ω3 Fatty Acids in Freshwater Fish from South Brazil

A.D. Andrade, A.F. Rubira, M. Matsushita and N.E. Souza*
Department of Chemistry, University of Maringá, Paraná, Brazil

ABSTRACT: Lipid and fatty acid levels in the edible flesh of 17 freshwater fish from Brazil's southern region were determined. Analyses of fatty acid methyl esters were performed by gas chromatography. Palmitic acid ($C_{16:0}$) was the predominant saturated fatty acid, accounting for 50–70% of total saturated acids. Oleic acid ($C_{18:1\omega9}$) was the most abundant monounsaturated fatty acid. Linoleic acid ($C_{18:2\omega6}$), linolenic acid ($C_{18:3\omega3}$), and docosahexaenoic acid ($C_{22:6\omega3}$) were the predominant polyunsaturated fatty acids (PUFA). The data revealed that species such as truta, barbado, and corvina were good sources of eicosapentaenoic acid ($C_{20:5\omega3}$) and docosahexaenoic acid ($C_{22:6\omega3}$), and that most freshwater fish examined were good sources of PUFA ω3.
JAOCS 72, 1207–1210 (1995).

KEY WORDS: Eicosanoids, fatty acids, freshwater fish, lipid composition, lipids.

Dietary trials aimed at reducing the risk of cardiovascular diseases have emphasized the importance of ingesting marine oil and fish products that are rich in ω3 polyunsaturated fatty acids (1,2). The beneficial effects have been attributed to an increased ratio of ω3 to ω6 polyunsaturated acids in blood lipids and in membrane lipids (3). The incidence of miocardial infarction and coronary atherosclerosis among the Greenland Eskimo population is low. This has been attributed to the protective effect of a diet rich in fatty fish and marine mammals (4). Greenland Eskimos have a prolonged bleeding time due to the reduced platelet aggregation which, as suggested, is caused by the large amount of eicosapentaenoic acid (EPA) in their diet (5).

Several studies concerning the composition of fatty acids in marine and freshwater fish have been reported (3,6–10). Wang *et al.* (10) reported that Lake Superior fish were excellent sources of polyunsaturated fatty acids (PUFA).

This study presents data on the investigation of the fatty acid composition and the amount of total lipids in several commonly consumed South Brazilian tropical freshwater fish.

MATERIALS AND METHODS

Seventeen freshwater fish were studied. The fish studied were purchased fresh from fish markets in Maringá, Paraná, Brazil and included barbado (*Pinirampus pinirampu*), carpa (*Cyprinus carpio*), cascudo abacaxi (*Megaloancistrus aculeatus*), cascudo cachorro (*Pterodoras granulosus*), corvina (*Plagioscion squamosissimus*), curimba (*Prochilodus lineatus*), dourado (*Salminus maxillosus*), jurupoca (*Hemisorubim plathyrhinchos*), mandi (*Pimelodus maculatus*), pacu (*Colossoma mitrei*), piapara (*Leporinus elongatus*), piau (*Leporinus friderici*), pintado (*Pseudoplatystoma corruscans*), piranha (*Serrasalmus marginatus*), tilápia (*Oreochromis niloticus*), traíra (*Hoplias malabaricus*) and truta (*Salmus* sp.). Skinned, deboned fillets were taken from the intact fish. Fillets from large fish species as pintado, dourado, and pacu were divided into anterior (front), mid, and posterior (tail) sections. The fillets were cut into small pieces and minced. Aliquots (30 g), in triplicate, of the samples were individually homogenized in 90 mL chloroform/methanol (2:1, vol/vol) according to the method of Bligh and Dyer (11) as modified by Kinsella *et al.* (8). The resulting lipid fraction was weighed.

