ISSN 2527-2675 https://10.25061/2527-2675/ReBraM/2024.v27i1.1684

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

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**Keywords**
Brazilian native farmed fish
Food safety
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.

**Recebido em:** 20/06/2023
**Aprovação final em:** 10/08/2023

## 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[1] (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 metodologia 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.

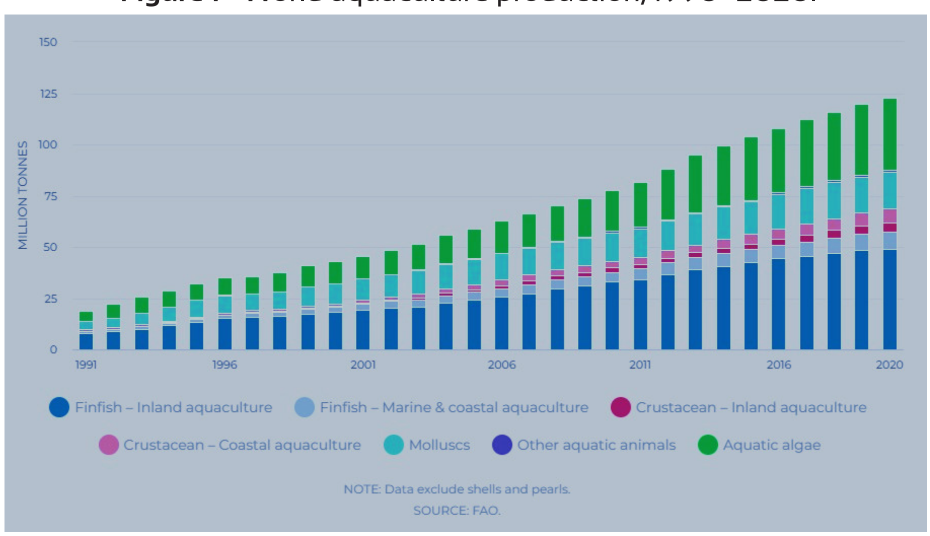
Lastly, the bibliometric analysis of research was performed to divulge the lipid quality of Amazonian's native fish, aquaculture overviews and market outlook of Brazilian fish farming. The program used for data storage was Dropbox™ (version 3.3, 2019). The stored data, after being transformed into information, 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.




**Source**: FAO, 2022.

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).

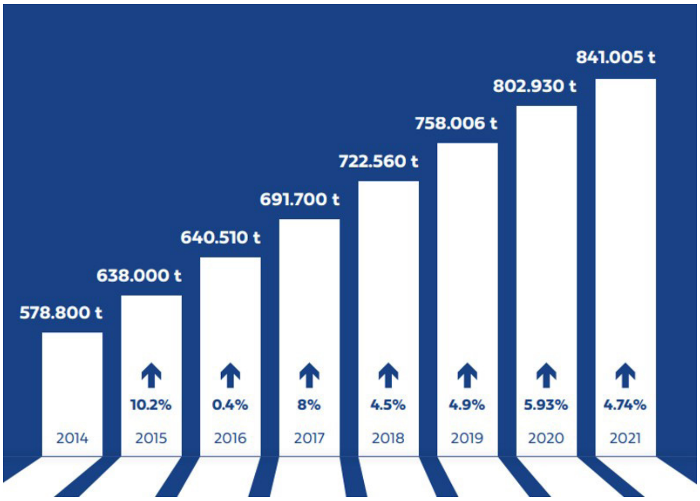
Cortegano *et al.* (2017) market outlook is that in the next decade there will no significant changes in terms of demand for agricultural products and an expanding global population remains the main driver of growth, although consumption profiles and projected trends will vary depending on the level 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" demonstratd 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).

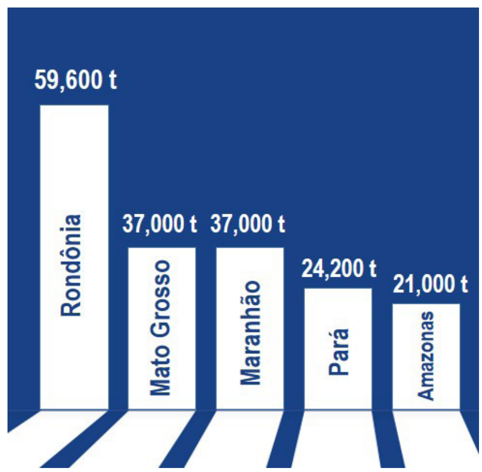
**Figure 2** - Brazilian production of farmed fish grew 4.74% in year 2021, reaching 841,005 metric tons.




**Source**: Peixe BR, 2022.

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.




