into information, were systematized and interpreted with the help of the DataMelt application (version 7, 2020).

Results and discussion
International aquaculture overview
According to Valenti et al. (2021) and Ribeiro et al. (2022) the expansion of the global population has caused an increase in demand for agricultural products. Among these products are farmed and fish, which are currently the most produced and consumed animal proteins in the world, ahead of pork, poultry, beef and sheep. In year 2018, out of a total of 96.4 million tons of catch fish, 12 million were of continental fish and 84.4 of marine origin. However, for aquaculture out of a total 82.1 million tonnes of fish produced, 51.3 million tonnes were from continental production and 30.8 million tonnes from marine production. For fishing, there was an increase 7.6% from years 2016 to 2018, something atypical since values are usually stagnant (Figure 1). This was due to the increased fishing effort in search of Engraulis ringens in the Pacific Ocean (Cortegano et al., 2017). The stability of volume’s fisheries capture has occurred since the 1980s. While in aquaculture production there was an increase 14.6% from years 2016 to 2020, considering an increase in average annual production of 5.4%. Fish production has increased over the years. However, in year 2018, 54% of fish was still caught, while 46% came from aquaculture (Figure 1). The results in years 2019 and 2020 will only appear in year 2022 report, and it is believed that by this period aquaculture will have already surpassed capture fisheries (Cortegano et al., 2017).

Figure 1 - World aquaculture production, 1990-2020.

A detail to note, much of fishery production is intended for the production of by-products for animal feed, while aquaculture production is largely destined for human consumption. And that’s why aquaculture is booming today. By year 2025, the volume of fisheries production is expected to increase by only 1% while aquaculture will continue to one of the fastest growing food sectors, at around 5.4% p.a. Aquaculture will exceed total catch fisheries by year 2022. Much of the increase is expected in freshwater species, especially cultivated inland and tropical areas (Valenti et al., 2021). It is estimated that the world consumption of fish as food will increase by 21% in year 2025 compared to the current period. In addition, by year 2025, fish from aquaculture corresponds to 57% of the fish consumed. Per capita consumption of fish is expected to increase on all continents, while the fastest consumption growth rates are projected for Oceania and Asia (Gonçalves et al., 2021).

Cortegano et al. (2017) market outlook is that in the next decade there will no significant chan-
changes in terms of demand for agricultural products and an expanding global population remains the main driver of growth, although consumption profiles and projected trends will vary depending on the level of development of each country. For aquaculture, the relevant factors are the accessibility and availability of water resources, as well as technology and finance; the sustainability, availability and cost of fingerlings and food; use of antibiotics; environmental impact assessment (including pollution and health issues); food safety and traceability issues. Furthermore, trade policies, trade agreements and market access remain important factors influencing the overall dynamics of world markets (VALENTI et al., 2021).

The FAO publication entitled “The State of World Fisheries and Aquaculture” demonstrated that the human population grew by 1.3% from years 2016 to 2018, with 7.6 billion inhabitants in year 2018 having a per capita consumption of fish. 20.5 kg year-1, a value that has increased over the years (GASCO et al., 2018). In fishing, Engraulis ringens, Merluccius merluccius, Katsuwonus pelamis, Clupea harengus and Micromesistius poutassou stand out. However, E. ringens and C. harengus are species of the Clupeidae family and the striped K. pelamis of the Scombridae family are classified as fatty fish. Although, M. merluccius and M. poutassou, which belong to the Gadidae family, are classified as low-fat fish and concentrate much of their body fat in the liver. However, the species commonly traded in world aquaculture are Ctenopharyngodon idella, Hypophthalmichthys molitrix, Nile Tilapia (Oreochromis niloticus), Cyprinus carpio and Hypophthalmichthys nobilis. It is important to note that carp are native to Asia and tilapia is native to Africa (FROUZ; FROUZOVÁ, 2022).

Brazilian aquaculture overview

Brazil has stood out worldwide in the production of food, including products from aquaculture, thanks to its water availability, favorable climate and natural occurrence of aquatic species that combine zootechnical and marketing interests (BRASIL, 2012, 2017). Despite this, the country has a difficulty with the tax legislation that favors the commercialization of raw materials and burdens processed foods. In addition, there is still a huge logistical deficiency that makes efficient production difficult (BRASIL, 2017). In this overview, in year 2020, national production of farmed fish increased by 4.74% compared to 2020 and reached 841,005 tons (Figure 2). Of this production, 486,155 tons were Oreochromis niloticus (Nile tilapia), and 278,671 tons were native farmed fish, Colossoma macropomum Cuvier, 1818 (in Brazil it is commonly called tambaqui) and Arapaima gigas Schinz, 1822 (in Brazil it is commonly called pirarucu). Continuing, 38,104 tonnes were from other fish species (C. carpio, trouts and Pangasius sp.). Among the Brazilian states, the largest producers of farmed fish were Paraná, São Paulo and Rondônia states, and the countries that most import fish from Brazilian fish farming are the USA, Chile, China, Peru and Colombia (MATTOS et al., 2021).