The preparation of fatty acid methyl esters was performed as described by Jham *et al.* (12). Analysis of methyl esters was performed by capillary gas chromatography on a Shimadzu CGS-14A (Shimadzu, Tokyo, Japan) with a Carbowax 20M (CG Instrumentos Científicos, São Paulo, Brazil) and quantitated by a flame-ionization detector. Chromatographic conditions were as follows: injection port temperature, 220°C; flame-ionization detector temperature, 245°C; initial oven temperature, 190°C for 4 min, rising to 240°C at 10°C/min. The carrier gas was nitrogen (30 mL/min). Retention times and peak areas were processed by a computing integrator CG-300 (CG Instrumentos Científicos). Compounds were identified and quantitated by comparison with the retention times and peak areas, respectively, of known standards from Sigma (St. Louis, MO). All reagents were of ACS grade.

RESULTS AND DISCUSSION

Table 1 summarizes our findings of fatty acid composition on Brazilian freshwater fish of commercial importance in Brazil's southern region. The fatty acids are ordered according to their chromatographic retention time, and the values are given as weight percent of total fatty acid methyl esters.

The data show that the amount of constituent fatty acids varied widely among the species. Table 1 also shows that $C_{16:0}$ and $C_{18:0}$ are the most predominant saturated acids. This observation was not totally surprising because Ackman and

*To whom correspondence should be addressed at Departamento de Química, Universidade Estadual de Maringá, CEP 87.020-900, Maringá, Paraná, Brazil.

TABLE 1
Fatty Acid Composition of Freshwater Fish Fillets[a]

Fatty acids	Barbado	Carpa	Cascudo abacaxi	Cascudo cachorro	Corvina	Curimba	Dourado	Jurupoca	Mandi
14:0	2.15 ± 0.07	ND	1.06 ± 0.10	ND	3.65 ± 0.07	2.66 ± 0.35	2.48 ± 0.05	ND	ND
16:0	30.31 ± 0.29	17.33 ± 1.03	18.11 ± 0.88	26.80 ± 2.54	24.65 ± 0.08	30.18 ± 1.27	39.44 ± 1.90	26.65 ± 1.40	27.93 ± 0.67
16:a	1.37 ± 0.02	ND	3.87 ± 0.04	3.49 ± 0.64	ND	1.39 ± 0.10	2.05 ± 0.03	ND	1.43 ± 0.04
16:b	ND	ND	ND	ND	ND	ND	ND	ND	ND
16:1ω7	10.22 ± 0.08	6.59 ± 0.29	5.17 ± 0.28	4.56 ± 0.64	9.74 ± 0.09	8.69 ± 1.23	5.27 ± 0.15	ND	6.57 ± 0.06
16:c	ND	ND	ND	ND	ND	1.27 ± 0.11	ND	ND	ND
18:0	10.27 ± 0.78	5.75 ± 0.35	10.10 ± 0.72	10.31 ± 0.98	10.50 ± 0.38	10.88 ± 0.33	9.25 ± 1.01	11.17 ± 0.86	9.33 ± 0.09
18:a	1.92 ± 0.07	ND	ND	ND	ND	ND	ND	ND	ND
18:1ω9	27.81 ± 1.02	41.80 ± 1.94	23.99 ± 0.51	25.20 ± 1.44	9.65 ± 0.26	23.22 ± 1.63	9.76 ± 1.05	17.65 ± 0.59	39.99 ± 0.28
18:1a	ND	ND	ND	ND	5.34 ± 0.18	ND	ND	ND	ND
18:2ω6	2.81 ± 0.09	14.55 ± 0.81	2.42 ± 0.68	8.80 ± 0.05	ND	6.85 ± 0.35	5.02 ± 0.24	21.92 ± 0.80	4.35 ± 0.47
18:3ω6	ND	ND	ND	ND	ND	ND	3.89 ± 0.90	ND	ND
18:3ω3	2.45 ± 0.02	2.16 ± 0.18	ND	1.44 ± 0.10	ND	2.48 ± 0.20	ND	ND	2.00 ± 0.32
18:4ω3	ND	ND	ND	ND	ND	ND	1.89 ± 0.20	ND	ND
20:0	ND	3.19 ± 0.52	7.11 ± 0.10	ND	ND	1.77 ± 0.12	ND	ND	2.58 ± 0.19
20:a	ND	ND	ND	ND	3.97 ± 0.44	ND	ND	ND	ND
20:2ω6	ND	1.82 ± 0.37	11.87 ± 0.66	ND	5.25 ± 0.07	ND	ND	ND	ND
20:3ω3	2.74 ± 0.01	ND	ND	5.40 ± 0.98	ND	3.90 ± 0.47	8.25 ± 0.40	7.60 ± 0.61	2.44 ± 0.26
20:5ω3	1.55 ± 0.03	ND	ND	ND	11.67 ± 0.13	1.21 ± 0.20	4.80 ± 0.23	ND	ND
22:a	1.00 ± 0.05	1.80 ± 0.13	3.17 ± 0.14	4.00 ± 0.11	5.20 ± 0.52	ND	2.92 ± 0.18	ND	ND
22:b	1.95 ± 0.04	1.99 ± 0.01	2.93 ± 0.13	ND	ND	ND	ND	ND	ND
22:c	ND	1.42 ± 0.10	5.24 ± 0.28	ND	ND	ND	ND	ND	ND
22:6ω3	3.70 ± 0.02	1.44 ± 0.11	4.28 ± 0.34	11.50 ± 2.67	10.34 ± 0.25	5.69 ± 0.72	7.08 ± 0.34	14.99 ± 1.10	1.90 ± 0.27

