Composition of Total, Neutral, and Phospholipids in Mapará (*Hypophthalmus* sp.) from the Brazilian Amazonian Area

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Ten lots of mapará (*Hypophthalmus* sp.), captured from the Amazon River, Brazil, were analyzed for their lipid content and fatty acid composition. This knowledge would allow for the development of adequate processing methods and the formulation of therapeutic diets. Separation into neutral and phospholipids was accomplished by silica-gel column chromatography. Fat from the muscular tissue and from the orbital cavity of the mapará was analyzed by high-resolution gas chromatography−mass spectrometry in two different seasonal periods. There were high levels of saturated and monounsaturated fatty acids in the total and neutral lipid with the principal components 16:0, 18:1ω9, 18:0, 16:1ω7, 14:0, 18:3ω3, and 18:1ω7 in both seasons. In the phospholipids there was a high level of polyunsaturated fatty acids, including primarily 16:0, 18:1ω9, 18:0, 16:1ω7, 22:6ω3, 20:4ω6, 18:3ω3, and 20:5ω3. The ratio ω3/ω6 was the same in the muscular tissue and in the orbital cavity, in both seasonal periods. The muscle tissue could be used in diets that need high levels of polyunsaturated fatty acids, but use of the head to produce an ω3 fatty-acid-rich oil still requires greater study with respect to its economic viability.

Keywords: *Freshwater fish; fatty acid composition; seasonal variation; Amazon River*

INTRODUCTION

It is well established that an increase in the ingestion of long-chain polyunsaturated fatty acids (LC-PUFA), particularly those of the ω3 series (EPA and DHA), in a diet reduces the risk of heart disease. Consumption of LC-PUFA and fish oils reduces the biochemical factors associated with arthritis, psoriasis, and cancer, besides acting directly in the growth process and human development (*1*, *2*, *3*). Food supplementation with EPA and DHA reduces the levels of prostaglandin of the E2 group, originated from arachidonic acid (AA) and associated with the production of cancerous cells, because EPA and DHA stimulate the production of the tumor necrosis factor, suppressing carcinogenesis (*4*).

Eicosanoids are messengers of cells and metabolic regulators, and they are involved in physiopathologies such as thromboses, arterioscleroses, inflammation, and disorders of the immune response, depending on their composition. Because eicosanoids are derived from PUFAs, which come from the diet, changes in food ingested can provide changes in health (*5*).

Simopoulos (*2*) observed that eicosanoids originating from AA were formed in larger amounts than those produced from ω3 PUFA, specifically EPA, and because of their toxic activity, they can become noxious to the health. As EPA and DHA are found in fish oils, and AA is found predominantly in the phospholipids of animals fed on grains, consumption of fish is important.

Modern aquaculture, in which feeding is based on grains, produces fish that contain less ω3 fatty acids than fish that develop naturally in oceans, rivers, and lakes (*6*, *7*). The diet of the fish has a great influence on their general chemical composition, mainly on fatty acid composition (*8*).

The mapará (*Hypophthalmus* sp.) is a catfish native to the Amazon area. Consumption by the local population is low, but the mapará has high acceptance on the external market. The mean production of this species was 84 tons per month in the State of Amazonas during 1996, and almost all production was destined for exportation (*9*). Mapará has no teeth, but has numerous long brachial grooves, a characteristic of planktophagic fish. In this case, because of the space between the grooves, the species selects the larger zooplankton members. This characteristic, as well as presenting a yield of 50% fillet, makes it highly suitable for aquaculture. Mapará is sold in markets and from cold stores, with an average weight of 400 g per fish. In the State of Amazonas, the selling price is very low due to local taboos about the consumption of catfish and similar species.

Knowledge of the lipid composition is essential for commercialization, both from a technological and a nutritional point of view. The seasonal variation which affects the lipid composition of the fish also affects the flavor and stability, parameters directly related to the oxidation of the fat, with great importance for industry.

There is a high concentration of DHA in the fat surrounding the eyeball in fishes such as tuna and bonito (*10*). Similarly, a DHA-rich oil was extracted from the tuna eyeball (*11*).

