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Nutritional Value of Seven Freshwater Fish Species From the Brazilian Pantanal

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Abstract This study determined the proximate composition and fatty acid profile of the lipid fraction in muscle tissue (fillet) of seven fish species from the Miranda River, Brazil. Total lipid content had the largest coefficient of variation among species (73%), while protein content had the smallest (4.5%), allowing *Pimelodus argenteus* (mandi-prateado) to be categorized as lean fish; *Pimelodus maculatus* (mandi-amarelo), *Hemisorubim platyrhynchos* (jurupoca), and *Pinirampus pirinampu* (barbado) as species with medium fat content, and *Paulicea luetkeni* (jaú) and *Surubim lima* (jurupensém) as fatty fish. In all the species investigated, palmitic acid (23.76–25.99%) was the predominant saturated fatty acid. Oleic acid (16.09–32.90%) was the most abundant monounsaturated fatty acid. Total omega-6 polyunsaturated fatty acids (5.99–15.56%) were the predominant polyunsaturated fatty acids, except in *Ageneiosus brevifilis* (palmito), in which total omega-3 polyunsaturated fatty acids predominated (10.30%). All the species had favorable indices of nutritional quality for total lipids, with respect to human consumption.

Keywords Freshwater fish · Proximate composition · Fatty acid · Omega-3 · Lipids · Brazilian Pantanal · Nutritional quality index (NQI) · Polyunsaturated fatty acids

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Introduction

Studies on food composition and its nutritional implications, aimed at improving consumer health, tend to focus on fatty acid profiles—particularly the relationships among saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA), including the omega-3 (ω-3) and omega-6 (ω-6) families—as a factor for preventing cardiovascular diseases and decreasing the incidence of breast cancer, rheumatoid arthritis, multiple sclerosis, and other inflammatory diseases [1–3].

The consumption of fatty acids, mainly long-chain PUFA (ω-3 family) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), plays an important role in human nutrition, disease prevention, and health promotion. EPA and DHA have alpha-linoleic acid (α-LNA ω-3) as a precursor, which is an essential nutrient, since it is not synthesized by humans and has to be consumed through diet.

Fish and fish-derived products contain a wide range of nutritional components and, as major sources of ω-3 PUFA, must be incorporated into the human diet. Epidemiological studies recommend their inclusion in 2–3 meals in a weekly menu [4–6]. Fatty acid composition, however, varies widely, not only among fish species, but also within a single species [1, 2, 7].

From 1993 to 2002, the Brazilian fishery production grew by 48.8%, from 676,442 to 1,006,869 t. In 2002, Brazil's Center-West region accounted for 5.0% of the national continental extractive production of 239,416 t. Mato Grosso do Sul's share was 4,744.0 t, obtained by artisanal extraction and representing around 64% of the state's total production [8].

Brazil has a large diversity of fish species, many of which are found in rivers located in the Upper Paraguay

Basin, which feeds the South Pantanal wetlands, in the state of Mato Grosso do Sul. Data on the nutritional composition of these fish species are limited.

The objectives of this study were to determine the proximate composition and fatty acid profile of the lipid fraction in muscle tissue (fillet) of seven fish species of the order Siluriformes (non-scaly).

Materials and Methods

Fish Samples

Samples ($n = 3$ or $n = 4$) of the seven species (Table 1) were captured during the allowed catch period in the Miranda River, at the Pantanal Field Station of the Universidade Federal de Mato Grosso do Sul (UFMS) (19°34′37″S; 57°00′42″W), and were placed in isothermal boxes filled with ice for transportation. Each sample was individually weighed and eviscerated, and the skin and spines separated from muscle tissue. Muscle tissue was ground and homogenized using an electric grinder-homogenizer, obtaining triturated samples that varied between 90 and 3,500 g, and weighed aliquots were taken from each homogenized fish muscle tissue, for analysis in triplicate.

Proximate Composition

For each species, muscle tissue was analyzed immediately after homogenization. Moisture content was determined by heating in an oven at 105 °C. Fixed mineral residue (ash) was quantified by incineration in a muffle furnace at 550 °C. Determination of the total protein content was based on the Kjeldahl method [9]. Total lipid extraction was carried out according to Bligh and Dyer [10], considering the recommended proportions of methanol, chloroform, and tissue water solvents (2:1:0.8, respectively). Lipid quantification was performed gravimetrically by vacuum evaporation and the remaining lipid fraction was stored in an amber flask under a nitrogen atmosphere at −20 °C until analysis. The proximate composition obtained in triplicate was expressed as means and standard deviation.