Eaton (13) have pointed out that $C_{16:0}$ is a key metabolite in fish. Wang *et al.* (10) show that the level of $C_{16:0}$ in Lake Superior fish was in the range of 68–79%. In the present study, the level of this acid $C_{16:0}$ shows variations in the range of 50–70% of the total saturated acids with exception of traira, in which the content was around 14%.

Regardless of the origin of the lipids, the monoethylenic fatty acids, $C_{16:1\omega7}$ and $C_{18:1\omega9}$ are the major constituents. Also, the $C_{18:1\omega9}$ level was higher than $C_{16:1\omega7}$, with only one exception (corvina), in which the values were basically the same.

Ackman (14) reported that high values of $C_{16:1\omega7}$ is one characteristic of freshwater fish. This value matches well with the results presented here.

The total lipid contents of fish are summarized in Table 2. The lipid concentration in some species, such as barbado and pacu, was much higher (≅20%) than in all other species analyzed. Values around 9% are found for piapara and 6% for truta. The values for all other species were smaller than 4%, and in the case of traira, the content was very low, 0.27%.

The saturated fatty acid (SFA) values were in the range of 26.27–51.17%, and values between 5–45% were obtained for PUFA. The PUFA/SFA ratio summarized in Table 2 was high, 1.18 and 0.98 for jurupoca and truta, respectively.

With regard to PUFA ω3, species, such as truta, contained more than 28% of total fatty acids, and values around 20% were obtained for dourado, jurupoca, corvina, and cascudo cachorro (Table 3). The values of PUFA ω3 for truta correspond to 82% of the total PUFA. Values around 60% of PUFA ω3 are found for eight of the seventeen samples of freshwater fish analyzed.

The importance of ingesting products that are rich in PUFA ω3 and poor in PUFA ω6 has been reported in the literature (1,2) as well as the beneficial effects of a high ratio of ω3 to ω6 (3). The contents of ω3 and ω6 and the ω3/ω6 ratio obtained for the seventeen species are included in Table 2. The value of 26.3 obtained for truta was noteworthy, where basically all PUFA was PUFA ω3. It has been reported (15,16) that EPA ($C_{20:5\omega3}$) and docosahexaenoic acid (DHA) ($C_{22:6\omega3}$) are the most important ω3 fatty acids, and the specific effect of each one has also been reported (15,16). Table 3 summarizes the total content of ω3 fatty acids as well as the percentages of EPA and DHA. The EPA and DHA contents of the various species revealed many interspecies differences, as we pointed out previously for the total PUFA ω3 content (Table 1). Nevertheless, the observed biological effects of $C_{22:6\omega3}$ acid itself, and its retroconversions to $C_{20:5\omega3}$ acid, would seem to justify the practice of reporting the content of both acids in assessing the ω-3 composition of fish. The DHA values, in all species except pacu, are higher than EPA values, which are not detected in species such as carpa, cascudo abacaxi, cascudo cachorro, dourado, jurupoca, mandi, and piapara.