Figure 2 - Brazilian production of farmed fish grew 4.74% in year 2021, reaching 841,005 metric tons.

In year 2020, native farmed fish accounted for 34.7% of total production in Brazil. Rondônia state ranks 3rd in ranking of farmed fish production in year 2022, being the largest producer of native fish. The production of farmed fish in Rondônia corresponds to 59,600 tons, followed by the states Mato Grosso 37,000 tons, Maranhão 37,000 tons, Pará 24,200 tons and Amazonas 21,000 tons (Figure 3). However, in year 2020 in Brazil, the production of native farmed fish decreased by 3.2% compared to the previous year, due to the high production costs caused by the increase in value of corn and soybeans and the stability of prices paid to fish producers. Furthermore, investments are needed in infrastructure (processing unit plants, development of new products, etc.), sanitary control, logistics and environmental licensing (PONTUSCHKA et al., 2022).

**Figure 3** - Ranking of Brazilian states with the highest production of native farmed fish.


Tambaqui (*C. macropomum*), *Brycon amazonicus* Spix & Agassiz, 1829 (in Brazil commonly called jatuarana) and pirarucu (*A. gigas*) are the most cultivated fish in Rondônia state (MEANTE; DÓRIA, 2017), together they account for about 90% of farmed fish. tambaqui (*C. macropomum*) is a native fish to the Amazon basin and is the second most produced species in Brazil (CAVALI et al., 2021). Another native Amazonian fish of equal importance in the North region is a pirarucu (*A. gigas*). In the natural environment it can reach up to 200 kg of total weight, and its high economic importance has determined the growing interest in its commercial exploitation by fish breeders (OLIVEIRA et al., 2014). With regard to the processing of these fish, the product of greatest interest in the industry is meat, which is often processed and offered in different commercial cuts without the presence of intramuscular bones, to meet the demands of the current consumer market (MEANTE; DÓRIA, 2017).

Fish meat characteristics

Fish meat, usually, is rich in amino acids, such as lysine and leucine (SALES; MAIA, 2013) and an important source of fatty acids, such as essential polyunsaturated fatty acids, Eicosapentaenoic acid (EPA; C20:5 n-3) and Docosahexanoic acid (DHA; C22:6 n-3). In addition, it has vitamins - Vitamin A, Vitamin D, Vitamin E, Vitamin B₁₂, Folic acid, choline, coenzyme Q10 and minerals - Calcium, Magnesium, Iron, Copper, Zinc, Iodine, Selenium and trivalent chromium (ERKAN; BILEN, 2010; LIMA et al., 2018; COUTINHO et al., 2019). It has characteristics such as easy digestibility, due to proteins of high biological value (BATALHA et al., 2017). Due to the content of essential amino acids, the nutritional value of fish proteins is significant (VALENTI et al., 2021). Several factors influence the proximate composition of meat, such as species, age, size, sex, time of year and cut; however, usually, the muscle contains about 20% protein, 0.4 to 1.5% minerals, 75% moisture and provides 97.12 kcal per 100g (ORDÔNEZ, 2005). In addition, body composition can express differences in same individual, depending on the assessment body site and the animal’s diet.

According to Memon et al. (MEMON et al., 2011), there is an inverse ratio between the moisture
content and the fat content in pulp of many fish species, which is reflected in color of the fibers, which become whiter as the lipid content reduces, as it waits for light-colored fish meat is assumed to correspond to lean meat. Also, according to the lipid content, fish meat can classified as lean (<2% fat), low fat (2-4%), medium fat (4-8%) and fat (>8%) (ACKMAN, 1989). This classification involves not only individual characteristics of the nutritional quality of the meat, although also the visual appearance, yield during processing and flavor (CIRNE et al., 2019).

Lipids are a broad group of chemically diverse compounds that are soluble in organic solvents. They can solid (fats) or liquids (oils). Lipids are also classified as nonpolar (e.g. triacylglycerol and cholesterol) and polar (e.g. phospholipids) which indicate differences in their solubility and functional properties. Lipids contribute to foods with attributes such as texture, flavor, nutrition and caloric value. The more stable in the face of oxidation, the longer the shelf life of the stored fish (AL-KHALAIFAH et al., 2020). The fat content is important for marketing, as a good lipid percentage provides tenderness to the meat, however, in excess, it can cause health problems for the consumer (HAUTRIVE et al., 2012).

Fat is not evenly distributed throughout the animal’s body, the composition varies significantly depending on tissue or organ considered. In fish there are reserve lipids and structural lipids. Reserve lipids are found in proportions greater than 1% of body weight and are mostly composed of triglycerides. Structural lipids perform some biological function and are made up of phospholipids (ORDÓÑEZ, 2005). In fish, there is a greater variety of fatty acids, a greater proportion of long-chain fatty acids, and fats richer in polyunsaturated fatty acids. In addition, it has a higher content of n-3 and is therefore a healthier food for the consumer.