Fatty Acids in the Lipid Fraction

The total lipid fraction (50 mg) was submitted to saponification with 0.5 M methanolic KOH (4 mL) by boiling for 3–5 min and the fatty acids were methylated with 5.0 mL of a mixture of H_2SO_4 conc. (3 mL) and NH_4Cl (2 g) in methanol (60 mL) by boiling for 3 min and then transferred to hexane (5.0 mL), according to the procedure described by Maia and Rodriguez-Amaya [11]. Analysis of fatty acid methyl esters was performed with a gas chromatograph (Varian, model Star 3400) with a flame ionization detector and split/splitless injector on a silica capillary column of 30 m × 0.25 mm internal diameter (J&W Scientific, USA) containing polyethylene glycol (DB-Wax) as the stationary phase. Chromatography conditions were: injector temperature, 250 °C; column temperature, 180 °C for 20 min, with a 2 °C/min gradient up to 220 °C; detector temperature, 260 °C; starter gas (hydrogen), 1.1 mL/min flow; auxiliary gas (nitrogen), 22 mL/min; injection volume, 0.5 µL. Pure fatty acid methyl esters from Sigma–Aldrich were used as standards for identification of sample fatty acids. After normalization, the results were expressed as the area percentage for each acid, relative to the total area for fatty acids. Peak areas of less than 0.01% of the total area were disregarded. The area percentages were converted to g/100 g of muscle tissue by multiplying each percentage value by the total lipid fraction content and the conversion factors corresponding to lean (0.700) or fatty (0.900) fish, according to Holland et al. [12].

Nutritional Quality Index (NQI) with Regard to Total Lipids

Lipid quality was estimated by three indices of fatty acid composition: the indices of atherogenicity (IA) and thrombogenicity (IT), according to Ulbricht and Southgate [13], and the hypocholesterolemic and hypercholesterolemic

Table 1 Biometric data of the fish species sampled

Species	Barbado[a]	Jaú[b]	Jurupensém[b]	Jurupoca[b]	Mandi-amarelo[b]	Mandi-prateado[a]	Palmito[b]
Length (cm)	63 ± 2	95 ± 5	53 ± 3	55 ± 8	18 ± 3	16 ± 2	39 ± 4
Body weight (g)	2,700 ± 350	5,950 ± 620	860 ± 100	935 ± 115	205 ± 60	120 ± 20	580 ± 30

Values reported are mean ± SD

[a] $n = 4$

[b] $n = 3$

fatty acid ratio (HH), according to Santos-Silva et al. [14], using the formulae below:

$$\mathrm{IA} = [(12:0 + (4 \times 14:0) + 16:0)]/(\mathrm{MUFA} + \mathrm{PUFA}\ \omega 6 + \mathrm{PUFA}\ \omega 3)$$

$$\mathrm{IT} = (14:0 + 16:0 + 18:0)/[(0.5 \times \mathrm{MUFA}) + (0.5 \times \mathrm{PUFA}\omega 6) + (3 \times \mathrm{PUFA}\omega 3) + (\mathrm{PUFA}\omega 3/\mathrm{PUFA}\omega 6)]$$

$$\mathrm{HH} = (18:1cis9 + 18:2\omega 6 + 20:4\omega 6 + 18:3\omega 3 + 20:5\omega 3 + 22:5\omega 3 + 22:6\omega 3)/(14:0 + 16:0)$$

where MUFA are monounsaturated acids, PUFA are polyunsaturated fatty acids

Statistical Analysis

The proximate composition and fatty acid composition values were subjected to analysis of variance (ANOVA). Tukey's test was applied to unequal variances among the mean values of samples, using Biostat software (version 4.0). The level of significance was set at 5% for all analyses.

Results and Discussion

The proximate composition of muscle tissue varied significantly among fish species (Table 2). Lipid content had the highest coefficient of variation (72.88%) among species, followed by ash, moisture, and protein contents (9.22, 5.11, and 4.49%, respectively). The lowest moisture content (71.78%) was found in muscle tissue of jurupensém and the highest (81.83%) occurred in mandi-prateado. In these two species, this variable exhibited an inverse correlation with lipid content (11.19 and 0.35%, respectively). No differences in moisture or lipid content were found between the groups of species composed of (a) barbado, jurupoca, and mandi-amarelo; (b) jaú and jurupensém; and (c) mandi-prateado and palmito. Andrade et al. [15], studying specimens acquired in the retail market in Maringá (Paraná State, Brazil), found for mandi-amarelo a total lipid value (5.50%) similar to that obtained in the present study, whereas the value for barbado was higher (19.75%) and that for jurupoca was lower (2.98%). Gutierrez and Silva [16] found a total lipid value of 7.08% for mandi (unreported species) acquired in the Piracicaba (São Paulo State) retail market.

In the present study, protein content in muscle tissue (minimum, 16.07%, for jurupensém; maximum, 18.10%, for jurupoca) exhibited a small range of variation, of around 2.0%, although with significant statistical differences ($p < 0.0001$). Protein content ranged from 16.39 to 17.77% across species.

