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Original article

Comparative study of the chemical composition, fatty acid profile, and nutritional quality of *Lophiosilurus alexandri* (Siluriformes: Pseudopimelodidae), a Brazilian carnivorous freshwater fish, grown in lotic, lentic, and aquaculture environments

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Lophiosilurus alexandri is a carnivorous freshwater fish endemic of São Francisco basin and an endangered species. In this study, we analysed the chemical composition (moisture, protein, ash and lipid), fatty acid profile**,** and nutritional quality (atherogenic index, thrombogenecity index, ratio between hypocholesterolemic and hypercholesterolemic fatty acids and ω6/ω3 = ratio) of *L. alexandri* in lotic (river), lentic (hydroelectric dams) environments, under natural fed, and in laboratory controlled conditions fed with commercial diets. Cultured and lentic fish had significantly higher lipid levels (1.5 and 1.9- fold, respectively) than lotic fish. Lentic *L. alexandri* had significantly higher eicosapentaenoic acid (EPA) levels (4×) than cultured or lotic *L. alexandri*. Docosahexaenoic acid (DHA) levels were the highest in lentic fish, followed by lotic fish. Lentic fish had greater proportion of fatty acid ω6/ω3 than lotic or cultured fish. The results of this study showed that *L. alexandri* is a lean fish (1–2% of total lipids) and that the environment has a great influence on the fatty acid profile. These results may be a reference for further studies, primarily as a source of information for conservation *L. alexandri* through restocking and the development of commercial projects of aquaculture.

Keywords: Dam, Feeding, Lipids, Pacamã, Ω3.

Lophiosilurus alexandri é um peixe de água doce, carnívoro, endêmico da bacia do rio São Francisco e encontra-se vulnerável a extinção. Neste estudo, analisamos a composição química (umidade, cinzas, lipídeos e proteína), o perfil de ácidos graxos e qualidade nutricional (índices de aterogênicidade e trombogenicidade, razão entre ácidos graxos hipocolesterolêmicos e hipercolesterolêmicos e ω6/ω3) de *L. alexandri* em ambientes lóticos (rio), lênticos (hidrelétricas), sob alimentação natural, e em laboratório, com condições controladas e alimentados com dietas comerciais. Os peixes cultivados e capturados em ambientes lênticos apresentaram níveis lipídicos significativamente mais altos (1,5 e 1,9 vezes, respectivamente) do que os peixes cultivados em ambientes lóticos. Os animais cultivados em ambiente lênticos, apresentaram níveis significativamente mais altos de ácido eicosapentaenoico (EPA) (4×) que os animais cultivados em laboratório e ambiente lóticos. Os níveis de ácido docosaexaenoico (DHA) foram os mais altos em peixes lênticos, seguidos pelos peixes lóticos. Os peixes lênticos apresentaram melhor proporção de ácidos graxos ω6/ω3 que peixes lóticos ou de cativeiro. Os resultados deste estudo mostraram que *L. alexandri* é um peixe magro (1–2% do total de lipídios) e que o ambiente tem uma grande influência no perfil de ácidos graxos. Esses resultados podem ser uma referência para novos estudos, principalmente como fonte de informações para sua conservação por meio do repovoamento e desenvolvimento de projetos para sua criação comercial.

Palavras-chave: Alimentação, Barragem, Lipídeos, Pacamã, Ω3.

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Introduction

The São Francisco River, which is one of the most important Brazilian water resources, is considered the River of National Integration, draining seven states along its 2,863 km (Santos *et al*., 2014). The basin of the São Francisco River, located in Minas Gerais State, has been subjected to intensive mining and land use for agricultural, urban, and industrial purposes with negative consequences on the chemical and physical integrity of drainage, due to sewage, domestic, and industrial pollution, mining residues, dams, and riparian forest elimination, among others (Langeani *et al*., 2009).

