Fatty Acids in Cultivated and Wild Fish

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Abstract. Some years ago, the U.S. Dept. of Agriculture undertook a study of the nutrient profile of the leading species of cultivated and wild fish and shellfish. Some data from that work were published, but information on fatty acids was not included. This paper presents data on the fat, cholesterol and major fatty acid content of cultivated and wild channel catfish (*Ictalurus punctatus),* rainbow trout *(Salmo gairdneri),* and coho salmon *(Oncorynchus kisutch).* Two samples of each species were obtained from the wild at two different seasons, reflecting differences in spawning status; three samples of cultivated channel catfish and rainbow trout plus two of coho salmon were obtained at peak season to coincide with one of the sampling times of the wild samples. Analyses were conducted on raw and cooked fillets. Fatty acids were determined by gas-liquid chromatography. Fat content of cultivated catfish and salmon ranged from 2.5-5 times that of wild samples; fat levels in wild and cultivated trout were similar. Monounsaturates predominated in cultivated catfish and salmon but not trout. Differences in fatty acid profile between wild and cultivated fish were greatest among polyunsaturates; linoleic acid was substantially higher in all cultivated samples than in wild fish. Omega-3 fatty acid levels were related to species and were higher in cultivated than wild samples owing to higher fat content. Data do not support the notion that wild fish are higher in omega-3 fatty acids than cultivated fish.

Key Words: fatty acids, cultivated and wild fish, n-3 fatty acids

INTRODUCTION

As data demonstrating the protective effects of n-3 fatty acids (n-3FA) against heart disease accumulate (Connor 2000) and the relative imbalance in the consumption of n-6 and n-3FA is recognized (Simopoulos et al. 1999), efforts to boost consumption of foods rich in n-3FA can be expected to increase. One indication of this possibility is official acknowledgement in the recent Dietary Guidelines for Americans 2000 (Dietary Guidelines Advisory Committee 2000) that omega-3 fatty acids may protect against heart disease.

Certain species of fish are among the most concentrated food sources of long chain n-3FA (Nettleton 1991). While domestic consumption of fish and shellfish has remained essentially constant over the past decade (Harvey 1999), consumption patterns may be amenable to change. For example, among those who consume seafood, consumption of salmon doubled between 1988 and 1999 (Rice 2000). It is unlikely, however, that wild-caught fish could supply substantial increases in demand.

The U.S. seafood market is supplied from domestic catch, aquaculture, and imports of both wild and cultivated species. Pressure on wild resources, development of efficient, cost-effective aquaculture methods, consistent, high quality product and year round availability have fostered the development of aquaculture. Data are limited and sometimes conflicting whether cultivated fish resemble their wild counterparts, particularly in total fat, fatty acid composition and n-3FA content (George and Bhopal 1995).

As a result of the increasing market share contributed by aquaculture, the U.S. Department of Agriculture (USDA), in 1988-1990, undertook a comparison of the nutrient profile of the leading species of wild and cultivated fish and shellfish. Species evaluated included channel catfish (*Ictalurus punctatus*), rainbow trout (*Salmo gairdneri*), coho salmon (O*ncorhynchus kisutch),* red swamp crayfish (P*rocambarus clarkii*), white river crayfish (*Procambarus acutus acutus*) and Eastern oysters (*Crassostrea virginica*). The study was designed primarily to furnish data for use in nutrient composition tables established and maintained by USDA. Results from the analysis of proximates, cholesterol and vitamins in both fish and shellfish have been published (Nettleton and Exler 1992). Total fat and fatty acid data for channel catfish, rainbow trout and coho salmon are presented here.

METHODS

Study design (Table 1), sampling timeframe, product sources and methods of sample preparation have been published (Nettleton and Exler 1992). Samples of 5-7 wild fish were obtained at two seasons to reflect pre and post spawning or early/late pre-spawning status (coho salmon). Samples of 12-20 cultivated fish were obtained at peak market season to coincide with one sampling period for wild samples. Analyses were conducted on composite samples of raw and cooked, skinless fillets, but only data from raw samples are reported here. Fatty acids of 8-22 carbons were quantified by gas-liquid chromatography from lipids extracted using chloroform-methanol and saponified with 0.5N methanolic sodium hydroxide. Fatty acids were methylated with 14% BF3-methanol and extracted with heptane. A check sample of menhaden oil was used for reference. Recovery of fatty acids varied from 97.5 to 101.0%.