Mineral (ash) content was highest in jurupensém muscle tissue, although this variable did not differ significantly ($p > 0.05$) across species.

Stansby [7] classified fish species into five categories (A–E), based on fat and protein content. The values of these components assign mandi-prateado and palmito to category A (<5% of lipids and 15–20% of proteins) and the other species herein investigated to category B (5–15% of lipids and 15–20% of proteins). Despite overall similarities in nutritional values, Stansby's classification allows fish species to be selected according to dietary needs—e.g., for diets designed to reduce calorie intake by providing lower fat content, while still maintaining high levels of protein, and diets aimed at controlling cholesterolemia by selecting species having medium to high fat content, including considerable amounts of unsaturated fatty acids [7].

Mandi-prateado and palmito, according to Ackman's classification, which is based on fat content [17], are

Table 2 Proximate composition of muscle tissue (fillet) of barbado, jaú, jurupensém, jurupoca, mandi-amarelo, mandi-prateado, and palmito, as g/100 g (fresh weight basis)

Fish	Moisture	Proteins	Lipids	Ash	TEV
Barbado[A]	75.31 ± 0.95b	16.39 ± 0.68bc	7.30 ± 0.45b	1.01 ± 0.06ab	551.50 ± 24.48b
Jaú[B]	72.23 ± 0.68c	16.92 ± 0.42ab	10.44 ± 0.46a	0.98 ± 0.01ab	678.88 ± 24.44a
Jurupensém[B]	71.78 ± 0.02c	16.07 ± 0.96c	11.19 ± 0.74a	1.14 ± 0.12a	692.79 ± 11.59a
Jurupoca[B]	74.69 ± 0.65b	18.10 ± 0.64a	6.35 ± 1.52b	0.94 ± 0.11b	544.11 ± 46.70b
Mandi-amarelo[B]	75.97 ± 0.07b	17.70 ± 0.24ab	5.55 ± 0.34b	0.90 ± 0.04b	507.10 ± 16.96b
Mandi-prateado[A]	81.83 ± 0.29a	16.73 ± 0.36abc	0.35 ± 0.18c	0.89 ± 0.05b	294.29 ± 9.40c
Palmito[B]	80.74 ± 0.28a	17.77 ± 0.31ab	0.36 ± 0.05c	1.07 ± 0.00ab	312.10 ± 3.40c

Values are mean ± SD for triplicate samples. Values in the same column followed by the same letters do not differ significantly ($p > 0.05$)

[A] $n = 4$

[B] n = 3

TEV total energy value, expressed as kJ/100 g of muscle tissue (protein = 16.8 kJ/g; fat = 37.8 kJ/g) considered lean fish (<2% of fat), whereas mandi-amarelo, jurupoca, and barbado have medium fat content (4–8%) and jaú and jurupensém fall into the category of fatty fish (>8%) [17].

The seven species investigated showed variable fatty acid composition in the total lipid fraction of muscle tissue (Table 3). Palmitic acid (C16:0) content ranged from 23.76 to 25.99%, accounting for most of the SFA fraction (64 to 71%). Stearic acid (18:0) and myristic acid (C14:0) ranged from 7.35 to 9.39% and from 1.05 to 2.68%, respectively. These results are in accordance with data from other studies, showing that muscle tissue of freshwater fish species contains higher levels of C16:0 and C18:0 and lower levels of C20:0 and C22:0 relative to marine species, and that total SFA content in freshwater fish species is usually higher than in marine species [18, 19].

Irrespective of the species investigated, palmitoleic (C16:1 ω-7) and oleic (C18:1 ω-9) MUFA and vaccenic (C18:1 ω-7) isomers were the predominant fatty acids in this category, ranging from 3.50 to 8.80%, 16.09 to 32.90%, and 3.19 to 6.84%, respectively. Values from 1.00 to 1.74% for eicosenoic acid (C20:1) were found for all the species studied, and the presence of MUFA with 24 carbons (C24:1 ω-9, nervonic acid) was detected only in the mandi species. High levels of palmitoleic acid have been described as characteristic of freshwater species [16, 20–22].