Adding to the ongoing burdens of intensive agriculture, industrialization and urbanization, climate changes is an additional serious threat to freshwater ecosystems and biodiversity (Liu *et al*., 2015). Water availability in Brazil depends largely on the climate. The annual cycle of rains and stream flow in the country varies among river basins and on the annual climate changes associated with El Niño and La Niña phenomena (Marengo, 2008). The general effects of climate changes, altered hydrological regimes, and increased ground water temperature could affect the quality of fish (Roland *et al*., 2012).

Pacamã, *Lophiosilurus alexandri* Steindachner, 1876, family Pseudopimelodidae, order Siluriformes is a carnivorous fish, which is endemic of the São Francisco basin (Shibatta, 2003). This fish species presents good fillet quality without bones and is highly valued within the fishing community (Takata *et al*., 2014). The commercial interest in pacamã is considerable in the region of Submédio São Francisco. Specifically, there is a high demand for consumption and for use as ornamental fish (Campeche *et al*., 2011).

Pacamã not appear in the latest Red List of International Union for Conservation of Nature (IUCN, 2017), however Fishbase classifies species vulnerability as low to moderate (31 of 100) (Froese, Pauly, 2016). This classification is based on the Fuzzy set theory which aimed to evaluate the extinction vulnerability in: very high, high, moderate and low was scaled arbitrary from 1 to 100 (Cheung *et al*., 2005).

The Ministry of Environment of Brazil works with National Action Plans for the Conservation of Endangered Species. These guide the priority actions to combat threats that endanger people and their niches, and in the last action plan (Portaria nº 455) the pacamã is listed as an endangered species (MMA, 2014).

Since 1976, the restocking of reservoirs and rivers with native species has been performed by the electric power company Minas Gerais State (CEMIG). Fry production from the São Francisco River Basin occurs in Fish Culture Station and Hydrobiology Três Marias, in partnership with the Development Company of the Valley of the São Francisco and Parnaíba (CEMIG, 2014). Restocking with native species represents one of the most effective measures for conserving the fish fauna of the São Francisco River and for mitigating the effects caused by the construction of hydroelectric plants. Pacamã is a one of the species that has been used for restocking the São Francisco River (Costa *et al*., 2015).

To the best of our knowledge, there is no information on the chemical composition and fatty acid profile of pacamã. So, the objective of this study was to evaluate the influence of the environment in the chemical composition, fatty acid profile and nutritional quality of pacamã. The fish samples were collected from three different environments: lotic (rivers), lentic (hydroelectric dams) and laboratory controlled conditions.

Material and Methods

Pacamã were obtained from São Francisco River and tributaries (lotic fish) (n=10), the dam of Três Marias (lentic fish) (n=10), and the aquaculture laboratory (cultured fish) (n=10), of the Federal University of Minas Gerais (UFMG), Brazil. The representative material of the species used in this study was deposited in the collection of the Coleção Ictiológica at the Museu de Ciências Naturais da PUC Minas (MCNIP 3217). The fish were captured using fishing nets, the captures were realized between April and November 2013. In the laboratory, fish were maintained with ideal conditions (during 12 months the fish were fed with commercial diet to carnivorous fish until apparent satiety twice daily (08:00 and 16:00 h). The average temperature of water was 28 °C, dissolved oxygen above 5 mg/L, in recirculating aquaculture system). This experiment was carried out according to protocols approved by the Comissão de Ética no Uso de Animais (CEUA; Ethics Committee on Animal Use) of UFMG (CEUA Protocol 396/2012). Fish were subsequently euthanized with 285 mg L^{-1} eugenol overdose (Mattioli *et al*., 2017), frozen at -80°C and lyophilized for about 36 h. After lyophilization, the samples were transported to the Fish Technology Laboratory of Universidade Estadual Paulista Júlio de Mesquita Filho.

Fulton´s condition factor (K). Fish body weight and length were measured to calculate Fulton's condition factor (K) by the following equation.

$$K = (W/L^3) \times 100$$

Equation 1. Equation used to calculate Fulton's condition factor (K), where: W is weight (g) and L is length (Cm).