Table 1 showes the survey of research carried out on fatty acid profile in commercial cuts of native farmed fish in Brazil, tambaqui (C. macropomum), pirarucu (A. gigas), Pseudoplatystoma corruscans, Piaractus brachypomus, Piaractus mesopotamicus, C. macropomum x P. mesopotamicus, Brycon cephalus, Rhamdia quelen, Hoplias malabaricus, Prochilodus lineatus, Cichla ocellaris and Leporinus friderici. While Table 2 showes the survey of research carried out on the profile of fats in commercial cuts of exotic farmed fish in Brazil, Nile tilapia (Oreochromis niloticus), Oncorhynchus kisutch, Salmo salar, Salmo trutta macrostigma, trout (Onchorhynchus mykiss), codfish (Gadus morhua callaries), Clupea harengus membras, Pangasius hypophthalmus, Pangasius boccourt, Pangasianodon gigas, Ictalurus punctatus and Clarias gariepinus.

Fatty acid profile in Brazilian native farmed fish also varies according to body cut and fish species. That said, diet influences the fatty acid profile in fish produced, although the manufacturing processes can change the composition in terms of not guaranteeing the conservation of fatty acids that have a high capacity for oxidation. According to the Literature found, for native farmed fish from Brazil, the specie pirarucu (A. gigas) had the highest percentage SFA (42.44), Piaractus mesopotamicus had the highest percentage MUFA (52.40), Piaractus brachypomus expressed the highest percentages PUFAs (63.61), ΣPUFAs+ΣSFAs (3.93), n-3 (42.06), EPA (14.72) and DHA (27.34). While tambaqui (C. macropomum) had the highest percentage n-6 (31.59) (Table 1).

Simultaneously, for the exotic species commercialized in Brazil, according to the Literature found, Nile tilapia (Oreochromis niloticus) had the highest percentage SFA (47.00), Ictalurus puntatus had the highest percentage MUFA (46.79), codfish (Gadus morhua callaries) expressed the highest percentages PUFAs (67.40), ΣPUFAs+ΣSFAs (2.80), n-3 (62.60), DHA (50.80). While Pangasius hypophthalmus expressed the highest percentages n-6 (33.23) and EPA (19.18) (Table 2).
### Table 1 - Fatty acid profile in commercial cuts of Brazilian native farmed fish (total in percentage %).

<table>
<thead>
<tr>
<th>Species</th>
<th>SFAs</th>
<th>MUFA's</th>
<th>PUFA's</th>
<th>PUFA's+SFAs</th>
<th>ω-6</th>
<th>ω-3</th>
<th>EPA</th>
<th>DHA</th>
<th>Portions analyzed</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colossoma macropomum</td>
<td>19.82</td>
<td>27.32</td>
<td>52.86</td>
<td>2.67</td>
<td>31.59</td>
<td>20.35</td>
<td>6.86</td>
<td>13.49</td>
<td>Fillet</td>
<td>Rodrigues et al. (2020)</td>
</tr>
<tr>
<td>Arapaima gigas</td>
<td>42.44</td>
<td>34.82</td>
<td>22.74</td>
<td>0.54</td>
<td>19.02</td>
<td>3.72</td>
<td>9.25</td>
<td>8.50</td>
<td>Bacth muscle</td>
<td>Cortegano et al. (2017)</td>
</tr>
<tr>
<td>Pseudoplatystoma corrucrans</td>
<td>41.40</td>
<td>30.10</td>
<td>18.10</td>
<td>0.44</td>
<td>9.90</td>
<td>8.20</td>
<td>2.20</td>
<td>2.90</td>
<td>Frozen whole fish</td>
<td>Martino et al. (2002)</td>
</tr>
<tr>
<td>Piaractus brachypomus</td>
<td>16.24</td>
<td>20.14</td>
<td>63.61</td>
<td>3.93</td>
<td>19.51</td>
<td>42.06</td>
<td>14.72</td>
<td>27.34</td>
<td>Fillet</td>
<td>Rodrigues et al. (2020)</td>
</tr>
<tr>
<td>Piaractus mesopotamicus</td>
<td>36.20</td>
<td>52.60</td>
<td>10.86</td>
<td>0.30</td>
<td>8.80</td>
<td>0.90</td>
<td>0.10</td>
<td>0.20</td>
<td>Muscle</td>
<td>Tanamani et al. (2009)</td>
</tr>
<tr>
<td>C. macropomum x P. mesopotamicus</td>
<td>20.18</td>
<td>25.01</td>
<td>54.81</td>
<td>2.73</td>
<td>20.08</td>
<td>33.38</td>
<td>11.30</td>
<td>19.17</td>
<td>Fillet</td>
<td>Rodrigues et al. (2020)</td>
</tr>
<tr>
<td>Brycon cephalus</td>
<td>35.82</td>
<td>29.26</td>
<td>34.92</td>
<td>0.97</td>
<td>26.59</td>
<td>8.33</td>
<td>1.15</td>
<td>2.29</td>
<td>Fillet</td>
<td>Petenuci et al. (2019)</td>
</tr>
<tr>
<td>Rhamdia quelen</td>
<td>34.90</td>
<td>34.20</td>
<td>29.00</td>
<td>0.84</td>
<td>22.30</td>
<td>6.51</td>
<td>-</td>
<td>3.90</td>
<td>Fillet</td>
<td>Weber et al. (2008)</td>
</tr>
<tr>
<td>Hoplias malabaricus</td>
<td>41.29</td>
<td>24.48</td>
<td>34.23</td>
<td>0.83</td>
<td>-</td>
<td>-</td>
<td>9.17</td>
<td>13.06</td>
<td>Whole fish</td>
<td>Torres et al. (2012)</td>
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<tr>
<td>Leporinus friderici</td>
<td>21.00</td>
<td>28.09</td>
<td>50.91</td>
<td>2.43</td>
<td>28.63</td>
<td>22.29</td>
<td>6.41</td>
<td>15.63</td>
<td>Fillet</td>
<td>Rodrigues et al. (2017)</td>
</tr>
</tbody>
</table>