This work aimed at characterizing the fatty acid composition of the muscular tissue and of the orbital

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cavity of Mapará (*Hypophthalmus* sp.) in different seasons of the Amazon River basin, Brazil.

MATERIALS AND METHODS

Sampling. Ten samples, each consisting of 2−6 fish, depending on individual size, were obtained from the Amazon river, near Manaus, Amazonas, in the sub-regions of Janauacá (3°23′ S, 60°16′ W), Paciência (3°22′ S, 60°12′W), and Aruanã (3°16′ S, 60°12′ W) during two different seasons: the drought period (July−December) and the wet season (January−June). The muscle and the fatty tissue from the orbital cavity were dissected out, freeze-dried, and frozen at −18 °C under N_2, and then transported by air to the Laboratory of Food Analysis/FEA/UNICAMP for extraction and analysis. Each lot was considered as a sample and analyzed in duplicate.

Moisture and Lipid Determinations. The moisture content of the fish muscle was determined by freeze-drying, according to Pitombo (*12*). The Bligh and Dyer method (*13*) was used for the determination of total lipids in the muscle tissue and in the orbital cavity.

Separation into Lipids Classes. The lipids extracted from the muscle tissue and from the eyes were fractionated on a silica-gel column into neutral lipids and phospholipids, according to Johnston et al. (*14*). Neutral lipids were eluted with 200 mL of 20% acetone in chloroform, and phospholipids were eluted by 200 mL of methanol, as previously described (*15*).

Gas Chromatograph Analysis. Derivatization of the fatty acids was accomplished according to Joseph and Ackman (*16*). Separation of the methyl esters was by gas chromatography, using a VARIAN model 3300 gas chromatograph equipped with a flame ionization detector and a fused-silica DB-WAX capillary column (30 m × 0.25 mm i.d.) (J&W Scientific, Folsom, CA). The operation parameters were as follows: detector temperature, 280 °C; injection port temperature, 250 °C; column temperature, 170 °C for 16 min, programmed to increase at 2 °C/min up to 210 °C, with a final holding time of 25 min; carrier gas, hydrogen at 0.8 mL/min, linear velocity of 38 cm/s, with an oxygen filter coupled to the line; nitrogen was used as the makeup gas at 30 mL/min, hydrogen and synthetic air at 30 mL/min and 300 mL/min for the detector; split injection at 1:100 ratio. All the stages, from the transesterification to the final injection, were accomplished under nitrogen. Retention times and peak area percentages were automatically computed by a Varian 4290 integrator. Quantification was expressed as area percentages.

Statistical Analysis. Area percentage data were submitted to an analysis of variance (ANOVA), by the widespread linear model procedure (PROC GLM−Duncan's test at a level of 5% of significance), with one factor (season or parts of the body) and two levels (drought/wet season or muscle/eye). The statistical package used was from SAS (Cary, NC).

Identification of Fatty Acids. For identification, the retention times of the fatty acids were compared to those of standard methyl esters (Sigma, St. Louis, MO). Equivalent chain-length values (ECL) were also used (*17*−*20*), as well as a coupled system of gas chromatograph−mass spectrometer Shimadzu QP 5000. The fatty acids were fragmented by electron impact at 70 eV. Several fatty acids were additionally submitted to chemical ionization using methane as the reagent gas. Compounds identified only by GC−MS were considered as tentatively identified.

RESULTS AND DISCUSSION

The values for moisture and total lipids found in the muscle tissue of mapará (*Hypophthalmus* sp.) in the different seasonal periods of the Amazonian basin are presented in Table 1. Ackman (*21*) classified fish into four categories according to their lipid content: very low fat (<2% fat), low fat (2−4% fat), medium fat (4−8% fat), and high fat (>8% fat). The mapará is a fish which feeds on plankton and is classified as a high fat fish. It has a reduced mean moisture content (64% to 65%), considering that the usual moisture content in fish is from 70% to 85% (*22*). This composition was observed in both seasons. Contreras-Guzman (*23*) discussed the chemical composition of the Brazilian sea fish, and showed that the moisture content was inversely proportional to the lipid content in all fishes throughout the year, indicating age, gonadal development, and the seasons as main factors.