Chemical composition and fatty acid profile. The fillets were obtained after removal of the head and skin of the eviscerated fish. Fish cutting started in the dorsal region, lateral to the fin, from the cranial region to the caudal end. The fillets were then lyophilized and crushed for

analysis. The proximate composition of filet fish (n=5 for treatment) and the commercial diet used at controlled conditions were analysed according to the Association of Official Analytical Chemists (AOAC, 2010): Moisture was determined by oven-drying at 103 °C to constant weight (AOAC, 938.08). Crude protein was estimated by Kjeldahl method (AOAC, 940.25) with a nitrogen-to-protein conversion factor of 6.25. Ash was measured following sample incineration in a muffle oven at 550°C for 18 h (AOAC, 923.03). Fatty acids were extracted by the method reported by Folch *et al*. (1957) and converted into fatty acid methyl esters (1 ml of lipids contained 25-50 mg of lipids (Hartman, Lago, 1973). A gas chromatograph (model 3900, Varian Analytical Instruments, Walnut Creek, CA, USA) equipped with a capillary column (Chrompack CP-Sil 88, 100 m × 0.25 mm; 0.20 µm) was used for fatty acid analysis. The injector and detector temperatures were maintained at 270 °C and 310 °C, respectively. The carrier gas consisted of hydrogen and nitrogen with auxiliary gas, both at 30 ml/min and with a split ratio of 1/75. The oven temperature program consisted of 140 °C for 2 min, which was increased to 235 °C at 2.5 °C/min and then maintained at 235 °C for 10 min. The detector temperature was 310 °C. Fatty acids were identified by comparing their retention times to those of fatty acid standards using FAME standard (Supelco 37 FAME mix). Each fatty acid was quantified by calculating its peak area relative to the total peak area and expressed as fatty acid content relative to total lipid content (%).

Nutritional quality. Nutritional quality was determined by calculating the aterogenic index (AI), thombogenic index (TI), hypocholesterolemic-to-hypercholesterolemic ratio (HH), and ω6-to-ω3 ratio

$$AI = (C12{:}0 + C14{:}0 + C16{:}0)/(\sum MUFA + \sum PUFA)$$

$$TI = [(C14{:}0 + C16{:}0 + C18{:}0)/(0.5 \times \sum MUFA) + 0.5 \times \sum n6PUFA) + 3 \times \sum n3PUFA) + (n3/n6)]$$

$$HH = (C18{:}1n9 + C18{:}2n6 + C20{:}4n6 + C18{:}3n3 + C20{:}5n3 + C22{:}5n3 + C22{:}6n3)/(C14{:}0 + C16{:}0)$$

$$(4)\ \omega 6\text{-to-}\omega 3 \text{ ratio} = \sum PUFA\ \omega 6/\sum PUFA\ \omega 3$$

Indexes (1) and (2) were calculated according to the method by Ulbricht, Southgate (1991), and index (3) was determined according to the method by Santos-Silva *et al*. (2002).

Statistical analysis. The data were analyzed using SAS version 6.12 (SAS Institute Inc., Cary, NC, USA). Significant differences between the means were determined with a Tukey-Kramer test. Differences were considered significant at $P < 0.05$.

Results

The biometrics and proximate composition of cultured, lentic, and lotic fish are presented in Tab. 1. Fish from lentic and lotic environments had higher body weight than cultured fish. The highest and lowest body length was recorded from lotic and cultured fish, respectively. Lotic fish had a significantly lower condition factor K than cultured or lentic fish. Cultured and lentic fish had significantly higher lipid levels (1.5 and 1.9- fold, respectively) than lotic fish. Cultured fish had significantly lower ash level than lentic and lotic fish. No significant differences were observed in the protein levels of the fish analyzed.

Tab. 1. Biometric measurements and chemical composition of *Lophiosilurus alexandri* from lotic and lentic environments and aquaculture. Mean ± standard deviation, different letters in the same row are significantly different ($P < 0.05$).