SFAs = saturated fatty acids; MUFA’s = monounsaturated fatty acids; PUFA’s = polyunsaturated fatty acids; PUFA’s+SFAs = WHO-recommended quality assurance ratio; ω-6 = omega 6; ω-3 = omega 3; EPA = Eicosapentaenoic acid; DHA = Docosahexanoic acid. Note: Researches with similar chromatographic analyzes and performed in certified laboratories were been reported.

### Table 2 - Fatty acid profile in commercial cuts of Brazilian exotics farmed fish (total in percentage %).

<table>
<thead>
<tr>
<th>Species</th>
<th>SFAs</th>
<th>MUFA’s</th>
<th>PUFA’s</th>
<th>PUFA’s+SFAs</th>
<th>ω-6</th>
<th>ω-3</th>
<th>EPA</th>
<th>DHA</th>
<th>Portions analyzed</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oreochromis niloticus</td>
<td>47.00</td>
<td>28.00</td>
<td>25.00</td>
<td>0.53</td>
<td>2250</td>
<td>5.33</td>
<td>0.99</td>
<td>2.30</td>
<td>Muscle</td>
<td>Lu et al. (2003)</td>
</tr>
<tr>
<td>Oncorhynchus tibullus</td>
<td>30.60</td>
<td>32.40</td>
<td>36.70</td>
<td>1.20</td>
<td>2190</td>
<td>23.80</td>
<td>6.02</td>
<td>16.50</td>
<td>Muscle</td>
<td>Hallilgo et al. (2004)</td>
</tr>
<tr>
<td>Salmo salar</td>
<td>34.30</td>
<td>26.16</td>
<td>49.60</td>
<td>2.05</td>
<td>5.90</td>
<td>43.70</td>
<td>3.80</td>
<td>26.60</td>
<td>Muscle</td>
<td>Usydus et al. (2011)</td>
</tr>
<tr>
<td>Salmo trutta macrostigma</td>
<td>28.50</td>
<td>35.90</td>
<td>35.19</td>
<td>1.23</td>
<td>9.78</td>
<td>25.64</td>
<td>7.88</td>
<td>8.62</td>
<td>Muscle</td>
<td>Altipinar et al. (2009)</td>
</tr>
<tr>
<td>Onchorhynchus mykiss</td>
<td>22.10</td>
<td>31.60</td>
<td>46.30</td>
<td>2.01</td>
<td>8.80</td>
<td>37.50</td>
<td>8.00</td>
<td>17.50</td>
<td>Muscle</td>
<td>Usydus et al. (2011)</td>
</tr>
<tr>
<td>Gadus morhua callaries</td>
<td>24.10</td>
<td>8.50</td>
<td>67.40</td>
<td>2.80</td>
<td>4.80</td>
<td>62.60</td>
<td>7.60</td>
<td>50.80</td>
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<td>Usydus et al. (2011)</td>
</tr>
<tr>
<td>Clupea harengus membras</td>
<td>28.60</td>
<td>30.70</td>
<td>40.70</td>
<td>1.40</td>
<td>6.30</td>
<td>34.40</td>
<td>6.20</td>
<td>20.40</td>
<td>Muscle</td>
<td>Usydus et al. (2011)</td>
</tr>
<tr>
<td>Pangasius hypophthalmus</td>
<td>31.14</td>
<td>23.89</td>
<td>38.02</td>
<td>1.22</td>
<td>33.23</td>
<td>4.79</td>
<td>19.18</td>
<td>21.17</td>
<td>Fillet</td>
<td>Solhtame et al. (2020)</td>
</tr>
<tr>
<td>Pangasius bocourti</td>
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<td>32.70</td>
<td>14.80</td>
<td>0.50</td>
<td>15.50</td>
<td>1.63</td>
<td>0.25</td>
<td>0.87</td>
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<td>Thammapat et al. (2010)</td>
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<td>Pangasianodon gigas</td>
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<td>28.26</td>
<td>26.56</td>
<td>0.59</td>
<td>-</td>
<td>-</td>
<td>3.46</td>
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<td>Bach muscle</td>
<td>Chaijan et al. (2010)</td>
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<td>Ictalurus punctatus</td>
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<td>6.34</td>
<td>0.027</td>
<td>18.61</td>
<td>2.73</td>
<td>-</td>
<td>0.75</td>
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<td>Li et al. (2010)</td>
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<td>Clarias gariepinus</td>
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<td>43.30</td>
<td>20.50</td>
<td>0.62</td>
<td>11.27</td>
<td>9.50</td>
<td>1.20</td>
<td>2.00</td>
<td>Muscle</td>
<td>Wing-Keong et al. (2003)</td>
</tr>
</tbody>
</table>

