COMMUNICATION

Fatty Acid Composition of Wild and Farmed Atlantic Salmon (*Salmo salar*) and Rainbow Trout (*Oncorhynchus mykiss*)

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ABSTRACT: The goal of this study was to examine the FA composition of wild and farmed Atlantic salmon (AS) and rainbow trout (RT). FA profiles were obtained by GC/FID. Results showed that lipid and n-3 highly unsaturated FA contents of farmed and wild AS were similar. Total n-3 and n-6 PUFA were significantly higher in farmed AS than in wild AS. Farmed RT contained more fat and less n-3 PUFA than wild RT. Our results show that farmed salmonids provide high levels of n-3 HUFA to consumers.

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Public interest in the health benefits of long-chain n-3 FA is increasing because numerous studies report that a diet rich in fish protects against chronic diseases such as coronary heart disease (CHD) (1). Hence, it is recommended to consume at least two meals of fish, preferably oily, per week (1).

However, wild fish is a finite resource. The increase in demand for fish products over the past two decades has been met by aquaculture production. Given the increasing role of aquaculture in ensuring future per capita fish supplies as world population grows, farmed fish has a significant role to play in providing n-3 FA sources to consumers (2). Atlantic salmon (AS; *Salmo salar*) and rainbow trout (RT; *Oncorhynchus mykiss*) are the major farmed fish consumed by Quebecers, because of their great availability and accessibility in food markets. The goal of the present study was to examine and compare the FA composition of wild and farmed AS and RT.

MATERIAL AND METHODS

In 2003, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ) collected farmed AS (n = 46) and RT (n = 37) in Québec food markets. Wild AS samples (n = 10) were obtained from anglers of the Gaspésie area, the Centre Interuniversitaire de Recherche sur le Saumon Atlantique (CIRSA), and the Ministère des Ressources Naturelles, de la Faune et des Parcs du Québec (FAPAQ). Wild RT samples (n = 10) were obtained from the Freshwater Fisheries Society of British Columbia and FAPAQ. Fish fillets were packaged in plastic bags and stored at −20°C until laboratory analyses (within 2 months following sampling).

FA analyses. Analyses were conducted on raw, skinless fillets, excluding other types of fat such as subcutaneous or mesenteric fat. In the presence of PC containing 15:0 FA used as an internal standard, 300 mg of tissues was extracted three times with chloroform/methanol (2:1 vol/vol) (3). Lipid extract solvents were then evaporated under a stream of nitrogen, weighed, and methylated (4). FA profiles were obtained by capillary GC (Hewlett-Packard 5890 gas chromatograph, equipped with an automated injector 7673A and an FID injector). Injector and detector temperatures were 200 and 260°C, respectively. A capillary column (DB-23: 30 m × 0.25 mm i.d. × 0.25 μm film thickness; Agilent Technologies, Palo Alto, CA) was used with nitrogen as the carrier gas. The FA were identified with a standard mixture of 37 different FA (FAME 37; Supelco, Bellefonte, PA).

The arithmetic mean of total lipids and FA concentrations was calculated for each species. For each FA, comparison of the concentrations between the wild and farmed fish was assessed with the nonparametric Wilcoxon test. Statistical significance was set at $P < 0.05$.

RESULTS

Table 1 shows the FA compositions of wild and farmed AS and RT. The average total lipid contents of wild and farmed AS were similar. However, the range of lipid values was quite large for both types of AS, varying between 1.3 and 16.1 g/100 g of fish flesh. Total n-6 PUFA, n-6 HUFA (highly unsaturated FA), and linoleic acid in farmed AS were four-, two-, and sixfold higher, respectively, than in wild AS. Total n-3 PUFA, α-linolenic acid, and EPA were significantly higher in farmed AS than in wild AS, whereas concentrations of DHA and n-3 HUFA were similar. The ratio of n-3 to n-6 PUFA was 11.0 in wild AS compared with 3.6 in farmed AS. PUFA were the major FA in farmed AS compared with wild AS. Saturated FA (SFA) were 35% higher in farmed AS than in wild AS. In contrast, monounsaturated FA (MUFA) were 60% higher in wild AS than in farmed AS.