**Source**: Peixe BR, 2022.

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 $B_{12}$, 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 (ORDÓÑEZ, 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 (eg triacylglycerol and cholesterol) and polar (eg 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 boccourti*, *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 SFAs (42.44), *Piaractus mesopotamicus* had the highest percentage MUFAs (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 SFAs (47.00), *Ictalurus punctatus* had the highest percentage MUFAs (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 %).

| Species | Fatty acid profile | | | | | | | | Portions analyzed | Authors |
|---|---|---|---|---|---|---|---|---|---|---|
| | SFAs | MUFAs | PUFAs | PUFAs+SFAs | ω-6 | ω-3 | EPA | DHA | | |
| Colossoma macropomum | 19.82 | 27.32 | 52.86 | 2.67 | 31.59 | 20.35 | 6.86 | 13.49 | Fillet | Rodrigues *et al.* (2020) |
| Arapaima gigas | 42.44 | 34.82 | 22.74 | 0.54 | 19.02 | 3.72 | 9.25 | 8.50 | Back muscle | Cortegano *et al.* (2017) |
| Pseudoplatystoma corruscans | 41.40 | 30.10 | 18.10 | 0.44 | 9.90 | 8.20 | 2.20 | 2.90 | Frozen whole fish | Martino *et al.* (2002) |
| Piaractus brachypomus | 16.24 | 20.14 | 63.61 | 3.93 | 19.51 | 42.06 | 14.72 | 27.34 | Fillet | Rodrigues *et al.* (2020) |
| Piaractus mesopotamicus | 36.20 | 52.40 | 10.86 | 0.30 | 8.80 | 0.90 | 0.10 | 0.20 | Muscle | Tanamati *et al.* (2009) |
| C. macropomum x P. mesopotamicus | 20.18 | 25.01 | 54.81 | 2.73 | 20.08 | 33.38 | 11.30 | 19.17 | Fillet | Rodrigues *et al.* (2020) |
| Brycon cephalus | 35.82 | 29.26 | 34.92 | 0.97 | 26.59 | 8.33 | 1.15 | 2.29 | Fillet | Petenuci *et al.* (2019) |
| Rhamdia quelen | 34.90 | 34.20 | 29.00 | 0.84 | 22.30 | 6.51 | - | 3.90 | Fillet | Weber *et al.* (2008) |
| Hoplias malabaricus | 41.29 | 24.48 | 34.23 | 0.83 | - | - | 9.17 | 13.06 | Whole fish | Torres *et al.* (2012) |
| Prochilodus lineatus | 23.99 | 22.45 | 53.56 | 2.23 | 26.38 | 26.85 | 7.44 | 18.65 | Fillet | Rodrigues *et al.* (2017) |
| Cichla ocellaris | 17.45 | 26.11 | 56.44 | 3.24 | 21.83 | 32.97 | 7.34 | 25.42 | Fillet | Rodrigues *et al.* (2017) |
| Leporinus friderici | 21.00 | 28.09 | 50.91 | 2.43 | 28.63 | 22.29 | 6.41 | 15.63 | Fillet | Rodrigues *et al.* (2017) |

SFAs= saturated fatty acids; MUFAs= monounsaturated fatty acids; PUFAs= polyunsaturated fatty acids; PUFAs/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 exotices farmed fish (total in percentage %).

| Species | Fatty acid profile | | | | | | | | Portions analyzed | Authors |
|---|---|---|---|---|---|---|---|---|---|---|
| | SFAs | MUFAs | PUFAs | PUFAs+SFAs | ω-6 | ω-3 | EPA | DHA | | |
| Oreochromis niloticus | 47.00 | 28.00 | 25.00 | 0.53 | 22.50 | 5.33 | 0.99 | 2.30 | Muscle | Lu *et al.* (2003) |
| Oncorhynchus kisutch | 30.60 | 32.40 | 36.70 | 1.20 | 12.90 | 23.80 | 6.02 | 16.50 | Muscle | Haliloglu *et al.* (2004) |
| Salmo salar | 24.30 | 26.10 | 49.60 | 2.05 | 5.90 | 43.70 | 3.80 | 26.60 | Muscle | Usydus *et al.* (2011) |
| Salmo trutta macrostigma | 28.50 | 35.90 | 35.19 | 1.23 | 9.78 | 25.40 | 7.88 | 8.42 | Muscle | Akpinar *et al.* (2009) |
| Onchorhynchus mykiss | 22.10 | 31.60 | 46.30 | 2.01 | 8.80 | 37.50 | 8.00 | 17.50 | Muscle | Usydus *et al.* (2011) |
| Gadus morhua callaries | 24.10 | 8.50 | 67.40 | 2.80 | 4.80 | 62.60 | 7.60 | 50.80 | Muscle | Usydus *et al.* (2011) |
| Clupea harengus membras | 28.60 | 30.70 | 40.70 | 1.40 | 6.30 | 34.40 | 6.20 | 20.40 | Muscle | Usydus *et al.* (2011) |
| Pangasius hypophthalmus | 31.14 | 23.89 | 38.02 | 1.22 | 33.23 | 4.79 | 19.18 | 21.17 | Fillet | Sokamte *et al.* (2020) |
| Pangasius boccourti | 30.20 | 32.70 | 14.80 | 0.50 | 15.50 | 1.63 | 0.25 | 0.87 | Back muscle | Thammapat *et al.* (2010) |
| Pangasianodon gigas | 45.22 | 28.26 | 26.56 | 0.59 | - | - | 3.46 | - | Back muscle | Chaijan *et al.* (2010) |
| Ictalurus punctatus | 23.20 | 46.79 | 6.34 | 0.027 | 18.61 | 2.73 | - | 0.75 | Fillet | Li *et al.* (2010) |
| Clarias gariepinus | 32.90 | 43.30 | 20.50 | 0.62 | 11.27 | 9.50 | 1.20 | 2.00 | Muscle | Wing-Keong *et al.* (2003) |