SFAs = saturated fatty acids; MUFA’s = monounsaturated fatty acids; PUFA’s = polyunsaturated fatty acids; PUFA’s+SFAs = WHO-recommended quality assurance ratio; ω-6 = omega 6; ω-3 = omega 3; EPA = Eicosapentaenoic acid; DHA = Docosahexanoic acid. Note: Researches with similar chromatographic analyzes and performed in certified laboratories were been reported.
Nutritional aspects and benefits of native farmed fish consumption

Meat with high percentages SFAs is harmful because of the action of LDL cholesterol in body, that is, it carries cholesterol particles from liver and other organs to arteries (SIQUEIRA et al., 2018). Brazilian native farmed fish meat is rich in MUFAs and PUFAs, among the benefits of consuming the fatty acids found in this Brazilian farmed fishes is prevention of heart disease, autoimmune diseases, arrhythmias, reduction of triglyceride levels in plasma and blood pressure (PAL et al., 2018). Furthermore, they support proper brain function in human body and provide protection against various psychological disorders, in particular depression, attention deficit disorder (SINN, 2007), and cancer (CAYGILL et al., 1995). In addition, they reduce cholesterol levels, reduce cases of stroke, Alzheimer’s, increase cognitive function in adults and reduce the rates of children who are born with low weight and premature birth (SARTORI et al., 2012; VIEIRA et al., 2015).

MUFAs provide more stability, flavor and nutrition, and are better for health than PUFAs (AL-KHALAIFAH et al., 2020). It is noteworthy that monounsaturated fats have been linked to a reduction in total cholesterol and LDL cholesterol, also increasing plasma HDL cholesterol levels (MAHAN; ESCOTT-STUMP, 2018). Polyunsaturated fats found in fish also have a positive effect on total cholesterol, LDL cholesterol and triglycerides. LDL cholesterol is known as harmful cholesterol, it is a low-density lipoprotein, it can accumulate in the arteries and coronary arteries 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 heart attack (VASCONI et al., 2019). However, good HDL cholesterol has the function of removing harmful LDL cholesterol from the bloodstream (MARTINS et al., 2011). Tropical fishes from Brazilian Amazon such as pirarucu (A. gigas) and tambaqui (C. macropomum) are excellent suppliers PUFAs (n-3, n-6), which are polyunsaturated lipids, so bromatological studies indicate the consumption of cooked fish to reduce LDL cholesterol by maintaining the presence of HDL cholesterol in bloodstream (MARTINS et al., 2011; FRANCO et al., 2018; VIEIRA et al., 2018).

Consumption of foods rich in n-3 has increased in recent years due to the positive effect of these fatty acids in prevention of cardiovascular diseases. The most beneficial n-3 are Eicosapentanoenic acid (EPA; C20:5 n-3) and Docosahexanoenic acid (DHA; C22:6 n-3) (PAL et al., 2018). According to Harris et al. (2009), it is recommended to consume between 250 to 500 mg of EPA+DHA per day. The group n-3 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).

It is worth emphasizing that usually, eicosanoids produced n-3 fatty acids, mainly EPA and DHA, are reported as essential fatty acids due to the inhibition of stearic metabolism to inflammatory eicosanoids, since they increase the anti-inflammatory mediators, vasodilation and also inhibit platelet aggregation, compared to those produced in n-6 series of eicosanoids (ANTONELO et al., 2020). That is, the enzymatic action of these PUFAs in modulating the lipid profile from unsaturated to saturated during metabolism changes the efficiency of the diet consumed and the profile ingested, making the meat healthier (VIEIRA et al., 2015).

EPA and DHA play an important role in regulation of inflammatory immune reactions and blood pressure, in brain development in utero, and in early postnatal life, in the development of cognitive function. They also have anticarcinogenic properties (AL-KHALAIFAH et al., 2020). A key function of α-Linolenic acid (ALA; C18:3 n-3) is as a substrate for the synthesis of long-chain n-3 fatty acids found in fish, Eicosapentanoenic acid (EPA; C20:5 n-3) and Docosahexanoenic acid (DHA; C22:6 n-3), which are showes in retina of the eye and in the cerebral cortex (AL-KHALAIFAH et al., 2020). Very long chain PUFAs are derived from fatty acid Linolenic (ALA; C18:3 n-3) with priority to EPA and DHA by elongations and denaturations, and have the ability to modulate inflammatory processes by competing with n-6 derived from ALA and Docosatetraenoic acid (DTA; C22:4 n-3) by the deposition of phospholipids on the membrane of immune cells (SOUZA et al., 2017; PETENUCCI et al., 2019; ANTONELLO et al., 2020).

