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Omega-3 fatty acids in baked freshwater fish from south of Brazil

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SUMMARY. - Lipid and fatty acid levels in the edible flesh of 17 baked freshwater fish from Brazil's southern region were determined. Analyses of fatty acids methyl esters were performed by gas chromatography. Palmitic acid (C16:0) was the predominant saturated fatty acid, accouting for 50-70% of total saturated acids. Linoleic acid (C18:2ω6), linolenic acid (C18:3ω3), and docosahexaenoic acid (C22:6ω3) were the predominant polyunsatured fatty acids (PUFA). The data revealed that species such as barbado, corvina, pintado, and truta were good sources of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), and that most freshwater fish examined were good sources of PUFA-ω3.

RESUMEN. Acidos grasos omega-3 en peces de agua dulce asados del sur de Brasil.- Se determinaron los niveles de ácidos grasos y lípidos en 17 peces comestibles de la región sur de Brasil. Los análisis de los ésteres metílicos de los ácidos grasos se realizaron por cromatografía gaseosa. Se encontró que el ácido graso saturado predominante, aproximadamente 50 a 70% de los acidos saturados totales, fue el ácido palmítico (C16:0). Los ácidos grasos insaturados mas abundantes encontrados fueron el ácido linoléico (C18:2ω6), ácido linolênico (C18:3ω3) y ácido docosahexenoico (C22:6ω3). Los datos mostraron que las especies como barbado, corvina, pintado y trucha son buenas fuentes de ácidos eicosapentaenoico (EPA) y docosahexenoico (DHA) y que la mayoria de los peces de agua dulce examinados fueron buenas fuentes de ácidos grasos poliinsaturados ω-3.

INTRODUCTION

Fish lipids are known for the complexity of their fatty acid composition. The lipids of marine and freshwater fish have certain characteristic differences in the fatty acid composition (1,2). These distinctions are based mainly on the chain lengths rather than any other fundamental properties (3). Epidemiological studies have linked the dietary intake of ω3 polyunsaturated fatty acids (PUFA) in Greeland Eskimos to their low incidence of coronary heart disease (4,5).The most importat of the ω3-PUFA seems to be eicosapentaenoic acid (EPA) which has an anti-aggregatory potency that results from competitive inhibition of the synthesis of thrombotic eicosanoid thromboxane (6) or alternatively from increased production of prostacyclins which are anti-aggregatory agents (7).

Several studies concerning to the composition of fatty acids in marine and freshwater fish have been reported (8-12). Wang *et al.* (10) observed that Lake Superior fish were excellent sources of PUFA.

This study presents data on the investigation of the fatty acid composition and 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*), traira (*Hoplias malabaricus*) and truta (*Salmus sp*). Skinned deboned fillets were taken from the intact fish. The fillets were oven baked at 190°C for 30-50 minutes. After baking, the fillets were cutted into small pieces and minced. Aliquots (30g), in triplicate, of the minced samples were individually homogeneized in 90mL chloroform/methanol (2:1 v/v) according to the method of Bligh and Dyer as modified by Kinsella *et al.* (13). The resulting lipid fraction was weighed.

The preparation of fatty acid methyl esters was performed

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TABLE 1

Fatty acid composition of baked freswater fish fillets[a]