Table 1. Moisture and Total Lipid Contents of Mapará (*Hypophthalmus* sp.) Fillets in Different Seasonal Periods

wet period (January−July)			drought period (July−December)		
weight of the lot (g)	moisture[a] %	total lipids[a] %	weight of the lot (g)	moisture[a] %	total lipids[a] %
539 ± 61	64 ± 3	19 ± 2	357 ± 171	65 ± 1	15 ± 1

[a] Means and standard deviations of duplicate analyses (5 lots).

Eighty two fatty acids and a dimethylacetal were detected in the total lipid of mapará. The principal fatty acids, in decreasing order, were 16:0, 18:1ω9, 18:0, 16:1ω7, 14:0, 18:3ω3, and 18:1ω7 in both seasons, and in both muscle and the orbital cavity of the fish (Table 2). Andrade et al. (*24*), analyzing the lipid composition of several freshwater fish consumed in the southern area of Brazil, showed a similar tendency for the composition of the major fatty acids in some species. However, in other species, the 18:1ω9 acid was the most abundant, followed by 16:0; and in one of these species, the major fatty acid was 20:0, followed by an unidentified acid. In trouts (*Salmo gairdneri*) coming from three different countries, oleic acid (18:1ω9) was always the major fatty acid, followed by palmitic (16:0) and cervonic acids (22:6ω3) (*25*).

The total lipid fraction of the muscle tissue and of the eyes was characterized by high proportions of saturated fatty acids (SFA), followed by monounsaturated (MUFA), polyunsaturated (PUFA), and diunsaturated (DUFA) fatty acids, both in the wet season and in the drought (Table 5).

The SFA 17:0 and 18:0, the MUFA 18:1ω11, and the DUFA 20:2ω6 had a significant difference at the 5% level, with a predominance in the orbital cavity during the wet season, whereas the PUFA 18:3ω3, 18:4ω3, 20:4ω6, 20:4ω3, and 20:5ω3 predominated in the muscle. In the drought, the fatty acids had a quantitative balance between the body parts studied. Only EPA (20:5ω3) was higher in the muscle at a 5% level of significance.

Comparing the compositions found in the two seasons, the muscle of the mapará showed significant differences at a 5% level for the SFA 13:0 and i-19:0, the MUFA 16:1ω9 and 16:1ω5, and the DUFA 16:2ω7, which had a higher percentage during the wet season, whereas 17:0, 22:0, 24:0, 18:1ω11, and 20:2ω6 were higher during the drought season.

During the wet season, the major fatty acids of the neutral lipid with a significant difference ($p < 0.05$) in the muscle were the MUFA 18:1ω9 and the PUFA 18:3ω3, 18:4ω3, 20:4ω6, 20:5ω3, and 22:6ω3, whereas in the orbital cavity the SFA 14:0, 17:0, 18:0, the MUFA 16:1ω7, and the DUFA 18:2ω6 were significantly different (Table 3). During the drought, the fatty acids which predominated in the muscle were the DUFA 18:2ω6 and the PUFA 18:3ω3, 20:4ω6, 20:5ω3, and 22:6ω3,

Table 2. Fatty Acid Composition (%) of the Total Lipids of Mapará (*Hypophthalmus* sp.) of the Amazonian Area in Different Seasonal Periods[a]