Fish meat is composed of essential fatty acids for human health, and in addition to aforementioned
EPA and DHA, which are group $n$-3, the contents of Eicosatetraenoic acid (AA; C20:4 $n$-6) can also highlighted Eicosatrienoic acid (C20:3 $n$-6) and Octadecadienoic acid (C18:2 $n$-6), as they are fatty acids that help to accelerate the healing process and renewal of erythrocytes and defense cells (AL-KHALAIFAH et al., 2020). Despite this, not all group $n$-6 are entirely beneficial. According to Souza et al. (2017), of the $n$-6 are pro-inflammatory. They increase the production of cytokines with vasoconstrictor action that promote platelet aggregation. It is related to occurrence of cardiovascular, autoimmune and inflammatory diseases such as arthritis, asthma, psoriasis, lupus and ulcerative colitis. Nonetheless, group $n$-7 are responsible for increasing insulin sensitivity, preventing type 2 diabetes. It reduces 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).

Palmitoleic acid (C16:1 $n$-7) was proposed as a lipokine, a molecule produced by adipocytes that acts as a signaling agent in several organs, which regulates systemic metabolic homeostasis, stimulating insulin action in muscle and suppressing hepatic steatosis (SOBCZAK et al., 2022). Hexadecenoic acid (Palmitoleic acid, C16:1 $n$-7) is a fatty acid of $n$-7, which has been gaining prominence in scientific publications because it is considered a potent anti-inflammatory. Furthermore, it is suggested that these MUFAs increase the gene expression of PPAR-$\alpha$, an inhibitor of nuclear factor kappa B (NFkB), known to increase cellular inflammation (SOUZA et al., 2017). In addition, Palmitoleic acid acts as an important signal for metabolic reactions in adipocytes (PASSOS et al., 2016). Therefore, some studies propose its consumption to reduce the risk of inflammatory and metabolic diseases (FRIGOLET et al., 2017).

Likewise, research carried out in obese rats demonstrated that the administration of Palmitoleic acid, for 12 weeks, promoted an improvement in insulin sensitivity, since this fatty acid regulates the phosphorylation cascade mediated by the hormone in question (SOUZA et al., 2017). It is worth mentioning that this benefit was also verified clinically. A study approved by the Human Subject Review Committee at the University of Washington (USA), was carried out with 17 subjects and there a positive correlation in plasma concentrations of Palmitoleic acid and in the improvement of insulin sensitivity. Thus, consumption of $n$-7 is suggested to reduce this trigger related to diabetes and other metabolic diseases (KRATZ et al., 2014).

Another study was carried out with 20 patients diagnosed with ulcerative colitis and indicated that Palmitoleic acid supplementation for 8 weeks was responsible for a significant reduction in Interleukin-6 (cytokine related to inflammatory condition of the disease). In addition, some have observed an increase in gene expression of HNF4-g (hepatocyte nuclear factor 4 gamma) and HNF-a (hepatocyte nuclear factor alpha), proteins that are also involved in immune response of this condition (BUENO-HERNÁNDEZ et al., 2017). Furthermore, $n$-7 can found in some oilseeds such as macadamia and some tropical fish (PASSOS et al., 2016). In a balanced way, these acids can part of the diet, promoting their benefits to organic balance (BUENO-HERNÁNDEZ et al., 2017; VASCONI et al., 2019).

In a study conducted by Moraes et al. (2018) with the supplementation of $n$-9 by enteral injection in mice with induced sepsis there was a significant reduction in the inflammation detected. Albuquerque et al. (2016) analyzed the effect of oleic acid supplementation (C18:1 $n$-9) on sepsis and from the study suggested that Oleic acid (C18:1 $n$-9) has a beneficial role in sepsis by decreasing metabolic dysfunction, supporting the benefits of diets rich in monounsaturated fatty acids. The main component of olive oil is Oleic acid $n$-9.

Gultekin et al. (2014) found similar results in humans when providing a total parenteral nutrition (TPN) solution enriched with $n$-3 containing $n$-9 as there was a decrease in the levels of inflammatory mediators and an improvement in biochemical parameters in septic patients. A method prescribed by the World Health Organization (WHO) to assess lipid quality is based on $\Sigma$PUFAs/$\Sigma$SFAs fatty acid ratio, with values below 0.45 considered unhealthy (WOOD; ENSER, 1997). Ruminant meat lipids are characterized by having high proportions SFAs and a low $\Sigma$PUFAs/$\Sigma$SFAs ratio (XIONG et al., 2022). SFAs are considered hypercholesterolemic and the most worrisome for cardiovascular health, in this sense, are Myristic acid (C14:00), Lauric acid (C12:00) and Palmitic acid (C16:00) (NUNES et al., 2012).
SFAs increase blood cholesterol levels by reducing LDL cholesterol receptor activity and reducing LDL-free space in bloodstream (KLEIN-SZANTO; BASSI, 2019). Palmitic acid is most harmful to cardiac functions and is most commonly found in beef and pork fats (HAUTRIVE et al., 2012).