Table 1. Study design and sampling timeframe.

Species	Environ-ment	Mo.	Spawn-ing status	No. sam-ples	Fish/ sample
Channel catfish	wild	Apr.	Pre	2	7
	wild	Nov.	Post	2	5
	cult'd	Apr.	Pre	3	20
Rainbow Trout	wild	June	Post	2	5-6
	wild	Nov.	Pre	2	5-6
	cult'd	June	Pre	3	16
Coho Salmon	wild	July	Pre	1	9
	wild	Sep.	Late Pre	1	12
	cult'd	July	Early	1	12
		Sep.	Late	1	12

RESULTS AND DISCUSSION

As shown in the sampling plan in Table 1, all cultivated samples represented pre-spawning fish and wild samples of salmon represented early and late season pre-spawning fish. Wild catfish were obtained both pre and post-spawning. Spawning status had no appreciable effect on total fat or individual fatty acid levels. Thus, for comparisons between wild and cultivated fish, means combining all wild samples were used. Total fat, total and individual fatty acid levels (g/100 raw fillet) for each species are shown in Tables 2-4. In each species, total fat in cultivated fish exceeds that of wild fish, though for rainbow trout, the difference, 5.4 vs. 4.6 g/100g is not statistically significant.

As shown in Table 2, cultivated catfish had nearly five times as much fat as wild (11.3 vs. 2.3 g/100g), although lower values for farm-raised catfish have been reported (Mustafa and Medeiros 1985, Nettleton 1990). Fatty acid profile of farmed catfish differed from wild in having proportionately more monounsaturated fatty acids, primarily 18:1 (55% vs. 41%, respectively). The proportion of polyunsaturates was lower in farmed fish (19% vs. 25%) but the relative contribution of n-6FA was similar (15% vs 12%). The proportion of n-3FA was substantially lower in cultivated compared to wild fish (4% vs 14%, respectively). Cultivated catfish were notable for their strikingly high levels of oleic, palmitic and linoleic acids, which constituted approximately 50%, 18% and 15% of total fatty acids, respectively.

Table 2. Fatty acid content of wild and cultivated channel catfish.

	Wild			Cultivated
Fatty Acid	Pre-spawn	Post-spawn	Mean ± SD	Pre-spawn Mean ± SD
	g100g raw fillet			
8:0	<.01	<.01	<.01	<.01
10:0	<.01	<.01	<.01	<.01
12:0	<.01	<.01	<.01	<.01
14:0	.05	.05	.05 ± .02	.16 ± .02
15:0	.02	.02	.02 ± .01	<.01
16:0	.39	.33	.36 ± .10	1.82 ± .2
17:0	.02	.02	.02 ± .01	.03 ± .01
18:0	.10	.08	.10 ± .02	.44 ± .06
20:0	<.01	<.01	<.01	.02 ± .01
22:0	.01	.02	.01 ± .01	<.01
24:0	<.01	<.01	<.01	<.01
Σ Sats	.59	.52	.56 ± .16	2.48 ± 29
14:1	<.01	.01	<.01	<.01
15:1	<.01	<.01	<.01	<.01
16:1	.17	.16	.16 ± .06	.40 ± .06
17:1	.02	.02	.02 ± .01	.02 ± .01
18:1	.66	.55	.60 ± .20	5.17 ± .72
20:1	.03	.02	.02 ± .01	.13 ± .02
22:1	<.01	<.01	<.01	<.01
24:1	<.01	.01	<.01	<.01
Σ Monos	.88	.76	.82 ± .28	5.72 ± .78
18:2(n-6)	.16	.12	.14 ± .04	1.51 ± .19
20:2(n-9)	.02	-	.01 ± .01	.07 ± .03
18:3(n-3)	.07	.08	.07 ± .03	.10 ± .01
20:3(n-6)	<.01	.08	.04 ± .05	<.01
18:4	.01	.01	.01	.02
20:4(n-6)	.08	<.01	.04 ± .05	.05 ± .01
20:5(n-3)	.08	.07	.08 ± .02	.08 ± .02
22:6(n-3)	.13	.10	.12 ± .02	.17 ± .01
Σ Polys	.54	.46	.50 ± .14	2.02 ± .22
Σ n-6FA	.24	.20	.22	1.56
Σ n-3FA	.29	.26	.28	.37
n-3:n-6	1.2	1.3	1.3	0.2
Total fat	2.4	2.1	2.3	11.3 ± 1.4
Σ Fatty acids	2.14	1.82	1.98 ± .57	10.4 ± 1.3