PUFA content varied widely, from 9.34% in barbado to 26.33% in mandi-prateado. There was a higher prevalence of PUFA of the ω-6 family (5.99–15.56%), with a predominance of linoleic acid (C18:2 ω-6) (4.07–9.87%), except in mandi-prateado, which exhibited a higher content of arachidonic acid (C20:4 ω-6) (8.12%), and in palmito,

Table 3 Fatty acid composition of muscle tissue (fillet) of barbado, jaú, jurupensém, jurupoca, mandi-amarelo, mandi-prateado, and palmito, expressed as percentage of total fatty acids

Fatty acid	Barbado[A]	Jaú[B]	Jurupensém[B]	Jurupoca[B]	Mandi-amarelo[B]	Mandi-prateado[A]	Palmito[B]
C12:0	0.24 ± 0.09b	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.41 ± 0.17a	0.00 ± 0.00	0.00 ± 0.00
C14:0	2.68 ± 0.31a	1.75 ± 0.24b	1.26 ± 0.21bc	1.50 ± 0.03bc	1.63 ± 0.08bc	1.07 ± 0.21c	1.05 ± 0.04c
C16:0	25.99 ± 1.90a	24.68 ± 1.22a	25.04 ± 1.62a	25.17 ± 1.10a	25.43 ± 0.85a	23.76 ± 0.51a	23.78 ± 0.17a
C17 0	1.63 ± 0.14b	2.29 ± 0.04a	0.67 ± 0.00d	0.71 ± 0.03d	1.29 ± 0.33c	0.91 ± 0.14 cd	1.19 ± 0.00c
C18:0	9.35 ± 0.49a	7.35 ± 0.63b	7.92 ± 0.03bc	7.61 ± 0.05bc	8.71 ± 0.44ab	9.25 ± 0.13a	9.39 ± 0.83a
C20:0	0.49 ± 0.04a	0.25 ± 0.04d	0.41 ± 0.01ab	0.42 ± 0.01ab	0.42 ± 0.00ab	0.36 ± 0.08bc	0.26 ± 0.02cd
C22:0	0.26 ± 0.08a	0.16 ± 0.00ab	0.08 ± 0.00b	0.07 ± 0.00b	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C24:0	0.11 ± 0.05c	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.80 ± 0.07 b	1.48 ± 0.20a	0.00 ± 0.00
∑ SFA	**40.74 ± 1.60**a	**36.48 ± 1.16**bc	**35.39 ± 1.83**b	**35.46 ± 0.97**bc	**38.70 ± 1.45**ab	**36.80 ± 0.76**abc	**35.69 ± 1.07**bc
C14:1 ω-5	0.99 ± 0.11b	1.28 ± 0.05a	0.31 ± 0.11c	0.30 ± 0.08c	0.19 ± 0.06c	0.31 ± 0.07c	0.00 ± 0.00
C16:1 ω-7	7.69 ± 0.66b	8.80 ± 0.10a	4.89 ± 0.48 cd	6.86 ± 0.01b	6.27 ± 0.65bc	3.50 ± 0.75d	3.76 ± 0.61d
C18:1 ω-9	23.07 ± 2.98c	24.51 ± 1.95c	32.90 ± 0.08a	27.23 ± 0.93b	26.23 ± 2.10bc	18.56 ± 1.61d	16.09 ± 0.02d
C18:1 ω-7	4.55 ± 0.28bcd	5.15 ± 0.06bc	3.97 ± 0.13 cd	6.84 ± 0.24a	3.30 ± 0.96d	3.19 ± 0.41d	5.30 ± 0.18b
C20:1 ω-9	1.51 ± 0.12ab	1.20 ± 0.04cd	1.45 ± 0.04ab	1.53 ± 0.09bc	1.20 ± 0.00cd	1.00 ± 0.13d	1.74 ± 0.12a
C22:1 ω-9	0.10 ± 0.02a	0.13 ± 0.00a	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
C24:1 ω-9	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.68 ± 0.02b	2.37 ± 0.40a	0.00 ± 0.00
∑ MUFA	**37.94 ± 2.55**bc	**41.07 ± 2.80**abc	**43.51 ± 0.61**a	**42.75 ± 0.72**ab	**37.86 ± 0.41**c	**28.93 ± 2.11**d	**26.89 ± 0.92**d
C18:2 ω-6	4.07 ± 0.40de	4.62 ± 0.37cde	9.87 ± 2.00a	6.90 ± 0.57bc	5.65 ± 0.88bc	7.45 ± 1.01ab	2.68 ± 0.13e
C18:3 ω-3	1.95 ± 0.24bc	1.87 ± 0.02bc	2.12 ± 0.53bc	3.29 ± 0.79ab	3.91 ± 1.17a	1.29 ± 0.30c	0.95 ± 0.07c
C20:4 ω-6	1.93 ± 0.10cd	2.06 ± 0.20cd	1.01 ± 0.01e	1.22 ± 0.07de	2.43 ± 0.05c	8.12 ± 0.56a	6.54 ± 0.14b
C20:5 ω-3	0.35 ± 0.05bc	0.46 ± 0.02bc	0.20 ± 0.01c	0.32 ± 0.01c	0.44 ± 0.02bc	1.28 ± 0.22a	0.68 ± 0.02b
C22:6 ω-3	1.05 ± 0.06b	0.79 ± 0.03b	0.75 ± 0.02b	0.70 ± 0.01b	1.88 ± 0.15b	8.19 ± 0.70a	8.67 ± 0.92a
∑ PUFA	**9.34 ± 0.75**d	**9.80 ± 0.13**d	**13.94 ± 2.54**c	**12.41 ± 1.29**cd	**14.30 ± 1.88**c	**26.33 ± 1.11**a	**19.52 ± 0.60**b
ω-6	**5.99 ± 0.45**d	**6.68 ± 0.09**cd	**10.88 ± 2.01**b	**8.11 ± 0.50**cd	**8.08 ± 0.88**d	**15.56 ± 0.79**a	**9.23 ± 0.27**bc
ω-3	**3.35 ± 0.32**c	**3.12 ± 0.22**c	**3.06 ± 0.54**c	**4.30 ± 0.00**bc	**6.23 ± 1.00**b	**10.75 ± 0.80**a	**10.30 ± 0.87**a
∑ NIFA	**11.76 ± 1.55**	**12.54 ± 0.02**	**6.99 ± 0.19**	**9.25 ± 0.36**	**8.91 ± 0.83**	**9.20 ± 0.20**	**17.84 ± 0.80**