	wet period		drought period	
fatty acid	muscle (means ± s.d.)	eyes (means ± s.d.)	muscle (means ± s.d.)	eyes (means ± s.d.)
14:0	4.4 ± 0.1	4.5 ± 0.2	4.7 ± 0.2	5.8 ± 0.6
i 15:0	1.1 ± 0.2	1.1 ± 0.0	1.4 ± 0.1	1.5 ± 0.1
15:0	1.4 ± 0.2	1.5 ± 0.2[a]	1.1 ± 0.2	1.3 ± 0.0[a]
16:0	30.1 ± 0.1	31.6 ± 0.7	30.0 ± 1.0	31.0 ± 0.9
16:1ω9	1.3 ± 0.1[a]	1.3 ± 0.1	1.2 ± 0.1[a]	1.3 ± 0.0
16:1ω7	9.0 ± 1.0	8.7 ± 0.8	7.1 ± 0.2	8.1 ± 0.4
17:0	1.3 ± 0.1[a]	1.5 ± 0.1[a]	1.4 ± 0.1	1.6 ± 0.1
18:0	8.9 ± 0.4[a]	9.4 ± 0.3[a]	8.6 ± 0.6	8.5 ± 0.3[a]
18:1ω9	11.4 ± 0.8	11.0 ± 1.0	12.0 ± 0.7	11.0 ± 0.7
18:1ω7	3.5 ± 0.2	3.7 ± 0.2	3.3 ± 0.2	3.7 ± 0.2
18:2ω6	2.2 ± 0.2	2.4 ± 0.2	3.0 ± 0.2	2.9 ± 0.1
18:3ω3	4.1 ± 0.4[a]	3.5 ± 0.1[a]	3.8 ± 0.0	3.6 ± 0.2
20:4ω6	2.4 ± 0.2[a]	2.1 ± 0.1[a]	2.5 ± 0.1	1.9 ± 0.0
20:4ω3	0.8 ± 0.1[a]	0.7 ± 0.0[a]	1.1 ± 0.1	0.7 ± 0.0
20:5ω3	2.5 ± 0.2[a]	1.8 ± 0.1[a]	2.4 ± 0.2[b]	1.6 ± 0.0[b]
22:5ω3	0.9 ± 0.1	0.8 ± 0.1	1.1 ± 0.1	0.8 ± 0.1
22:6ω3	2.4 ± 0.3	2.0 ± 0.4	2.4 ± 0.2	1.7 ± 0.1
ΣAGω3	11.7	9.9	12.3	9.6
ΣAGω6	7.4	7.3	8.4	7.4
Σω3/Σω6	1.6	1.4	1.5	1.3

[a] Fatty acid of the total lipids of Mapará (*Hypothalmus* sp.) smaller than 1%: 10:0; 11:0; 12:0; i 13:0; 13:0; i 14:0; ai 15:0; X_1; 14:1ω9; 14:1ω7; 14:1ω5; 15:1ω9; 15:1ω7; i 16:0; 16:0DMA; X_3; X_4; 16:1ω5; i 17:0; 16:2ω7; ai 17:0; X_5; 16:2ω4; 16:3ω6; 17:1ω11; 17:1ω9; 16:4ω6c; 17:1ω6; i-18:0; 16:4ω3; 17:2ω5; 18:1ω11; 18:1ω6; 18:1ω5; i 19:0; 18:1ω3; X_6; 18:2ω4; 19:0; 18:3ω6; 18:3ω4c; 19:1ω7; 18:4ω3; 20:0; 20:1ω11; 20:1ω9; 20:1ω7; X_7; 20:2ω6; 20:3ω6; 21:0; 20:3ω3; 22:0; 22:1ω11; 22:1ω9; X_8; 21:3ω3; 21:4ω3; 22:2ω6; 21:5ω3; 22:3ω6; 22:4ω6; 22:5ω6; 22:4ω3; 24:0; 24:1ω9. Abbreviations: s.d., standard deviation; nd, not detected; ΣFAω3, ω3 fatty acids total sum; i, iso; tr, trace (mean value below 0.1%); ΣFAω6, ω6 fatty acids total sum; ai, anteiso; DMA, dimethylacetal; X, not identified; [c], tentatively identified. Conditions: column DB-WAX 20M (30 m × 0.247 mm × 0.25 mm); 170 °C/16min, 2 °C/min, 210 °C/25 min. Significant difference at a level of 5% is designated by [a] and [b]: different letters in the same period indicate a significant difference between the muscle and eyes. The same letters in different periods indicate a significant difference in the referenced part of the body. Double letters ([aa] or [bb]) indicate a significant difference only between the periods. =, No significant difference in the referenced period, even with the presence of the letters *a* or *b*. The absence of letters indicates no significant difference among the observations.