	Lotic environment	Lentic environment	Aquaculture
Biometrics measurements (n=10)			
Total weight (g)	2274.0 ±378.26^{a}	1560.0±844.39^{a}	433.0±101.3^{b}
Length(cm)	59.61±3.58^{a}	46.00±5.38^{b}	30.60±2.70^{c}
Condition factor K	1.07±0.07^{b}	1.49±0.25^{a}	1.50±0.18^{a}
Proximate composition (g/100g) (n=5)			
Moisture	80.64 ± 1.23^{a}	80.25 ± 1.65^{a}	79.76 ± 3.22^{b}
Protein	17.18 ± 0.69	17.75 ± 1.26	17.86 ± 0.37
Ash	1.02 ± 0.04^{ab}	1.17 + 0.24^{a}	0.98 ± 0.12^{b}
Lipid	1.40 ± 0.72^{b}	2.10 ± 0.72^{ab}	2.66 ± 0.36^{a}

Cultured fish had significantly ($P< 0.05$) higher myristic Acid (C14), palmitic acid (C16), linoleic *Acid (*C18:2 n-6*), alpha linolenic acid (*C18:3 n-3), and total polyunsaturated fatty acids (∑PUFA) n6 fatty acid levels than lentic or lotic fish. Lentic pacamãs had significantly higher ($P< 0.05$) eicosapentaenoic acid (C20:5 n-3) levels (4×) than cultured or lotic pacamãs (Tab. 2). Docosahexaenoic acid (C22:6 n-3) levels were the highest in lentic fish, followed by lotic fish (Tab. 2).

Tab. 3 presents the chemical and fatty acid composition of feed from the cultured fish. From this table it was observed that linoleic *acid (*C18:2 n-6*)*, palmitic acid (C16:0) and oleic acid (C18:1 n-9) were present in higher quantity than the others. While the arachidonic acid (C20:4 n-6) percentage in feedstuff was < 1%.

There were no differences in thrombogenecity index (TI), atherogenic index (AI) and ratio between hypocholesterolemic-to-hypercholesterolemic fatty acids (HH) values among the three environment conditions. The ω6-to-ω3 PUFA ratio was different among the three habitats. The ω6/ω3 lowest ratio was observed with lentic fish, whereas the lotic fish showed intermediate values and the cultured higher (Tab. 4).

Tab. 2. Fatty acid composition (g\100g fatty acid) of *Lophiosilurus alexandri* from lotic and lentic environments and aquaculture. Mean ± standard deviation (n=5) followed by different letters to each other ($P < 0.05$). Only the most important fatty acids are listed. C12:0= dodecanoic acid; C14:0= myristic Acid; C15:0= pentadecanoic acid; C16:0=palmitic acid; C17:0=heptadecanoic acid; C18:0= Stearic acid; C20:0= eicosenoic *acid;* C21:0=*heneicosanoic acid; C22:0=docosanoic acid;* ∑ SFA= total saturated fatty acids; C16:1n-7= palmitoleic acid= Cis 10-Heptadecenoic acid; C18:1 n-9 trans = acid elaidic; C18:1 n-9= oleic acid; C20:1 n-11= gadoleic acid; ∑MUFA= total de monounsaturated fatty acid; C18:2 n-6=linoleic *Acid;* C18:3 n-3 trans = *trans alpha linolenic acid;* C18:3 n-3= *alpha linolenic acid;* C20:2 n-6= eicosadienoic acid; C20:4 n-16 trans= trans arachidonic acid; C20:4 n-6= arachidonic acid; C20:5 n-3= eicosapentaenoic acid; C22:5 n-3 = docosapentaenoic acid; C22:6 n-3 = docosahexaenoic acid; ∑ PUFA = total polyunsaturated fatty acids; ∑ PUFA n-3= total polyunsaturated fatty acids n-3 e ∑ PUFA n-3= total polyunsaturated fatty acids n-6**.**