Values reported are mean ± SD. Values in the same row followed by the same letters do not differ significantly ($p > 0.05$)

SFA Saturated fatty acids, *MUFA* Monounsaturated fatty acids, *PUFA* Polyunsaturated fatty acids, *NIFA* Non-identified fatty acids

[A] $n = 4$

[B] $n = 3$

with a higher content of PUFA of the ω-3 family (10.30%). These two species contrasted with the others with regard to eicosapentaenoic acid (EPA C20:5 ω-3) and docosahexaenoic acid (DHA C22:6 ω-3), which ranged from 1.28 to 8.19%, respectively, in mandi-prateado and from 0.68 to 8.67%, respectively, in palmito. Freshwater fish species usually have more polyunsaturated acids of the ω-6 family, whereas their marine counterparts are richer in ω-3 acids, especially DHA and EPA [18, 19, 23, 24].

Table 4 addresses the indices used to evaluate the nutritional quality of the lipid fraction. The ratio between PUFA of the ω-6 and ω-3 families is one of the indices used to evaluate the nutritional value of the lipid fraction present in foods. According to nutritional recommendations [14, 25], human diet should contain foods in which the ω-6/ω-3 ratio does not exceed 4.0, so as to prevent cardiovascular risks [26]. All the fish species evaluated in this study had a ω-6/ω-3 ratio below the recommended maximum, varying from 0.90 in palmito to 3.55 in jurupensém muscle tissue. The ω-3/ω-6 values ranged from 0.28 to 1.12, which are lower than those reported in the literature for freshwater species. Mapará (*Hypophthalmus* sp.) from the Amazon River had a ω-3/ω-6 ratio of 1.5–1.6 [20]. Values of 0.22–4.19 for freshwater species from southern Brazil have been reported [15]. Henderson and Tocher [27] reported ω-3/ω-6 value of 0.5–3.8 and 4.7–14.4 for freshwater and marine fish, respectively.

The polyunsaturated and saturated fatty acid (P/S) ratio is another index usually adopted to evaluate the nutritional quality of lipids in a diet. Diets with a P/S ratio lower than 0.45 have been viewed as unfavorable [14, 25], as they possibly promote the occurrence of hypercholesterolemia. In the present study, the lipid fraction of muscle tissue showed values ranging from 0.23 (barbado) to 0.71 (mandi-prateado). However, this index, which is based only on the degree of fatty acid saturation, may not prove adequate when used alone to evaluate the nutritional quality of lipids, because it not only takes into account all the SFA responsible for increasing blood cholesterol, but also ignores the metabolic effects of MUFA [13, 26].

Table 4 Nutritional quality indices for the lipid fraction in muscle tissue (fillet) of barbado, jaú, jurupensém, jurupoca, mandi-amarelo, mandi-prateado, and palmito

Species	P/S	ω-6/ω-3	ω-3/ω-6	IA	IT	HH
Barbado[A]	0.23e	1.79b	0.56c	0.79a	1.18a	1.14c
Jaú[B]	0.27de	2.14b	0.47c	0.62b	1.00ab	1.30bc
Jurupensém[B]	0.40c	3.55a	0.28d	0.53b	0.94b	1.80a
Jurupoca[B]	0.35cd	1.89b	0.53c	0.56b	0.89bc	1.49abc
Mandi-amarelo[B]	0.37cd	1.30c	0.77b	0.62b	0.85bc	1.51abc
Mandi-prateado[A]	0.71a	1.45c	0.69bc	0.51b	0.65d	1.80a
Palmito[B]	0.55b	0.90d	1.12a	0.60b	0.68cd	1.43abc

Values in the same column followed by the same letters do not differ significantly ($p > 0.05$)