Table 3. Fatty Acid Composition (%) of the Neutral Lipids of Mapará (*Hypophthalmus* sp.) from the Amazonian Area in Different Seasonal Periods[a]

	wet period		drought period	
fatty acid	muscle (means ± s.d.)	eyes (means ± s.d.)	muscle (means ± s.d.)	eyes (means ± s.d.)
14:0	4.4 ± 0.0[a]	4.8 ± 0.2[a]	5.4 ± 0.2[a]	5.1 ± 0.1
i 15:0	1.1 ± 0.2	1.4 ± 0.1	1.7 ± 0.1	1.6 ± 0.1
15:0	1.8 ± 0.1	2.0 ± 0.0[a]	1.5 ± 0.1	1.7 ± 0.1[a]
16:0	30.0 ± 1.4	31.0 ± 0.7[a]	31.0 ± 1.0[a]	31.0 ± 0.8[a]
16:1ω9	1.4 ± 0.1	1.3 ± 0.1	1.2 ± 0.1	1.1 ± 0.1
16:1ω7	8.5 ± 1.0[a]	9.9 ± 0.7[a]	6.8 ± 0.3[a]	8.5 ± 0.7[b]
17:0	1.7 ± 0.1[a]	1.8 ± 0.1[a]	1.8 ± 0.1[a]	1.8 ± 0.1
18:0	8.9 ± 0.5[a]	9.1 ± 0.3[a]	8.6 ± 0.3[b]	9.0 ± 0.2[b]
18:1ω9	11.0 ± 0.3[a]	10.4 ± 0.1[a]	9.8 ± 0.4[a]	11.0 ± 0.8[b]
18:1ω7	3.5 ± 0.3	3.6 ± 0.2	3.4 ± 0.1	3.6 ± 0.2
18:2ω6	2.3 ± 0.4[a]	2.4 ± 0.1[a]	3.1 ± 0.2[a]	2.7 ± 0.0[b]
18:3ω3	4.0 ± 0.4[a]	3.4 ± 0.0[a]	4.6 ± 0.3[b]	3.3 ± 0.2[b]
20:4ω6	2.3 ± 0.1[a]	1.8 ± 0.0[a]	2.4 ± 0.1[b]	1.7 ± 0.1[a]
20:4ω3	0.8 ± 0.1[a]	0.7 ± 0.0[a]	1.1 ± 0.1[a]	0.7 ± 0.0[b]
20:5ω3	2.5 ± 0.2[a]	1.7 ± 0.2[a]	2.3 ± 0.2[a]	1.6 ± 0.1[b]
22:6ω3	2.2 ± 0.3[a]	1.6 ± 0.1[a]	1.9 ± 0.1	1.4 ± 0.1

[a] Fatty acid of the neutral lipids of Mapará (*Hypophthalmus* sp.) smaller than 1%: 10:0; 11:0; 12:0; i 13:0; 13:0; i 14:0; 14:1ω9; 14:1ω7; 14:1ω5; ai 15:0; X_1; 15:1ω9; 15:1ω7; i 16:0; 16:0DMA; X_3; X_4; 16:1ω5; i17:0; 16:2ω7; ai 17:0; X_5; 16:2ω4; 16:3ω6; 17:1ω11; 17:1ω9; 16:4ω6[c]; 17:1ω6; i-18:0; 16:4ω3; 17:2ω5; 18:1ω11; 18:1ω6; 18:1ω5; i 19:0; 18:1ω3; X_6; 18:2ω4; 19:0; 18:3ω6; 18:3ω4[c]; 19:1ω7; 18:4ω3; 20:0; 20:1ω11; 20:1ω9; 20:1ω7; X_7; 20:2ω6; 20:3ω6; 21:0; 20:3ω3; 22:0; 22:1ω11; 22:1ω9; X_8; 21:3ω3; 21:4ω3; 22:2ω6; 21:5ω3; 22:3ω6; 22:4ω6; 22:5ω6; 22:4ω3; 22:5ω3; 24:0; 24:1ω9. Abbreviations: s.d., standard deviation; nd, not detected; i, iso; tr, trace (mean value below 0.1%); ai, anteiso; DMA, dimethylacetal; X, not identified; [c], tentatively identified. Conditions: column DB-WAX 20M (30 m × 0.247 mm × 0.25 mm); 170 °C/16min, 2 °C/min, 210 °C/25 min. Significant difference at a level of 5% is designated by [a] and [b]. Letters in the same period indicate a significant difference between the muscle and eyes. The same letters in different periods indicate a significant difference in the referenced part of the body. Double letters ([aa] or [bb]) indicate only a significant difference between periods. =, No significant difference in the referenced period, even with the presence of the letters [a] or [b]. The absence of letters indicates no significant difference among the observations.