Fatty acid	Lotic environment	Lentic environment	Aquaculture
C12:0	0.04 ± 0.06	0.04 ± 0.06	0.04 ± 0.06
C14:0	2.17 ± 0.53^{a}	2.23 ± 0.57^{a}	2.28 ± 0.18^{b}
C15:0	0.66 ± 0.31	1.09 ± 1.01	0.25 ± 0.03
C16:0	26.03 ± 0.65^{b}	25.68 ± 1.57^{b}	28.42 ± 0.63^{a}
C17:0	1.45 ± 0.36^{a}	1.03 ± 0.17^{b}	0.46 ± 0.07^{c}
C18:0	9.16 ± 0.37^{a}	7.22 ± 0.59^{b}	6.82 ± 0.15^{b}
C20:0	0.19 ± 0.15	0.27 ± 0.07	0.35 ± 0.02
C21:0	-	0.05 ± 0.05	-
C22:0	0.21 ± 0.12	0.13 ± 0.13	0.21 ± 0.13
∑ SFA	40.00 ± 1.64^{a}	37.74 ± 1.18^{b}	38.97 ± 0.89^{a}
C16:1n-7	4.39 ± 1.08^{b}	9.01 ± 4.24^{a}	3.93 ± 0.49^{b}
C17:1	0.57 + 0.14^{a}	0.49 ± 0.11^{ab}	0.34 ± 0.05^{b}
C18:1 n-9 trans	0.33 ± 0.22	0.27 ± 0.16	0.38 ± 0.21
C18:1 n-9	23.16 ± 1.30^{b}	18.25 ± 2.46^{c}	26.37 ± 0.63^{a}
C20:1 n-11	3.65 ± 0.95^{a}	0.94 ± 0.42^{b}	1.11 ± 0.17^{b}
∑MUFA	32.51 ± 2.47	29.03 ± 3.06	32.28 ± 0.61
C18:2 n-6	5.84 ± 0.80^{b}	4.79 ± 0.32^{b}	14.25 ± 0.93^{a}
C18:3 n-3 trans	0.13 ± 0.17^{b}	0.20 ± 0.05^{b}	0.53 ± 0.05^{a}
C18:3 n-3	1.12 ± 0.37^{b}	2.13 ± 0.63^{a}	0.32 ± 0.39^{b}
C20:2 n-6	0.85 ± 0.11^{a}	0.33 ± 0.04^{c}	0.48 ± 0.04^{b}
C20:4 n-6	3.14 ± 1.32^{ab}	3.83 ± 1.87^{a}	1.35 ± 0.19^{b}
C20:5 n-3	0.99 ± 0.12^{b}	3.74 ± 1.25^{a}	0.96 ± 0.06^{b}
C22:5 n-3	1.52 ± 0.41^{b}	2.20 ± 0.50^{a}	0.87 ± 0.05^{c}
C22:6 n-3	4.22 ± 2.14^{b}	6.52 ± 2.85^{a}	3.60 ± 0.23^{c}
∑ PUFA	18.74 ± 3.45^{c}	25.53 ± 5.87^{a}	23.17 ± 3.50^{b}
∑ PUFA n-3 (g/100g flesh)	0.096 ± 0.144^{b}	0.278 ± 0.186^{a}	0.142 ± 0.448^{b}
∑ PUFA n-6 (g/100g flesh)	0.144 ± 0.059^{b}	0.186 ± 0.021^{b}	0.448 ± 0.048^{a}

Tab. 3. Chemical and fatty acid composition of feed. Mean ± standard deviation. C16:0=palmitic acid; C16:1= *palmitoleic acid;* C18:1 n-9= oleic acid; C20:1 n11= eicosenoic acid; C18:2 n-6= linoleic *Acid;* C18:3 n-3= *alpha linolenic acid;* C20:2 n-6= eicosadienoic acid; C20:4 n-6= arachidonic acid; C20:5 n-3= eicosapentaenoic acid; C22:5 n-3 = docosapentaenoic acid; C22:6 n-3 = docosahexaenoic acid.