P/S polyunsaturated/saturated fatty acid ratio, *ω-6/ω-3* omega-6/omega-3 fatty acid ratio, *ω-3/ω-6* omega-3/omega-6 fatty acid ratio, *IA* index of atherogenicity, *IT* index of thrombogenicity, *HH* hypocholesterolemic/hypercholesterolemic fatty acid ratio

[A] $n = 4$

[B] $n = 3$

Indices based on the functional effects of different fatty acids allow for better nutritional quality evaluation of lipids in foods. The hypocholesterolemic and hypercholesterolemic fatty acid ratio (HH) considers the specific effects of fatty acids on cholesterol metabolism. Higher values of this ratio, which are desirable, were obtained for jurupensém and mandi-prateado in the present study (HH = 1.80).

The indices of atherogenicity (IA) and thrombogenicity (IT), which relate pro- and antiatherogenic and pro- and antithrombogenic fatty acids, ranged from 0.51 to 0.79 and from 0.65 to 1.18, respectively. The lower the values of both indices, the better the nutritional quality of diet—a factor that reduces the potential risk for cardiovascular disease [13]. The variation found in the indices expressing nutritional quality, both across species and for different individuals of the same species is presented in Table 5. It has been reported that fat content and composition in fish muscle vary mainly with fish diet, but other factors, such as species, size, age, gender, reproductive status, geographic location, and season, may also influence fatty acid composition [1, 2, 17, 19].

Jaú and mandi-amarelo species had the highest combined EPA and DHA levels (117.5 and 115.7 mg/100 g, respectively), followed by barbado and jurupensém (90.8 and 95.2 mg/100 g, respectively) (Table 6). These values account for 37 and 30%, respectively, of the minimum recommended daily requirements of 300–500 mg/day. Higher values of α-LNA were obtained for jurupensém, mandi-amarelo, and jurupoca, ranging from 187.74 to 213.00 mg/100 g. These levels correspond approximately to one-fourth of the minimum recommended daily requirements of 800–1,000 mg/day [4, 5, 28].

Conclusions

All the fish species investigated are good sources of protein. Jaú and jurupensém are also rich in lipids. Unsaturated fatty acids predominated in the lipid fraction of the species analyzed. Mandi-prateado and palmito contained higher EPA and DHA levels than the other species, but the low lipid content makes those two species inadequate sources of these PUFA. Nutritional quality indices for total lipids

Table 5 Comparison of nutritional quality indices for total lipids in muscle tissue of freshwater fish species, determined from fatty acid composition

Species	IA	IT	HH	ω-3/ω-6
Jurupoca (*Hemisorubim platyrhynchos*), marketed in Maringá, Brazil[a]	0.43	0.43	2.05	1.03
Cultured rainbow trout (*Oncorhynchus mykiss*), living in freshwater, Turkey[b]	0.45	0.31	2.63	1.83
Mandi (*Pimelodus maculatus*), marketed in Maringá, Brazil[a]	0.49	0.81	1.73	1.46
Cultured rainbow trout, marketed in Italy[c]	0.50	0.22	2.40	4.10
African catfish (*Clarias gariepinus*), from market at Ijmuiden, Holland[d]	0.57	0.33	1.92	1.97
Zander (*Sander lucioperca*), from Egirdir Lake, Turkey[e]	0.58	0.44	1.77	1.82
Pintado (*Pseudoplatystoma coruscans*), marketed in Maringá, Brazil[a]	0.58	0.59	1.65	2.65
Mapará (*Hypophthalmus edentatus*), from the Itaipu Reservoir, Brazil[f]	0.63	0.53	1.40	1.98
Cultured hybrid striped bass, from Bozdogan/Aydin (Dam Lake), Turkey[g]	0.68	0.23	3.23	1.29
Zander (*Sander lucioperca*), from Seyhan Dam Lake, Turkey[e]	0.69	0.56	1.60	2.98
Trucha arco iris (*Salmo gairdneri*), from Bucaramanga, Colombia[h]	0.71	0.60	1.89	0.49
Barbado (*Pinirampus pirinampu*), marketed in Maringá, Brazil[a]	0.76	0.77	1.18	3.71
Wild Rainbow trout (*Salmo trutta forma fario*), from Salihli-Manisa, Turkey[g]	0.78	0.23	2.24	2.22
Cultured rainbow trout (*O. mykiss*), from Bozdogan/Aydin (Dam Lake), Turkey[g]	0.80	0.25	2.82	1.99
Cultured rainbow trout (*O. mykiss*), from Salihli-Manisa (Dam Lake), Turkey[g]	0.95	0.25	2.45	2.05
Mapará (*Hypophthalmus* sp.), wet period, from the Amazonian region, Brazil[i]	1.08	0.82	0.75	1.60
Cachama blanca (*Piaractus brachypomus*), from Bucaramanga, Colombia[h]	1.10	1.49	1.29	0.13
Tilapia roja (*Oreocliromis* sp.), from Bucaramanga, Colombia[h]	1.99	1.42	0.69	0.24
Bagre (*Pseudoplatystoma fasciatum*), from Bucaramanga, Colombia[h]	2.68	0.57	0.52	0.80
Bocachico (*Prochilodus reticulatus magdalenae*), from Bucaramanga, Colombia[h]	2.89	0.53	0.25	1.80