SFAs= saturated fatty acids; MUFAs= monounsaturated fatty acids; PUFAs= polyunsaturated fatty acids; PUFAs/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 Eicosapentaenoic acid (EPA; C20:5 *n*-3) and Docosahexaenoic 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, Eicosapentaenoic acid (EPA; C20:5 *n*-3) and Docosahexanoic 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 Docosatetranoic acid (DTA; C22:4 *n*-3) by the deposition of phospholipids on the membrane of immune cells (SOUZA *et al.,* 2017; PETENUCI *et al.,* 2019; ANTONELO *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-α, 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 ΣPUFAs/ΣSFAs 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 ΣPUFAs/ΣSFAs 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) showes 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 calculated from fatty acid profile by averages of atherogenicity index (AI), thrombogenicity index (TI) (ULBRIGHT; SOUTHGATE, 19991). and the ratio between hypocholesterolemic and hypercholesterolemic fatty acids (h/H) (SANTOS-SILVA *et al.,* 2002). Concerning the mathematical formulas of the índices, AI = [(C12:0 + 4 x C14:0 + C16:0)]/ ΣMUFAs + Σ*n*-6+Σ*n*-3; 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)]; 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 indeces 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 AI and TI values are desirable to prevent cardiovascular disorders, as high AI 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 showes lipid quality indices ∑PUFAs/∑SFAs, *n*-6/*n*-3, AI, 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 brachypomus, 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 ∑PUFAs/∑SFAs (0.509 and 2.670), ∑PUFAs (*n*-6/*n*-3) (3.173 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 ∑PUFAs/∑SFAs, *Piaractus brachypomus* (3.933), *Brycon cephalus* (3.470), *C. macropomum* x

*P. mesopotamicus* (2.733), *Prochilodus lineatus* (2.230) and *Pseudoplatystoma corruscans* (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 corruscans* (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 corruscans* (3,330), respectively (Table 3).

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

| Species | Lipid quality indices | | | | | Authors |
|---|---|---|---|---|---|---|
| | ∑PUFAs/∑SFAs | n-6/n-3 | AI | TI | h/H | |
| **Tambaqui (**C. macropomum**)*** | 0.509 | 3.173 | 0.398 | 0.797 | 2.255 | Cavali *et al.* (2022) |
| **Tambaqui (**C. macropomum**)**** | 2.670 | 1.580 | 0.250 | 0.122 | 3.640 | Rodrigues *et al.* (2020) |
| **Pirarucu (**A. gigas**)***** | 0.602 | 3.253 | 0.425 | 0.772 | 2.260 | Cavali *et al.* (2023) |
| **Pirarucu (**A. gigas**)****** | 0.540 | 0.220 | 0.590 | 1.020 | 1.410 | Cortegano et al. (2017) |
| Piaractus mesopotamicus | 3.470 | 0.550 | 0.200 | 0.050 | 4.560 | Rodrigues *et al.* (2020) |
| C. macropomum x P. mesopotamicus | 2.733 | 0.604 | 0.240 | 0.060 | 3.680 | Rodrigues *et al.* (2020) |
| Piaractus brachypomus | 3.933 | 0.460 | 0.180 | 0.040 | 5.111 | Rodrigues *et al.* (2020) |
| Brycon cephalus | 3.470 | 0.980 | 0.190 | 0.060 | 4.620 | Rodrigues *et al.* (2017) |
| Brycon microlepis | 0.980 | 3.190 | 0.390 | 0.630 | 2.320 | Petenuci *et al.* (2019) |
| Prochilodus lineatus | 2.230 | 0.910 | 0.340 | 0.110 | 3.610 | Rodrigues *et al.* (2017) |
| Pseudoplatysto-ma corruscans | 2.110 | 1.010 | 0.280 | 0.100 | 3.330 | Rodrigues *et al.* (2017) |

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 divulgue 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.

**Acknowledgments**

To the CNPq/FAPERO for financial support to the research project and also for granting scholarships.

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