Chemical composition	
Moisture (g/100g)	8.88±0.26
Protein (g/100g)	36.72±1.48
Ash (g/100g)	8.82±0.11
Lipids (g/100g)	6.99±0.33
Fatty acid	
C16:0	21.20±0.34
C16:1	2.89±0.07
C18:1 n-9	28.25±0.64
C20:1 n-11	2.09±0.15
C18:2 n-6	24.10±0.67
C18:3 n-3	0.60±0.03
C20:2 n-6	0.19±0.03
C20:4 n-6	0.54±0.31
C20:5 n-3	1.30±0.03
C22:5 n-3	0.50±0.03
C22:6 n-3	1.80±0.15

Tab. 4. Nutritional quality assessment of *Lophiosilurus alexandri* from lotic and lentic environments and aquaculture. Mean ± standard deviation (n=5) followed by different letters to each other ($P < 0.05$). AI= Atherogenic index, TI= Thrombogenecity index, HH= ratio between hypocholesterolemic and hypercholesterolemic fatty acids and ω6/ω3 = ratio.

	Lotic environment	Lentic environment	Aquaculture
AI	0.71 ± 0.10^{a}	0.65 ± 0.08^{a}	0.67 ± 0.03^{a}
TI	1.65 ± 0.11^{a}	1.48 ± 0.11^{a}	1.55 ± 0.10^{a}
HH	1.42 ± 0.19^{a}	1.50 ± 0.31^{a}	1.56 ± 0.09^{a}
ω6/ω3	1.56 ± 0.18^{b}	0.67 ± 0.04^{c}	3.19 ± 0.53^{a}

Discussion

The difference of body weight and body length is difficult to compare because the age of animals captured in natural conditions is unknown. The nutritional composition of fish may vary depending on their stage of development (Costa *et al.*, 2018), feeding (Li *et al.*, 2014) and species (Mohanty *et al*., 2019). Fish containing levels of protein greater than 15% are considered a high nutritional value food (Coutinho *et al.*, 2019; Memon *et al*., 2011). In addition, fish are commonly classified into groups according to their total lipid content: high-fat (> 8%), medium-fat (4% to 8%), low-fat (2% to 4%) and lean (< 2%) (Haard, 1992). Due to the characteristics found in the present study, pacamã proved to be a food with high nutritional value.

The condition factor K reflects the physical and biological fluctuations in feeding conditions, parasitic infections, and physiological factors (Le Cren, 1951). Morphometric condition indicators represent the simplest indicators of energy storage in fish species (Lloret *et al.*, 2014). The K index is based on the assumption that within a cohort, individuals with high K values contain more energy reserves (fat and protein) than those with low K values (Caldarone *et al*., 2012). These results may be attributed to higher lipid reserves in fish of lentic and aquaculture habitats.

LA values, which were three times higher in cultured fish, explain the high ∑PUFA n6 values. The high levels of C18:2 n-6 in cultured fish have been attributed to the presence of plant-based C18:2 n6 in the feed (Grigorakis, 2007). The main ingredient of the feed was soybean meal which contained high C18:2 n-6*,* levels.

The fatty acid trophic marker is based on the observation that the primary producer lays down certain fatty acid patterns that may be conservatively transferred (Dalsgaard *et al*., 2003). Cyanobacteria and diatoms contain C16:1 n-7 (Mortillaro *et al*., 2011) and EPA (C20: 5 n-3) (Lau *et al*., 2009). These two fatty acids are biomarkers of cyanobacteria and diatoms in freshwater habitats (Lau *et al*., 2009). Compared to cultured and lotic fish, lentic fish had significantly higher levels of these fatty acids, suggesting that in this environment there are higher amounts of cyanobacteria and diatoms, food source for of smaller fish and crustaceans that will be consumed by pacamã. Certain herbivorous copepods produce considerable amounts of C20:1 n11 from the desaturation of C20:00 (Dalsgaard *et al*., 2003; Saito, Murata, 1998), which may explain the higher amount of this fatty acid in lotic fish.