Fatty Acids	Barbado	Carpa	Cascudo Abacaxi	Cascudo Cachorro	Corvina	Curimba	Dourado	Jurupoca	Mandi
14:0	2.21±0.01	ND	1.10±0.03	2.75±0.22	2.92(±0.12	4.22±0.09	2.44±0.36	ND1.	35±0.01
6:0	30.81±0.17	18.45±0.31	17.94±0.17	27.66±0.91	21.72±0.35	27.64±1.31	26.70±0.33	21.83±0.61	26.80±0.06
16:a	ND	ND	4.11±0.06	1.17±0.03	1.73±0.02	2.61±0.09	1.46±0.10	ND	1.66±0.04
16:b	ND	ND	1.40±0.04	ND	ND	5.33±0.76	ND	ND	1.38±0.02
16:1ω7	10.53±0.26	6.24±0.15	5.41±0.06	7.71±0.37	8.41±0.15	17.21±0.81	8.92±0.17	ND	7.22±0.08
16:c	ND	ND	ND	ND	ND	2.94±0.08	ND	ND	ND
18:0	10.89±1.80	6.37±0.07	10.26±0.09	11.91±0.49	10.36±0.14	8.21±0.06	9.52±0.63	9.45±0.29	9.65±0.29
18:a	1.93±0.06	ND	ND	ND	ND	6.34±0.15	ND	ND	ND
18:1ω9	27.60±2.10	42.28±0.71	25.37±0.55	30.40±1.99	9.36±0.21	7.19±0.09	26.48±0.12	23.58±1.31	37.15±0.94
18:1a	ND	ND	ND	ND	5.02±0.08	ND	ND	ND	ND
18:2ω6	2.74±0.03	16.97±0.37	1.69±0.58	8.85±0.19	ND	5.18±0.09	5.06±0.31	26.60±0.75	4.25±0.09
18:3ω6	ND	ND	ND	ND	ND	ND	9.09±0.07	ND	ND
18:3ω3	2.51±0.03	2.24±0.01	ND	1.28±0.11	ND	4.22±0.09	ND	ND	2.86±0.05
18:4ω3	ND	ND	ND	ND	ND	ND	2.57±0.18	ND	ND
20:0	ND	2.61±0.03	3.00±0.14	2.18±0.13	ND	2.48±0.16	ND	6.83±1.16	1.90±0.14
20:a	ND	ND	3.10±0.18	ND	3.94±0.11	ND	ND	ND	ND
20:2ω6	ND	2.31±0.25	9.56±0.99	ND	5.54±0.08	ND	ND	ND	ND
20:3ω3	2.77±0.05	ND	2.60±0.10	2.63±0.51	ND	3.37±0.19	2.93±0.43	6.00±0.97	2.79±0.49
20:5ω3	1.62±0.03	ND	ND	ND	12.13±0.25	1.79±0.20	ND	ND	ND
22:a	1.96±0.04	1.49±0.10	2.19±0.18	1.45±0.27	4.41±0.08	ND	1.65±0.19	ND	ND
22:b	ND	ND	2.98±0.06	ND	ND	ND	ND	ND	ND
22:c	ND	ND	6.06±0.12	ND	ND	ND	ND	ND	ND
22:6ω3	3.92±0.12	2.02±0.27	2.91±0.22	4.04±0.31	12.80±1.43	2.94±1.00	3.92±0.41	7.01±1.22	1.82±0.14

Fatty Acids	Pacu	Piapara	Piau	Pintado	Piranha	Tilapia	Traira	Truta
14:0	15.47±0.42	1.93±0.05	ND	ND	3.55±0.28	3.66±0.17	2.48±0.34	1.75±0.01
16:0	22.12±0.77	23.35±0.40	25.12±1.09	33.50±1.57	22.99±1.9466	27.10±1.06	22.38±0.90	22.05±0.37
16:a	ND	ND	ND	ND	1.46±0.07	ND	1.60±0.10	ND
16:b	ND	ND	ND	ND	1.21±0.01	ND	1.02±0.23	ND
16:1ω7	4.75±0.19	11.17±0.16	5.91±0.28	7.81±0.57	7.91±0.47	6.69±0.22	6.98±0.57	7.20±0.17
16:c	ND	ND	ND	ND	ND	ND	1.75±0.35	ND
18:0	7.35±0.22	5.78±0.35	5.70±0.31	9.99±0.10	7.93±0.07	6.58±0.08	8.59±0.31	5.62±0.16
18:a	ND	ND	ND	ND	ND	ND	ND	ND
18:1ω9	39.69±2.49	44.34±0.50	30.85±2.07	26.78±1.08	28.22±1.92	34.50±0.54	28.31±0.70	27.16±0.98
18:1a	ND	ND	ND	4.57±0.12	ND	ND	ND	3.54±0.07
18:2ω6	5.20±0.03	1.88±0.19	8.46±0.59	10.06±0.62	7.52±0.34	10.40±0.97	13.49±0.71	ND
18:3ω6	ND	ND	ND	ND	ND	ND	ND	ND
18:3ω3	2.21±0.07	1.65±0.12	12.82±0.57	ND	4.14±0.22	1.00±0.01	4.84±0.28	12.61±0.15
18:4 ω3	ND	ND	ND	ND	1.76±0.10	ND	ND	ND
20:0	2.28±0.09	2.47±0.07	1.58±0.05	ND	1.24±0.15	1.63±0.11	2.80±0.10	2.24±0.09
20:a	ND	ND	ND	ND	ND	2.48±0.75	ND	ND
20:2ω6	ND	2.56±0.06	ND	ND	ND	2.09±0.71	ND	1.04±0.04
20:3ω3	ND	ND	ND	ND	2.93±0..07	1.56±0.44	1.97±0.06	1.25±0.04
20:5ω3	0.98±0.09	0.58±0.05	1.59±0.03	2.97±0.29	ND	1.12±0.10	1.75±0.20	1.69±0.05
22:a	0.33±0.03	1.60±0.61	4.63±0.19	ND	2.11±0.24	0.80±0.01	1.55±0.24	1.21±0.08
22:b	ND	1.30±0.59	2.55±0.10	ND	1.51±0.01	1.37±0.01	ND	ND
22:c	ND	0.55±0.05	ND	ND	1.33±0.02	ND	ND	ND
22:6ω3	ND	0.72±0.07	2.96±0.12	4.29±0.13	2.76±0.21	0.79±0.02	2.34±0.35	11.89±0.52