Overall, the fatty acid profile of cultivated rainbow trout resembled that of wild-caught fish and the relative proportions of saturates, monounsaturates, polyunsaturates, n-6 and n-3FA were similar (Table 3). Cultivated trout had notably higher levels of linoleic acid (18:2), 14% compared to 5% total fatty acids in wild samples, and total n-6FA was twice the level in the wild samples (14% vs 7%, respectively). The proportion of n-3FA was higher in wild samples but absolute amounts in wild and cultivated samples were similar. Thus, fatty acids of these farmed and wild rainbow trout can be considered similar from a nutrition perspective. Cultivated coho salmon samples had approximately 2.7 times the total fat as wild samples (Table 4). Distribution of fatty acid classes, however, was similar in wild and cultivated fish and both were strikingly low in their proportion of n-6FA (4% vs 2%, respectively). Omega-3 fatty acids comprised 29% and 19% total fatty acids in wild and cultivated fish, respectively, proportions that were similar to those in the rainbow trout samples.

Table 3. Fatty acid content of wild and cultivated rainbow trout.

	Wild			Cultivated
Fatty Acid	Pre-spawn	Post-spawn	Mean ± SD	Pre-spawn Mean ± SD
g/100g raw fillet				
8:0	<.01	<.01	<.01	<.01
10:0	<.01	.01	<.01	<.01
12:0	<.01	<.01	<.01	<.01
14:0	.08	.26	.17 ± .12	.18 ± .03
15:0	.01	.02	.02 ± .01	.01 ± .002
16:0	.61	.75	.68 ± .14	.94 ± .12
17:0	.02	.09	.05 ± .04	.03 ± .004
18:0	.21	.17	.19 ± .04	.27 ± .03
20:0	.02	.02	.02± .005	.01 ± .002
22:0	.01	.17	.09 ± .10	.05 ± .01
24:0	<.01	<.01	<.01	<.01
Σ Sats	.97	1.48	1.22± .39	1.50 ± .18
14:1	.01	<.01	<.01	<.01
15:1	<.01	<.01	<.01	<.01
16:1	.24	.82	.53 ± .37	.22 ±.03
17:1	.03	.08	.05 ± .03	.01 ± .002
18:1	.74	.52	.63 ± .15	1.02 ± .15
20:1	.05	.01	.03 ± .02	.23 ± .04
22:1	<.01	<.01	<.01	<.01
24:1	.04	<.01	.02 ± .02	<.01
Σ Monos	1.11	1.44	1.27± .30	1.49 ± .23
18:2(n6)	.24	.17	.20 ± .09	.67 ± .07
20:2(n-9)	.02	.01	.01 ± .01	.03 ± .001
18:3(n-3)	.07	.23	.15 ± .10	.06 ± .007
20:3(n-6)	<.01	<.01	<.01	<.01
18:4	.02	.40	.21 ± .24	.05 ± .01
20:4(n-6)	.10	.08	.09 ± .02	.02 ± .003
20:5(n-3)	.20	.56	.38 ± .22	.25 ± .03
22:6(n-3)	.48	.31	.39 ± .16	.64 ± .06
Σ Polys	1.13	1.75	1.44± .48	1.74 ± .17
Σ n-6FA	.33	.25	.29	.71
Σ n-3FA	.77	1.49	1.13	1.00
n-3:n-6	2.3	6.0	4.2	1.4
Total fat	3.8	5.4	4.6	5.4
ΣFatty acids	3.4	4.9	4.17±1.18	4.92 ± .53

Table 4. Fatty acid content of wild and cultivated coho salmon.