while in the orbital cavity, the SFA 16:0 and 18:0 and the MUFA 16:1ω7 and 18:1ω9 predominated.

Comparing fatty acids between the two periods, the muscle differed significantly in the wet season with the major acids being 18:0, 16:1ω7, 18:1ω9, and 20:5ω3, whereas the SFA 14:0 and 17:0 and the DUFA 18:2ω6 were the major fatty acids during the drought. However, in the orbital cavity, the SFA 15:0 and 16:0 and the PUFA 20:4ω6 were more abundant during the wet period.

In the phospholipid of mapará, the PUFA were dominant, although quantitatively there were more SFA and MUFA. The most abundant fatty acids were 16:0, 18:1ω9, 18:0, 16:1ω7, 22:6ω3, 20:4ω6, 18:3ω3, and 20:

Table 4. Fatty Acid Composition (%) of the Phospholipids of Mapará (*Hypophthalmus* sp.) of the Amazonian Area in Different Seasonal Periods[a]

	wet period		drought period	
fatty acid	muscle (means ± s.d.)	eyes (means ± s.d.)	muscle (means ± s.d.)	eyes (means ± s.d.)
14:0	3.0 ± 0.1[a]	2.2 ± 0.2[a]	4.8 ± 0.3[a]	3.2 ± 0.5[a]
15:0	1.3 ± 0.1[aa]	1.3 ± 0.1[bb]	0.9 ± 0.1[aa]	1.1 ± 0.1[bb]
16:0	21.7 ± 2.1[aa]	22.1 ± 1.5[bb]	24.0 ± 1.0[aa]	24.0 ± 1.4[bb]
16:1ω9	1.1 ± 0.1[a]	1.0 ± 0.0	0.8 ± 0.1[a]	1.1 ± 0.2
16:1ω7	8.5 ± 1.0[a]	6.9 ± 1.0[a]	7.8 ± 1.0[a]	7.1 ± 1.0
17:0	1.3 ± 0.1	1.3 ± 0.0	1.1 ± 0.1	1.2 ± 0.2
16:4ω3	1.3 ± 0.2[a]	2.3 ± 0.2[a]	1.8 ± 0.1[b]	2.4 ± 0.1[b]
18:0	8.2 ± 0.7	10.5 ± 0.7	8.5 ± 0.5[a]	9.3 ± 0.0[a]
18:1ω9	10.5 ± 0.5[a]	11.6 ± 0.5	9.7 ± 0.6[a]	11.1 ± 0.7[a]
18:1ω7	3.8 ± 0.3[a]	3.5 ± 0.1[a]	3.2 ± 0.1[a]	3.0 ± 0.2[a]
18:2ω6	2.9 ± 0.3[aa]	3.4 ± 0.3[bb]	3.8 ± 0.0[aa]	3.1 ± 0.5[bb]
18:3ω3	5.8 ± 0.8[a]	3.5 ± 1.0[a]	3.6 ± 0.0[a]	3.2 ± 0.4
20:4ω6	5.2 ± 0.1	5.5 ± 0.2[a]	4.8 ± 0.3	6.1 ± 0.2[a]
20:3ω3	0.5 ± 0.0	0.5 ± 0.0	0.4 ± 0.0	0.5 ± 0.1
20:4ω3	1.3 ± 0.1[aa]	1.4 ± 0.1[bb]	0.9 ± 0.0[aa]	0.7 ± 0.2[bb]
20:5ω3	5.0 ± 0.1[a]	3.6 ± 0.2[a]	3.8 ± 0.3[a]	2.9 ± 0.1[b]
22:5ω6	1.7 ± 0.2	1.6 ± 0.1	1.6 ± 0.1	1.5 ± 0.1
22:5ω3	1.6 ± 0.1	1.5 ± 0.1	1.6 ± 0.0	1.6 ± 0.1
22:6ω3	5.7 ± 1.0	6.6 ± 0.0	6.5 ± 0.1	6.5 ± 0.2