Regarding the total lipid contents and the percentage of DHA and EPA, we can postulate that barbado, truta, and corvina are good sources of DHA and EPA.

It is expected that the present study, along with others of similar nature, may provide valuable information in selecting freshwater fish and fish oils for nutritional studies.

TABLE 1 (continued)

Pacu	Piapara	Piau	Pintado	Piranha	Tilápia	Traíra	Truta
15.42 ± 0.29	1.94 ± 0.13	ND	0.96 ± 0.02	2.01 ± 0.01	3.34 ± 0.49	ND	1.73 ± 0.01
21.26 ± 0.85	23.50 ± 1.31	21.52 ± 2.21	23.99 ± 0.70	22.82 ± 0.15	26.68 ± 2.62	5.02 ± 0.87	20.75 ± 0.12
ND	1.02 ± 0.10	ND	1.16 ± 0.04	1.70 ± 0.03	ND	ND	ND
ND	1.00 ± 0.20	ND	0.92 ± 0.02	1.34 ± 0.03	ND	ND	ND
6.79 ± 0.72	9.83 ± 0.83	3.84 ± 0.51	5.02 ± 0.15	7.82 ± 0.17	6.60 ± 0.79	ND	7.29 ± 0.09
ND	ND	ND	ND	ND	ND	ND	ND
6.18 ± 0.45	6.09 ± 0.48	6.97 ± 0.66	10.20 ± 0.16	7.71 ± 0.29	6.48 ± 0.44	3.42 ± 0.45	5.37 ± 0.02
ND	ND	ND	ND	ND	ND	ND	ND
40.30 ± 0.71	42.10 ± 2.56	39.13 ± 0.75	23.60 ± 0.31	26.88 ± 0.64	37.62 ± 0.61	6.76 ± 0.01	27.88 ± 1.40
ND	ND	ND	3.83 ± 0.04	ND	ND	ND	3.45 ± 0.09
6.08 ± 0.46	2.06 ± 0.19	3.90 ± 0.92	5.66 ± 0.06	7.15 ± 0.62	9.31 ± 1.01	5.45 ± 0.01	ND
ND	ND	ND	ND	ND	ND	ND	ND
ND	1.46 ± 0.01	5.08 ± 0.56	ND	3.44 ± 0.07	0.91 ± 0.01	ND	12.71 ± 0.15
ND	ND	ND	1.61 ± 0.07	2.00 ± 0.19	ND	ND	1.08 ± 0.13
1.21 ± 0.09	2.24 ± 0.20	2.02 ± 0.10	2.77 ± 0.04	1.05 ± 0.17	2.07 ± 0.35	27.49 ± 0.08	2.33 ± 0.02
ND	ND	ND	1.79 ± 0.14	ND	1.69 ± 0.10	ND	ND
ND	2.68 ± 0.09	0.96 ± 0.11	ND	ND	2.23 ± 0.01	ND	1.08 ± 0.02
ND	ND	1.33 ± 0.03	1.46 ± 0.06	4.57 ± 0.40	0.98 ± 0.04	5.14 ± 0.80	1.20 ± 0.01
1.38 ± 0.08	ND	1.39 ± 0.28	4.32 ± 0.14	1.15 ± 0.02	1.98 ± 0.15	6.05 ± 0.90	1.67 ± 0.01
1.45 ± 0.07	1.41 ± 0.08	3.52 ± 0.43	1.42 ± 0.09	2.17 ± 0.08	0.88 ± 0.03	9.38 ± 0.91	1.30 ± 0.03
1.54 ± 0.08	3.10 ± 0.01	3.03 ± 0.39	2.21 ± 0.10	1.49 ± 0.07	ND	13.71 ± 1.02	1.26 ± 0.01
ND	ND	3.24 ± 0.30	ND	1.57 ± 0.12	ND	14.01 ± 0.33	ND
ND	0.96 ± 0.02	4.50 ± 0.33	7.61 ± 0.31	3.56 ± 0.12	0.94 ± 0.05	6.47 ± 1.01	11.74 ± 0.13