[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, PUFA, SFA, PUFA/SFA and ω3/ω6-PUFA in baked freshwater fish

Fish	Total Lipids (%)	PUFA (%)	SFA (%)	PUFA/SFA	ω3/ω6-PUFA
Barbado	22.27±0.89	13.56±0.03	41.70±0.90	0.32±0.01	3.95±0.12
Carpa	6.01±0.09	23.54±0.13	27.43±0.11	0.86±0.01	0.22±0.01
Cascudo Abacaxi	1.61±0.01	16.76±0.29	32.30±0.06	0.52±0.01	0.49±0.03
Cascudo Cachorro	0.72±0.01	16.80±0.16	44.50±0.27	0.38±0.01	0.90±0.03
Corvina	1.90±0.01	30.47±0.48	35.00±0.13	0.87±0.01	4.50±0.15
Curima	2.02±0.02	17.50±0.21	42.55±0.33	0.41±0.01	2.38±0.07
Dourado	3.58±0.01	23.57±0.14	38.66±0.27	0.61±0.01	0.67±0.04
Jurupoca	2.15±0.01	39.61±0.58	38.11±0.45	1.04±0.02	0.49±0.03
Mandi	4.84±0.01	11.72±0.13	39.70±0.08	0.30±0.01	1.76±0.05
Pacu	21.50±0.15	8.39±0.04	47.22±0.23	0.18±0.01	0.61±0.12
Piapara	21.07±0.09	7.39±0.05	33.53±0.13	0.22±0.01	0.66±0.02
Piau	2.30±0.01	25.83±0.21	32.40±0.38	0.80±0.01	2.05±0.15
Pintado	3.39±0.09	17.32±0.23	43.49±0.79	0.40±0.01	0.72±0.05
Piranha	2.05±0.03	19.11±0.09	35.71±0.49	0.54±0.01	1.54±0.07
Tilapia	6.14±0.06	16.96±0.21	38.97±0.27	0.44±0.01	0.36±0.02
Traira	2.42±0.01	24.39±0.17	36.25±0.25	0.67±0.01	0.81±0.04
Truta	8.97±0.07	28.48±0.11	31.66±0.10	0.90±0.01	26.38±1.02

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

as one described by Jham *et al.* (14). 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 minutes, rising to 240°C at 10°C/min. The carrier gas was nitrogen (30mL/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, USA). All reagents were ACS grade.

RESULTS AND DISCUSSION

The Table 1 summarizes our finding of fatty acid composition on baked 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. In general, C16:0 and C18:0 are the most predominat saturated acids, observed in all fish lipids studied. Ackman & Eaton (15) have pointed out that C16:0 is a key metabolite in fish and its level is not influenced by the diet. In the present study the level of this acid accounted for almost 60% of the total saturated acids.

Regardless of the origin of the lipids, the monoethylenic fatty acids, C16:1ω7 and C18:1ω9 are the major constituents. Also, C18:1ω9 level was higher than C16:1ω7, with only exception (curimba).

Ackman (3) reported that high values of C16:1ω7 is one characteristic of freshwater fish. This value matches well with the results presented here.

The total lipids contents of fish are summarized in Table 2. The lipid concentration in some species, such as barbado, pacu, and piapara, was much higher (»20%) than in all other species analysed. Values around 9% are found for truta and 6% for carpa and tilapia. The values for all other species were smaller than 4%, and in the case of cascudo cachorro, the content was very low, 0.72%.

The sum of saturated fatty acid (SFA) values were in the range of 27.43-47.22%, and values between 7.39-39.61% were obtained for PUFA. The PUFA/SFA ratio summarized in Table 2 was high, 1.04; 0.90; 0.87 and 0.90 for jurupoca, truta, corvina, and carpa, respectively.

With regard to PUFA-ω3 fatty acids, species such as truta,

TABLE 3
Percentage of PUFA-ω3, EPA, and DHA in baked freshwater fish

Fish	PUFA-ω3	EPA	DHA
Barbado	10.82±0.06	1.62±0.03	3.92±0.12
Carpa	4.26±0.14	ND	2.02±0.27
Cascudo Abacaxi	5.51±0.12	ND	2.91±0.22
Cascudo Cachorro	7.95±0.20	ND	4.04±0.31
Corvina	24.93±0.72	12.13±0.25	12.80±1.43
Curimba	12.32±0.26	1.79±0.20	2.94±1.00
Dourado	9.42±0.21	ND	3.92±0.41
Jurupoca	13.01±0.78	ND	7.01±1.22
Mandi	7.47±0.17	ND	1.82±0.14
Pacu	3.19±0.06	0.98±0.09	ND
Piapara	2.95±0.05	0.58±0.05	0.72±0.07
Piau	17.37±0.19	1.59±0.03	2.96±0.12
Pintado	7.26±0.16	2.97±0.29	4.29±0.13
Piranha	11.59±0.08	ND	2.76±0.21
Tilapia	4.47±0.11	1.12±0.10	0.79±0.02
Traira	10.90±0.12	1.75±0.20	2.34±0.35
Truta	27.44±0.14	1.69±0.05	11.89±0.52