[a] Fatty acids of the phospholipids of Mapará (*Hypothalamus* sp.) smaller than 1%: 12:0; 13:0; i 14:0; 14:1ω7; i15:0; ai 15:0; X_1; 15:1ω9; 15:1ω7; i 16:0; 16:0DMA; X_3; X_4; 16:1ω5; i 17:0; ai 17:0; X_5; 16:2ω4; 16:3ω6; 17:2ω5; 18:1DMA; 18:1ω6; 18:1ω5; i 19:0; 18:1ω3; X_6; 18:1ω11; 16:3ω4; 16:4ω6[c]; 18:2ω4; 19:0; 18:3ω6; 18:3ω4[c]; 19:1ω7; 18:4ω3; 20:0; 20:1ω11; 20:1ω9; 20:1ω7; 20:2ω6; 20:3ω6; 22:0; 22:4ω6; 24:0. Abbreviations: s.d., standard deviation; nd, not detected; i, iso; tr, trace (mean value below 0.1%); ai, anteiso; DMA, dimethylacetal; X, not identified; [c], tentatively identified. Conditions: column DB-WAX 20M (30 m × 0.247 mm × 0.25 mm); 170 °C/16min, 2 °C/min, 210 °C/25 min. Significant difference at a level of 5% is designated by [a] and [b]. Letters in the same period indicate a significant difference between the muscle and eyes. The same letters in different periods indicate a significant difference in the referenced part of the body. Double letters ([aa] or [bb]) indicate only a significant difference between periods. =, No significant difference in the referenced period, even with the presence of the letters [a] or [b]. The absence of letters indicates no significant difference among the observations.

Table 5. Relative Percentage of Fatty Acids in the Total Lipids (TL), the Neutral Lipids (NL), and the Phospholipids (PL) of Mapará (*Hypophthalmus* sp.) in Different Seasonal Periods[a]

fatty acids	muscle (%)			eyes (%)		
in Mapará	TL	NL	PL	TL	NL	PL
wet period (first period of the year)						
∑saturated	50.4	51.3	38.2	53.1	54.2	40.2
∑monounsaturated	28.2	27.6	25.7	28.0	28.2	24.3
∑diunsaturated	3.0	3.0	3.2	3.0	2.8	4.0
∑polyunsaturated	16.7	16.4	31.0	14.4	13.3	29.0
∑other	nd	nd	nd	nd	nd	nd
∑not identified	0.6	0.8	0.4	0.4	0.5	0.3
drought period (second period of the year)						
∑saturated	51.3	54.2	42.3	53.9	54.0	42.0
∑monounsaturated	26.5	23.8	24.2	27.0	27.1	24.4
∑diunsaturated	3.4	3.8	4.3	3.5	3.3	3.8
∑polyunsaturated	17.5	17.0	27.5	14.0	12.5	27.8
∑other	0.1	tr	0.6	0.1	tr	0.7
∑not identified	0.5	0.5	0.2	0.5	1.2	0.6

[a] nd, not detected; tr, trace (<0.1%).

5ω3 (Table 4). There was an inversion between the relative percentages of 20:4ω6 comparing parts of the body, with a predominance in the orbital cavity during both seasonal periods. A similar composition was observed for the acid 22:6ω3, which, however, showed equal percentages during the drought. The MUFA 16:1ω7 had a greater proportion in muscle in both seasons.