[a]Calculated as wt% of fatty acid methyl esters as percentage of total lipids; all results are means of three determinations; ND = not detected; a, b ,c = not identified fatty acids.

TABLE 2
Total Lipids, Polyunsaturated Fatty Acids (PUFA), Saturated Fatty Acids (SFA), PUFA/SFA and ω3/ω6 PUFA in Freshwater Fish[a]

Species	Total lipids (%)	PUFA (%)	SFA (%)	PUFA/SFA	ω3/ω6 PUFA
Barbado	19.75 ± 0.58	13.25 ± 0.02	42.73 ± 0.28	0.31 ± 0.01	3.71 ± 0.12
Carpa	1.19 ± 0.03	5.42 ± 0.40	26.27 ± 0.40	0.21 ± 0.01	0.22 ± 0.01
Cascudo Abacaxi	0.70 ± 0.02	18.57 ± 0.34	36.38 ± 0.29	0.51 ± 0.01	0.30 ± 0.03
Cascudo Cachorro	3.18 ± 0.09	23.14 ± 0.71	37.11 ± 1.36	0.62 ± 0.03	2.08 ± 0.11
Corvina	0.69 ± 0.01	27.26 ± 0.10	38.80 ± 0.13	0.70 ± 0.01	4.19 ± 0.06
Curimba	3.68 ± 0.02	20.13 ± 0.19	45.49 ± 0.34	0.44 ± 0.01	1.94 ± 0.10
Dourado	0.88 ± 0.01	30.93 ± 0.19	51.17 ± 0.72	0.60 ± 0.01	2.47 ± 0.12
Jurupoca	2.98 ± 0.06	44.51 ± 0.50	37.82 ± 0.82	1.18 ± 0.03	1.03 ± 0.05
Mandi	5.50 ± 0.15	10.69 ± 0.17	39.84 ± 0.23	0.27 ± 0.01	1.46 ± 0.16
Pacu	18.31 ± 0.05	7.46 ± 0.23	44.07 ± 0.25	0.17 ± 0.01	0.23 ± 0.02
Piapara	9.17 ± 0.03	7.16 ± 0.05	33.77 ± 0.35	0.21 ± 0.01	0.51 ± 0.01
Piau	2.60 ± 0.08	17.16 ± 0.19	30.51 ± 0.77	0.56 ± 0.02	2.53 ± 0.24
Pintado	1.27 ± 0.03	20.66 ± 0.07	37.92 ± 0.18	0.54 ± 0.01	2.65 ± 0.03
Piranha	0.70 ± 0.01	21.87 ± 0.13	33.59 ± 0.09	0.65 ± 0.01	2.06 ± 0.18
Tilápia	2.86 ± 0.09	16.35 ± 0.17	38.57 ± 0.68	0.42 ± 0.01	0.42 ± 0.02
Traíra	0.27 ± 0.01	23.11 ± 0.34	35.93 ± 0.33	0.64 ± 0.01	3.24 ± 0.10
Truta	6.42 ± 0.02	29.48 ± 0.04	30.18 ± 0.03	0.98 ± 0.01	26.30 ± 0.49

[a]All results are means of three determinations, calculated as % w/w.