	Wild			Cultivated
Fatty Acid	Early pre-spawn	Late pre-spawn	Mean ± SD	Prespawn Mean ± SD
g/100g raw fillet				
8:0	<.01	<.01	<.01	<.01
10:0	<.01	<.01	<.01	<.01
12:0	<.01	<.01	<.01	<.01
14:0	.11	.11	.11	.30 ± .11
15:0	<.01	.01	.01	.03 ± .02
16:0	.54	.46	.50	1.10 ± .14
17:0	.02	.03	.02	.07 ± .02
18:0	.13	.10	.12	.31 ± .04
20:0	<.01	<.01	<.01	.01 ± .02
22:0	<.01	.03	.02	.02 ± .03
24:0	<.01	<.01	<.01	<.01
Σ Sats	.80	.74	.77	1.84 ± .32
14:1	<.01	<.01	<.01	.01 ± .01
15:1	<.01	<.01	<.01	<.01
16:1	.21	.18	.20	.46 ± .12
17:1	.02	.02	.02	.05 ± .01
18:1	.59	.53	.56	1.73 ± .12
20:1	.13	.25	.19	.53 ± .28
22:1	.12	<.01	.06	.19 ± .33
24:1	<.01	<.01	<.01	.02 ± .03
Σ Monos	1.07	.98	1.02	2.88 ± .74
18:2(n-6)	.03	.04	.04	.35 ± .01
20:2(n-9)	<.01	<.01	<.01	.01 ± .01
18:3(n-3)	.02	.05	.04	.08 ± .02
20:3(n-6)	<.01	.03	.02	.02 ± .03
18:4	.04	.04	.04	.12 ± .06
20:4(n-6)	.03	<.01	.02	.09 ± .09
20:5(n-3)	.37	.27	.32	.39 ± .11
22:6(n-3)	.49	.52	.51	.83 ± .09
Σ Polys	.98	.95	.96	1.87 ± .20
Σ n-6FA	.06	.07	.06	.46
Σ n-3FA	.92	.88	.90	1.42
n-3:n-6	15.3	12.6	14.0	3.1
Total fat	3.4	3.2	3.3	8.3
Σ Fatty acids	3.0	2.8	2.9	6.88 ± 1.2

In all samples except wild trout, DHA greatly exceeded EPA and linolenic acid levels (18:3n-3) were very low. These data further document higher fat levels in cultivated fish compared to their wild counterparts. Overall, the relative distribution of fatty acid classes, calculated as a percent of the total fatty acids, was remarkably similar between wild and farmed samples. In rainbow trout, fatty acid classes were approximately evenly distributed among saturated, monounsaturated and polyunsaturated fatty acids. In channel catfish and coho salmon the preponderance of fatty acids came from monounsaturates (55% and 42%, respectively). Both cultivated catfish and coho salmon had substantially lower proportions of n-3FA than their wild counterparts. Whether such shifts in fatty acid composition are nutritionally meaningful, however, is likely to depend on the overall pattern and composition of the diet. For example, although the proportion of n-3FA in cultivated catfish was only 4%, the amount in a 100 g serving was actually greater than in the wild fish, which means consumers are not being shortchanged on n-3FA intake. Although the absolute amounts of n-6FA in cultivated fish were greater than in the wild samples, whether these levels might be detrimental to n-3FA metabolism or be important in the overall fatty acid profile of the diet cannot be evaluated on the basis of the composition of a single food. Such fish would likely increase total dietary n-3FA intake while providing a generally desirable fatty acid profile rich in mono and polyunsaturates. While no information about the fish feeds was available, the fact that catfish accumulate less n-3FA than salmonids, in spite of having up to twice the fat content, suggests that species is an important determinant of n-3FA levels. Salmonid fish are particularly rich sources of long chain n-3FA (Nettleton 1991) and these data indicated that both wild and farmed fish supplied about 1 g n-3FA/100 g, a relatively small serving size for fish. It has been asserted that certain species of wild fish are a better source of n-3 fatty acids than their cultivated counterparts (van Vliet and Katan 1990), at least on the basis of n-3:n-6 ratios. These data might give a similar impression were it not for the fact that absolute amounts of n-3FA in cultivated fish on a weight basis exceed those found in their wild counterparts.

CONCLUSIONS

Cultivated fish exceeded their wild counterparts in total fat, by as much as five times. Differences in total fat and most fatty acids between cultivated and wild rainbow trout were not significant. Cultivated channel catfish, rainbow trout and coho salmon provided as much or more n-3FA as their wild counterparts on an absolute basis, but catfish and coho salmon had proportionately less n-3FA than their wild counterparts. The primary fatty acid class in cultivated catfish and coho salmon was monounsaturates. Ratios of fatty acid classes in individual foods may not be an appropriate reflection of the nutritional contribution of various fatty acids.

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