IA index of atherogenicity, *IT* index of thrombogenicity, *HH* hypocholesterolemic/hypercholesterolemic fatty acid ratio

[a] Calculated from Andrade, Rubra, Matsushita, and Souza [15]

[b] Calculated from Haliloglu, Bayir, Sirkecioglu, Aras, and Atamanalp [19]

[c] Calculated from Testi, Bonaldo, Gatta, and Badiani [24]

[d] Rosa, Bandarra, and Nunes [29]

[e] Calculated from Çelik, Diler, and Küçükgülmez [18]

[f] Calculated from Oliveira, Agostinho, and Matsushita [22]

[g] Diraman and Dibekliglu [30]

[h] Calculated from Perea, Gómez, Mayorga, and Triana [31]

[i] Calculated from Inhamuns and Franco [20]

Table 6 Omega-3 polyunsaturated fatty acids (ω-3 PUFA) in muscle tissue (fillet) of barbado, jaú, jurupensém, jurupoca, mandi-amarelo, mandi-prateado, and palmito, expressed as mg/100 g (fresh weight basis)

Fish	α-LNA	EPA	DHA	EPA + DHA	ω-3 PUFA
Barbado[A]	119.71 ± 15.51b	22.65 ± 3.00b	68.11 ± 3.73b	90.76 ± 6.11b	210.47 ± 20.61b
Jaú[B]	175.71 ± 20.15ab	43.22 ± 1.08a	74.23 ± 2.40b	117.45 ± 5.55a	293.16 ± 38.15a
Jurupensém[B]	213.00 ± 52.87a	20.14 ± 1.01bc	75.03 ± 2.52b	95.17 ± 1.51b	308.17 ± 54.38a
Jurupoca[B]	187.74 ± 45.43ab	18.29 ± 0.57c	39.72 ± 0.86c	58.01 ± 0.29c	245.75 ± 45.15ab
Mandi-amarelo[B]	195.54 ± 58.35ab	21.90 ± 1.22bc	93.84 ± 7.41a	115.74 ± 8.62a	311.28 ± 49.72a
Mandi-prateado[A]	3.14 ± 0.83c	3.49 ± 0.61d	22,16 ± 1.91d	25.65 ± 2.27d	28.79 ± 2.20c
Palmito[B]	2.38 ± 0.17c	1.71 ± 0.04d	21.85 ± 2.31d	23.56 ± 2.35d	25.95 ± 2.18c

Values reported are mean ± SD. Values in the same column followed by the same letters do not differ significantly ($p > 0.05$)

α-LNA alpha-linoleic acid (C18:3 ω-3), *EPA* eicosapentaenoic acid (C20:5 ω-3), *DHA* docosahexaenoic acid (C22:6 ω-3)

[A] $n = 4$

[B] $n = 3$

revealed that all the species investigated are suitable for human consumption.