Ulbricht, Southgate (1991) developed AI and TI, which are based on the fatty acid profile of the animal and its contribution to either the prevention or promotion of coronary heart disease in humans (Valfré *et al*., 2003). AI represents the ability to reduce blood lipid content, and TI represents the ability to inhibit platelet activity in humans. Low AI and TI values are indicative of a cardioprotective effect (Grigorakis *et al*., 2011). In this study, there were no differences in TI or AI values among lentic, lotic, and aquaculture habitats. HH is directly related to cholesterol metabolism. High HH values are considered to be beneficial for human health (Ramos-Filho *et al*., 2010). In this study, there were no differences in HH values among the three habitats. Similar results were reported in other Brazilian freshwater fish (Ramos-Filho *et al*., 2010). The ω6-to-ω3 PUFA ratio was different among the three habitats. The lowest ratio was observed with lentic fish.

It has been reported that cultured fish have lower C20:4 n-6 levels than their wild counterparts (Rodríguez-Barreto *et al*., 2012), possibly due to substantially higher C20:4 n-6 levels in the natural feed (Jainkowska *et al*., 2010). In this study, the C20:4 n-6 percentage is in agreement with the findings reported by Fasolato *et al*. (2010).

Our study findings revealed that the lipid levels of fish in aquaculture environments were higher than those of lotic, which suggests that habitat has a significant impact on lipid synthesis in fish (Deka *et al*., 2012).

Fish with high C20:5 n-3 (EPA) and C22:6 n-3 (DHA) levels and low ω6-to-ω3 ratios constitute a fundamental part of a healthy human diet (Turchini *et al*., 2009). The European Food Safety Authority recommends the daily consumption of 250 mg C20:5 n-3 (EPA) + 250 mg C22:6 n-3 (DHA) (EFSA, 2010). Lentic, cultured, and lotic pacamã (100 g) provide 74%, 44%, and 28%, respectively, of the recommended daily C20:5 n-3 (EPA) + C22:6 n-3 (DHA).

A ω6-to-ω3 PUFA ratio of 3:1 to 4:1 might prevent several diseases characteristic of the Western diet (ANSES, 2011). A ω6-to-ω3 PUFA ratio of 1:1 to 2:1 appears to be consistent with studies on evolutionary aspects of diet, neurodevelopment, and genetics (Simopoulos, 2010). In this study, the ω6-to-ω3 PUFA ratio were lower than those considered to be harmful to human health. Additionally, lentic and lotic fish had ideal ratios.

ARA is the main precursor of eicosanoids C20:5 n-3 (EPA) competitively interferes with ARA in the production of these hormone-like compounds, and C20:5 n-3 (EPA) derivatives are less biologically active than ARA derivatives (Rodríguez-Barreto *et al*., 2012). The high levels of C20:4 n-6 in lentic or lotic fish may function as suggested by Ogata *et al*. (2004); C20:4 n-6 is nutritionally more important in tropical species that in cold/temperate water species.

The fish used in this study were collected in 2013; however, some considerations are necessary because of climate changes in 2014 and 2015 in Brazil. From September 2014 to February 2015, the total rainfall over a large region of South Eastern Brazil was considered to be one of the lowest ever recorded (Liberto, 2015). Pacamã is an endemic, endangered fish of São Francisco River. The evolutionary history of tropical riverine ecosystems is complex and has contributed to high levels of endemism, because dams and other hydrological modifications can result in the loss of endemic species (Pringle *et al*., 2000). In lentic systems, eutrophication may be exacerbated or offset, and stratification will likely become more pronounced and stronger as a result of climate changes (Roland *et al*., 2012).

In summary, the results of this study showed that pacamã is a lean fish (1-2% of total lipids) and that the environment has a great influence on the fatty acid profile. Pacamã from the lentic environment has a high C22:6 n-3 (DHA) content, so it becomes more nutritionally suitable. Our study findings can be used as a preliminary data collection for further elaborated study to evaluate how climate changes in Brazil affect lipid metabolism of pacamã in different environments. Similar studies will be carried out from 2020 to 2021 to check the the chemical characteristics of the species in lentic and lotic environment after water stress, as well as the effects of prolonged drought in the nutritional characteristics of pacamã.

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