REFERENCES

1. Singer, P., W. Jaeger, M. Wirth, S. Voigt, E. Naumann, S.H. Zimantokoski, I. Hajdu and W. Goedicke, *Atherosclerosis 49*:99 (1983).
2. Herold, P.M., and J.E. Kinsella, *Am. J. Clin. Nutr. 43*:566 (1986).
3. Hearn, T.L., S.A. Sgoutas, J.A. Hearn and D.S. Sgoutas, *J. Food Sci. 52*:1209 (1987).
4. Dyerberg, J., H.O. Bang, S. Moncada and J.R. Vane, *Lancet* 2:117 (1978).
5. Dyerberg, J., and H.O. Bang, *Ibid. 2*:433 (1979).
6. Gruger, E.H., R.W. Nelson and M.E. Stansby, *J. Am. Oil Chem. Soc. 41*:662 (1964).
7. Vlieg, P., and D.R. Body, *New Zealand J. Marine and Freshwater Res. 22*:151 (1988).
8. Kinsella, J.E., J.L. Shimp, J. Mai and J. Weihrauch, *J. Am. Chem. Soc. 54*:424 (1977).
9. Viswanathan, P.G., and K. Gopakumar, *J. Food Sci. 43*:1162 (1978).
10. Wang, Y.J., L.A. Miller, M. Perren and P.B. Addis, *Ibid. 55*:71 (1990).

TABLE 3
Percentage of PUFA ω3, Eicosapentaenoic Acid (EPA), and Docosahexaenoic Acid (DHA) in Freshwater Fish[a]

Species	PUFA ω3	EPA	DHA
Barbado	10.44 ± 0.01	1.55 ± 0.03	3.70 ± 0.02
Carpa	3.60 ± 0.11	ND	1.44 ± 0.11
Cascudo abacaxi	4.28 ± 0.34	ND	4.28 ± 0.34
Cascudo cachorro	18.34 ± 0.96	ND	11.50 ± 2.67
Corvina	22.01 ± 0.14	11.67 ± 0.13	10.34 ± 0.25
Curimba	13.28 ± 0.23	1.21 ± 0.20	5.69 ± 0.72
Dourado	22.02 ± 0.15	4.80 ± 0.23	7.08 ± 0.34
Jurupoca	22.59 ± 0.63	ND	14.99 ± 1.10
Mandi	6.34 ± 0.16	ND	1.90 ± 0.27
Pacu	1.38 ± 0.08	1.38 ± 0.08	ND
Piapara	2.43 ± 0.01	ND	0.96 ± 0.02
Piau	12.30 ± 0.17	1.39 ± 0.28	4.50 ± 0.33
Pintado	15.00 ± 0.09	4.32 ± 0.14	7.61 ± 0.31
Piranha	14.72 ± 0.09	1.15 ± 0.02	3.56 ± 0.12
Tilápia	4.81 ± 0.04	1.98 ± 0.15	0.94 ± 0.05
Traíra	17.66 ± 0.52	6.05 ± 0.90	6.47 ± 1.01
Truta	28.40 ± 0.05	1.67 ± 0.01	11.74 ± 0.13

[a]All results are means of three determinations. ND = not detected. Abbreviation as in Table 2.

11. Bligh, E.G., and W.J. Dyer, *Can. J. Biochem. Physiol. 37*:911 (1969).
12. Jham, G.N., F.F.F. Teles and L.G. Campos, *J. Am. Oil Chem. Soc. 59*:132 (1982).
13. Ackman, R.G., and C.A. Eaton, *J. Fish Res. Bd. Can. 23*:991 (1966).
14. Ackman, R.G., *Comp. Biochem. Physiol. 22*:907 (1967).
15. Budowski, P., *Israel J. Med. Sci. 17*:223 (1981).
16. Leaf, A., and P.C. Weber, *N. Eng. J. Med. 318*:549 (1988).

[Received April 7, 1995; accepted June 8, 1995]