References

1. Alasalvar C, Taylor KDA, Zubcov E, Shahidi F, Alexis M (2002) Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*): total lipid content, fatty acid and trace mineral composition. Food Chem 79:145–150
2. Ozogul Y, Ozogul F (2007) Fatty acid profiles of commercially important fish species from the Mediterranean, Aegean and Black Seas. Food Chem 100:1634–1638
3. Valfré F, Caprino F, Turchini GM (2003) The health benefit of seafood. Vet Res Commun 27:507–512
4. Krauss RM, Eckel RH, Howard B, Appel LJ, Daniels SR, Deckelbaum RJ, JWJr Erdman, Kris-Etherton P, Goldberg IJ, Kotchen TA, Lichtenstein AH, Mitch WE, Mullis R, Robinson K, Wylie-Rosett J, St Jeor S, Suttie J, Tribble DL, Bazzarre TT (2000) American Heart Association Dietary Guidelines Revision 2000: a statement for healthcare professionals from the nutrition committee of the American Heart Association. Circulation 102:2284–2299
5. Kris-Etherton PM, Harris WS, Appel LJ (2003) Omega-3 fatty acids and cardiovascular disease: new recommendations from the American Heart Association. Arterioscler Thromb Vasc Biol 23:151–152
6. Ruxton CHS, Reed SC, Simpson MJA, Millington KJ (2004) The health benefits of omega-3 polyunsaturated fatty acids: a review of the evidence. J Hum Nutr Diet 17:449–459
7. Stansby ME (1973) Polyunsaturates and fat in fish flesh. J Am Diet Assoc 63:625–630
8. BRASIL (2004) Ministério do Meio Ambiente. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis–IBAMA. Estatística da pesca 2002, Brasil, Grandes Regiões e Unidades da Federação. Tamandaré-PE, 2004. http://www.ibama.gov.br/rec_pesqueiros/download.php?id_download=40. Accessed Nov 2004
9. Association of Official Analytical Chemists (AOAC) (1992) Official methods of analysis, 12th edn. Washington, p 1115
10. Bligh EG, Dyer WJ (1959) A rapid method of total lipid extraction and purification. Can J Biochem Physiol 37:911–917
11. Maia EL, Rodriguez-Amaya DB (1993) Avaliação de um método simples e econômico para a metilação de ácidos graxos com lipídios de diversas espécies de peixes. Rev Inst Adolfo Lutz 53:27–35
12. Holland B, Welch AA, Unwin ID, Buss DH, Paul AA, Southgate DAT (1994) The composition of foods. McCance and Widdowson's, Cambridge, pp 8–9
13. Ulbricht TLV, Southgate DAT (1991) Coronary heart disease: seven dietary factors. Lancet 338:985–992
14. Santos-Silva J, Bessa RJB, Santos-Silva F (2002) Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. Livest Prod Sci 77:187–194
15. Andrade AD, Rubira AF, Matsushita M, Souza NE (1995) ω3 Fatty acids in freshwater fish from south Brazil. J Am Oil Chem Soc 72:1207–1210
16. Gutierrez LE, Silva RCM (1993) Fatty composition of commercially important fish from Brazil. Sci Agri 50:478–483
17. Ackman RG (1989) Nutritional composition of fats in seafoods. Prog Food Nutr Sci 13:161–241
18. Çelik M, Diler A, Küçükgülmez A (2005) A comparison of the proximate compositions and fatty acid profiles of zander (Sander lucioperca) from two different regions and climatic conditions. Food Chem 92:637–641
19. Haliloglu HI, Bayir A, Sirkecioglu AN, Aras NM, Atamanalp M (2004) Comparison of fatty acid composition in some tissues of rainbow trout (*Oncorhynchus mykiss*) living in seawater and freshwater. Food Chem 86:55–59
20. Inhamuns AJ, Franco MRB (2001) Composition of total, neutral and phospholipids in Mapará (*Hypophthalmus* sp.) from the Brazilian Amazonian area. J Agric Food Chem 49:4859–4863
21. Maia EL, Rodriguez-Amaya DB, Amaya-Farfan J (1983) Proximate, fatty acid and amino acid composition of the Brazilian freshwater fish *Prochilodus scrofa*. Food Chem 12:275–286
22. Oliveira ERN, Agostinho AA, Matsushita M (2003) Effect of biological variables and capture period on the proximate composition and fatty acid composition of the dorsal muscle tissue of *Hypophthalmus edentatus* (Spix, 1829). Braz Arch Biol Technol 46:105–114
23. Mnari A, Bouhlel I, Chraief I, Hammami M, Romdhane MS, El Cafsi M, Chaouch A (2007) Fatty acids in muscles and liver of Tunisian wild and farmed gilthead sea bream, *Sparus aurata*. Food Chem 100:1393–1397
24. Testi S, Bonaldo A, Gatta PP, Badiani A (2006) Nutritional traits of dorsal and ventral fillets from three farmed fish species. Food Chem 98:104–111
25. Department of Health and Social Security (1994) Nutritional aspects of cardiovascular disease. Report on health and social subjects no 46. HMSO (Her Majesty's Stationer Office, London) p 178
26. Williams CM (2000) Dietary fatty acids and human health. Ann Zoot 49:165–180
27. Henderson RJ, Tocher DR (1987) The lipid composition and biochemistry of freshwater fish. Prog Lipid Res 26:281–347
28. Kris-Etherton PM, Harris WS, Appel LJ (2003) Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. Arterioscler Thromb Vasc Biol 23:20–30
29. Rosa R, Bandarra NM, Nunes ML (2007) Nutritional quality of African catfish *Clarias gariepinus* (Burchell 1822): a positive criterion for the future development of the European production of Siluroidei. Int J Food Sci Technol 42:342–351
30. Diraman H, Dibeklioglu H (2009) Chemometric characterization and classification of selected freshwater and marine fishes from Turkey based on their fatty acid profiles. J Am Oil Chem Soc 86:235–246
31. Perea A, Gómez E, Mayorga Y, Triana CY (2008) Caracterización nutricional de pescados de produccion y consume regional en Bucaramanga, Colombia. Arch Latinoam Nutr 58:91–97