During the wet season, many fatty acids of the phospholipids of mapará differed significantly at the 5% level, when comparing the two body parts. Generally, they showed a larger relative percentage during the wet season. The major fatty acids were 14:0, 16:1ω7, 18:1ω7, 18:3ω3, and 20:5ω3 in the muscular tissue, and only the 16:4ω3 in the orbital cavity (Table 4). During the drought period, a larger proportion of 14:0, 18:1ω7, and 20:5ω3 was found in the muscular tissue, while in the lipid of the orbital cavity 18:0, 18:1ω9, 16:4ω3, and 20:4ω6 were predominant.

The muscle, when compared between seasons, had a significant difference for the MUFA 16:1ω7, 18:1ω9, and 18:1ω7, and for the PUFA 18:3ω3 and 20:5ω3, which were the major acids in the wet season; whereas the SFA 14:0 and 16:0 and the DUFA 18:2ω6 were more abundant compounds during the drought. In the orbital cavity, the fatty acids that dominated during the drought period, with a significant difference, were the SFA 14:0 and 16:0 and the PUFA 20:4ω6, whereas the 18:0, 18:1ω7, 18:2ω6, and 20:4ω3 dominated during the wet season.

Significant differences were not verified among each group of fatty acids of the phospholipid fraction between the two seasonal periods and body parts studied (Table 5). However, there were relatively more PUFA in the lipid of the muscle and orbital cavity during the two seasons, when comparing the phospholipid fraction to the total and neutral lipid.

The ratio ω3/ω6 in this species of fish presented no significant difference between the seasonal periods nor between the parts studied. During the drought period, when the amount of total lipid in the muscle was smaller (15 ± 1%), an increase was verified in the PUFA, and despite the larger relative percentage of the ω3 fatty acids as compared to that in the wet season, there was also an increase in the relative percentage of the ω6 acids, thus maintaining the ratio ω3/ω6 at the same level (Table 2).

The tucunaré (*Cichla ocelaris*), another fish from the Amazon River, had a high value for DHA in the muscle (10 ± 1%) during the wet season, although the ω3/ω6 ratio was smaller (1.0) because of the high relative proportion of the w6 fatty acid series, especially that of arachidonic acid (*26*). The tucunaré is a piscivorous fish, and the high content of arachidonic acid probably comes

from the fatty acids of its prey, mostly herbivorous and planktophagic fish.

In both species of fish, mapará and tucunaré, the abundance of AA was decisive in reducing the $\omega 3/\omega 6$ ratio. Considering that AA and DHA are essential fatty acids for fetal development and for nursing infants, this composition could be useful in the formulation of diets for pregnant and nursing women.

A ratio of 0.42 for $\omega 3/\omega 6$ was found in wild tambaqui (*Colossoma macropomum*), from the State of Amazonas, Brazil (*18*). This value was less than those found in this work for mapará in both seasons. However, Andrade et al. (*24*), found $\omega 3/\omega 6$ ratios in freshwater fish between 0.2 ± 0.0 and 4.2 ± 0.1, values within the expected average, and a higher value of 26.3 ± 0.5 for the trout (*Salmus* sp.), than that of Henderson and Tocher (*8*) for freshwater and marine fish (from 0.5 to 3.8 and 4.7 to 14.4, respectively).

In the wet season, a time for fattening of the mapará, 90% of its diet is zooplankton, a source of $\omega 3$ PUFAs, and 10% is insects and algae (*27*). During the drought, when this fish begins its migratory and reproductive cycle, algae and insects, fish eggs, and vegetable leftovers start to contribute a significant percentage of the diet. Terrestrial or aquatic insects possess high levels of $\omega 6$ PUFA (*8*), which could cause their increase in mapará lipid during the period of drought.

The specimens captured in any seasonal period can be recommended for prescription diets, when the objective is to increase the ingestion of PUFA. For technological processing there is no recommendation for a more appropriate period, because a significant difference was not detected among the groups of PUFA between seasons.

Considering the fact that the mapará fish is a species widely used for exportation in the frozen state and that their residues are discarded, the use of the mapará head for the production of an $\omega 3$ fatty-acid-rich oil could be an economically viable alternative for this area.

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