Current Western diets tend to be relatively high in n-6 and low in n-3. This is due to the high intake of vegetable oils, which are rich in n-6, as well as the low intake of oils and foods rich in n-3, such as fish fats (DAMODARAN et al., 2010). This fact contributes to act that ΣPUFAs (n-6/n-3) ratio is approximately 20:1, when the recommended ratio is about 5:1 (KRATZ et al., 2014). Evidence points to importance of increasing the consumption of ΣPUFAs (n-6/n-3) as physiologically as possible and for that some changes in diet should be made, such as the consumption of tropical fish (PASSOS et al., 2016).

Proportion between n-3 and n-6 is very different in freshwater and marine fish, with an approximate ratio 12:5 and 33:5 respectively (ORDÓÑEZ, 2005). The n-6/n-3 has also been used as a criterion to assess lipid quality, which must be greater than 4.0 as established by the WHO. An excess of Linoleic acid (C18:2 n-6) shows the transformation of α-Linolenic acid (ALA; 18:3 n-3) into its derivatives EPA and DHA. The same happens in opposite case, with a lower consumption of Linoleic acid, there will be a reduction in activation of Arachidonic acid (n-6), because the Δ-6-desaturase enzyme has an affinity for both fatty acids [48, 52] (SARTORI et al., 2012; VIEIRA et al., 2015; MAHAN; ESCOTT-STUMP, 2018; SIQUEIRA et al., 2018). However, the enzyme has greater specificity for n-3 and will need lower percentages of these acids than the n-6 fatty acids to produce the same amount of PUFAs (MADSN et al., 1999; VASCONI et al., 2019). That is, there must a greater proportion of Linoleic acid than α-Linolenic acid. Therefore, a balance in supply of the two fatty acids through the diet is necessary.

Nutritional quality of the lipid fraction can be calculated from fatty acid profile by averages of atherogenicity index (AI), thrombogenicity index (TI) (ULBRIGHT; SOUTHGATE, 1999). and the ratio between hypocholesterolemic and hypercholesterolemic fatty acids (h/H) (SANTOS-SILVA et al., 2002). Concerning the mathematical formulas of the indices, AI = [(C12:0 + 4 x C14:0 + C16:0)/ ΣMUFA + Σn-6+Σn-3; TI = (C14:0 + C16:0 + C18:0)/(0,5 x ΣMUFA) + (0,5 x Σn-6) + (3 x Σn-3) + (Σ (n-3/n-6)]; h/H = (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-3)/ (C14:0 + C16:0) (SANTOS-SILVA et al., 2002).

The AI and TI indices are related to pro and anti-atherogenic fatty acids, with atheromas being fibrous fatty plaques located inside the arteries, and pro and anti-thrombogenic, with thrombosis caused by a blood clot in veins (ULBRIGHT; SOUTHGATE, 1991). Lower Al and TI values are desirable to prevent cardiovascular disorders, as high Al and TI values can stimulate platelet aggregation and subsequent thrombus and atheroma formation in the cardiovascular system (RODRIGUES et al., 2017). Higher h/H index values are considered more beneficial for human health, as this index is related to the specific effects of fatty acids on cholesterol metabolism (HERNÁNDEZ-MARTÍNEZ et al., 2018).

Table 3 shows lipid quality indices ΣPUFAs/ΣSFAs, n-6/n-3, Al, TI and h/H of the main commercial fish species native to different regions from Brazil. The reported species are tambaqui (C. macropomum), pirarucu (A. gigas), Piaractus mesopotamicus, C. macropomum x P. mesopotamicus, Piaractus brachyomus, Brycon cephalus, Brycon microlepis, Prochilodus lineatus and Pseudoplatystoma corruscans.

There is a notable difference between the lipid quality indices of tambaqui (C. macropomum) in different regions of Brazil – Amazon and Southern Regions, especially ΣPUFAs/ΣSFAs (0.509 and 2.670), ΣPUFAs (n-6/n-3) (1.373 and 1.580) and TI (0.797 and 0.122), respectively. Similarly, there is a notable difference between the lipid quality indices of pirarucu (A. gigas) – Western Amazon and Eastern Amazon regions, especially n-6/n-3 (3.253 and 0.220) and h/H (2.260 and 1.410), respectively (Table 3).

According to the specialized Literature, Cortegano et al. (2017), Rodrigues et al. (2017), Mahan and Escott-Stump (2018) and Xiyang et al. (2020), the species that expressed the better indices of ΣPUFAs/ΣSFAs, Piaractus brachypomus (3.933), Brycon cephalus (3.470), C. macropomum x
P. mesopotamicus (2.733), Prochilodus lineatus (2.230) and Pseudoplatystoma corrucans (2.110), respectively. The species that expressed the better indices of n-6/n-3, C. macropomum (3.173), A. gigas (3.253), Brycon microlepis (3.190) and Pseudoplatystoma corrucans (1.010), respectively (Table 3).