All results are means of three determinations. ND = not detected.

contained more than 27% of total fatty acids and values around 24% and 17% were obtained for corvina and piau (Table 3). The values of PUFA-ω3 for truta, corvina and piau correspond to 96%; 81%; and 67% of the total PUFA, respectively. Values around 70% of PUFA-ω3 are found for piau, barbado, and curimba.

The contents of ω3 and ω6, and the ω3/ω6 ratio obtained for the seventeen species are included in Table 2. The values of 26.38 obtained for truta was noteworthy, where basically all PUFA was PUFA-ω3. It has been reported (6,16) that EPA (C20:5ω3) and DHA (C22:6ω3) are most important ω3 fatty acids, and the specific effect of each are has also been reported (6,16). 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). The DHA values, in all species except in pacu and tilapia, are higher than EPA values, which are not detected in species such as carpa, cascudo abacaxi, cascudo cachorro, dourado, jurupoca, mandi, and piranha.

Regarding the total lipid contents and the percentage of DHA and EPA, we can postulate that barbado, corvina, pintado, and truta 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 for nutritional studies.

REFERENCES

1. Lovern, J. A. Biochemistry of Fish. Biochemical Symposia No 6. Cambridge, Cambridge University Press. 1951, p. 49.
2. Hilditch, T. P. & P. N. Williams. The Chemical Constitution of Natural Fats. 4th ed. London, Chapman & Hall. 1964, p. 62.
3. Ackman, R. G. Characteristics of the fatty acid composition and biochemistry of some freshwater fish oils and lipids in comparison with marine oils and lipids. Comp. Biochem. Physiol.. 22:907, 1967.
4. Dyerberg, J. & H. O. Bang. Haemostatic function and platelet polyunsaturated fatty acids in Eskimos. Lancet, 2:433, 1979.
5. Dyerberg, J., H. O. Bang, E. Stoffersen,, S. Moncada & J. R. Vane. Eicosapentaenoic acid and prevention of thrombosis and atherosclerosis. Lancet, 2:117, 1978.
6. Budowski, P. Nutritional effects of n3-polyunsaturated fatty acids. Israel J. Med. Sci., 17:223, 1981.
7. Goodnight Jr., S. H., S. W. Harris, W. E. Connor & R. D. Illingworth. The effect of dietary n-3 fatty acids on platelet composition and function in man: a prospective controlled study. Blood, 58:880, 1981.
8. Hearn,T.L.,S.A. Sgoutas, J.A.Hearn & D.S.Sgoutas. Polyunsaturated fatty acids and fat in fish flesh for selecting species for health benefits. J. Food Sci., 52:1209, 1987.
9. Vlieg, P. & D. R. Body. Lipid contents and fatty acid composition of some New Zealand freshwater finfish and marine finfish, shellfish, and roes. New Zeal. J. of Mar. and Fresh. Res., 22:151-162, 1988.
10. Wang, Y. J., L. A. Miller, M. Perren & P. B. Addis. Omega-3 fatty acids in Lake Superior fish. J. Food Sci., 55(1):71-76, 1990.
11. Andrade, A. D., A. F. Ribira, M. Matsushita & N. E. Souza. ω3 fatty acids in freshwater fish from South Brazil. J. Am. Oil Chem. Soc., 72(10):1207-1210, 1995.
12. Andrade, A. D., J. V. Visentainer, M. Matsushita & N. E. Souza. Omega-3 fatty acids in baked marine fish from South of Brazil. Arq. Biol. Tecnol., 39(1):187-192, 1996.
13. Kinsella, J. E., J. L. Shimp, J. MAE & J. Weihrauch. Fatty acid composition of freshwater finfish. J. Am. Chem. Soc.. 54:424-429, 1977.
14. Jham, G. N., F. F. F. Teles & L. G. Campos. Use of aqueous HCl/MeOH as esterification reagent for analysis of fatty acids derivated from soybean lipids. J. Am. Oil Chem. Soc., 59:132-133, 1982.
15. Ackman, R. G. & C. A. Eaton. Some commercial Atlantic herring oils: fatty acid composition. J. Fish Res. Bol. Canada. 23:991, 1966.
16. Leaf, A. & P. C. Weber. Cardiovascular effects of n-3 fatty acids. New Eng. J. Med., 318:549-557, 1988.

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