According to Rodrigues et al. (2017, 2020) and Xiyang et al. (2020), all fish species reported have lipid quality, although some stand out in the AI, gigas (0.590), C. macropomum (0.398, Brycon microlepis (0.390) and Prochilodus lineatus (0.340) indices; TI, A. gigas (1.020), C. macropomum (0.797) and Brycon microlepis (0.630); h/H, Piaractus brachypomus (5.111), Brycon cephalus (4.620), C. macropomum x P. mesopotamicus (3.680), C. macropomum (3.640), Prochilodus lineatus (3.610) and Pseudoplatystoma corrucans (3.330), respectively (Table 3).

Table 3 - Lipid quality indices in muscle tissue of the main commercial fish species Brazilian native.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lipid quality indices</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tambaqui (C. macropomum)*</td>
<td>0.509</td>
<td>3.173</td>
</tr>
<tr>
<td>Tambaqui (C. macropomum)**</td>
<td>2.670</td>
<td>1.580</td>
</tr>
<tr>
<td>Pirarucu (A. gigas)***</td>
<td>0.602</td>
<td>3.253</td>
</tr>
<tr>
<td>Pirarucu (A. gigas)****</td>
<td>0.540</td>
<td>0.220</td>
</tr>
<tr>
<td>Piaractus mesopotamicus</td>
<td>3.470</td>
<td>0.550</td>
</tr>
<tr>
<td>C. macropomum x P. mesopotamicus</td>
<td>2.733</td>
<td>0.604</td>
</tr>
<tr>
<td>Piaractus brachypomus</td>
<td>3.933</td>
<td>0.460</td>
</tr>
<tr>
<td>Brycon cephalus</td>
<td>3.470</td>
<td>0.980</td>
</tr>
<tr>
<td>Brycon microlepis</td>
<td>0.980</td>
<td>3.190</td>
</tr>
<tr>
<td>Prochilodus lineatus</td>
<td>2.230</td>
<td>0.910</td>
</tr>
<tr>
<td>Pseudoplatystoma corrucans</td>
<td>2.110</td>
<td>1.010</td>
</tr>
</tbody>
</table>

Atherogenicity Index (AI); Thrombogenicity Index (TI); Ratios between hypocholesterolemic and hypercholesterolemic (h/H) fatty acids. *C. macropomum from the Western Amazon region; **C. macropomum from the southern Brazil region; ***A. gigas from the Western Amazon region; ****A. gigas from the Estern Amazon region. Note: Researches with similar chromatographic analyzes and performed in certified laboratories were been reported.

Market outlook

Regarding the production chain problems of native species fish farming, Brazil is a very large and heterogeneous country and solutions suitable for one region or place may not suitable for others (CORTEGANO et al., 2017; TACON et al., 2020; VALENTI et al., 2021). Given the Brazilian overview, public policies and rural extension services must take into account the diversity of problems and solutions. For example, to improve the dissemination that consuming native Brazilian fish is healthy and sustainable, it is fundamentally necessary to build a big data database on Aquaculture that can be useful. However, the accuracy of these data is even more essential (MARMENTINI et al., 2022). It is necessary to develop market studies for each region of Brazil, to analyze unreliable data so that there is no loss of time and money. Furthermore, decisions resulting from fake data are sure to be ineffective.

It is important to clarify that quality certification is needed, to universalize native Brazilian fish it is necessary to label it as nutritionally optimal fish. And from what can this certification start? The fish industry and research on nutritional quality, are very lacking in integrated culture systems, more efficient use (reuse) of processing residues (filleting) and combining Aquaculture with Agriculture or Ecotourism initiatives may be possible paths (PAL et al., 2018; VALENTI et al., 2021; FROUZ; FROUZOVÁ, 2022).
In short, the challenge to improve the marketing of Brazilian fish is to develop truly sustainable production systems to maintain a perennial and profitable market (CORTEGANO et al., 2017; TACON et al., 2020; LUIZ et al., 2022). Therefore, the future of the native farmed fish market will depend on the better dissemination of this product to attract different market niches. As well as the ability of scientists, industry professionals and farmers to work together with these challenges in mind. Finally, the opportunity that presents itself is to publicize the brands “Amazon’s tambaqui” and/or “pirarucu – Amazon’s cod”, to value them and encourage cooperative and associative practices to increase productivity. These quality certification marks can attract market niches not only nationally, although especially from countries with a more developed economy and a more demanding market for environmental issues, for example the USA and Europe (LUIZ et al., 2022).

Conclusion
Data surveys such as the current study, address the nutritional value of the most cultivated Amazonian’s native species are important to divulge commercial promotion and strengthen Brazilian fish farming production chain. Therefore, in addition to being sustainable, consuming native farmed fish is a healthy choice from a nutritional point of view because they contain monounsaturated and polyunsaturated fatty acids that are related to an anti-inflammatory effect and a lower propensity for cardiovascular diseases in consumers.

Regarding the production chain problems, market studies must carried out for each region of Brazil. In addition, more investments are needed in integrated culture systems, for the development of the local industry and better dissemination of Brazilian fish. In other words, quality certification is needed, to universalize native Brazilian fish it is necessary to label it as nutritionally optimal fish. Possibly the biggest challenge to improve the marketing of Brazilian fish is to develop truly sustainable production systems. Therefore, the future of Brazilian fish will depend on better dissemination to attract different market niches.

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