The total lipid content in farmed RT was 5.6-fold higher than that of wild RT. Total n-6 PUFA and n-6 HUFA in wild

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Abbreviations: AS, Atlantic salmon; CIRSA, Centre interuniversitaire de Recherche sur le Saumon Atlantique; CHD, coronary heart disease; FAPAQ, Ministère des Ressources Naturelles, de la Faune et des Parcs du Québec; HUFA, highly unsaturated FA; MAPAQ, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec; MUFA, monounsaturated FA; RT, rainbow trout; SFA, saturated FA.

TABLE 1
FA Composition[a] of Farmed and Wild Atlantic Salmon and Rainbow Trout

	Atlantic salmon					Rainbow trout				
	Farmed (n = 46)		Wild (n = 10)			Farmed (n = 37)		Wild (n = 10)		
	$\bar{X}$	SD	$\bar{X}$	SD	P	$\bar{X}$	SD	$\bar{X}$	SD	P
Lipids (g/100 g)	7.4	3.8	7.0	3.8		5.6	3.5	1.0	0.4	[d]
Total FA (g/100 g)	4.1	1.9	4.0	1.3		3.2	1.7	0.6	0.2	[d]
FA (wt% of total FA)										
Σn-6 PUFA	9.8	2.7	2.3	0.3	[d]	8.5	2.6	12.5	4.7	[b]
Σn-6 HUFA	1.7	0.4	0.8	0.1	[d]	1.7	0.3	7.9	4.1	[c]
18:2 (linoleic acid)	7.4	2.7	1.2	0.2	[d]	6.2	2.6	4.2	1.1	[b]
20:4 (arachidonic acid)	0.9	0.2	0.4	0.1	[d]	0.9	0.2	5.4	3.0	[c]
Σn-3 PUFA	31.1	7.5	25.0	3.9	[b]	32.2	8.6	46.2	6.4	[c]
Σn-3 HUFA	28.3	7.9	23.8	3.8		30.1	8.6	44.0	7.2	[c]
18:3 (α-linolenic acid)	1.6	0.7	0.5	0.1	[d]	1.0	0.4	1.7	0.8	[b]
20:5 (EPA)	7.9	1.8	6.6	1.1	[b]	7.3	2.2	8.1	1.1	
22:6 (DHA)	15.2	5.7	13.1	2.7		18.7	6.4	32.2	7.6	[c]
Σn-3/Σn-6 PUFA	3.6	1.8	11.0	2.7	[d]	4.4	2.4	4.8	3.3	
ΣPUFA	41.0	5.8	27.3	3.9	[d]	40.6	6.6	58.6	3.8	[d]
ΣMUFA	33.4	7.9	53.7	3.9	[d]	32.5	7.2	17.0	4.0	[d]
ΣSFA	25.6	2.9	19.0	1.0	[d]	26.9	2.2	24.4	1.4	[c]

[a]$\bar{X}$ = arithmetic mean; SD = standard deviation; HUFA, highly unsaturated FA; SFA, saturated FA; MUFA, monounsaturated FA. Σn-6 PUFA, (18:2 + 18:3 + 20:2 + 20:3 + 20:4 + 22:2 + 22:4 + 22:5); Σn-6 HUFA, (20:3 + 20:4 + 22:4 + 22:5); Σn-3 PUFA, (18:3 + 18:4 + 20:3 + 20:4 + 20:5 + 22:5 + 22:6); Σn-3 HUFA, (20:3 + 20:4 + 20:5 + 22:5 + 22:6); ΣMUFA, (14:1 + 18:1 + 20:1 + 22:1 + 24:1); ΣSFA: (14:0 + 15:0 + 16:0 + 18:0 + 20:0 + 22:0 + 24:0).
[b]$P < 0.05$.
[c]$P < 0.005$.
[d]$P < 0.0001$.

RT were significantly higher than in farmed RT, whereas linoleic acid was higher in farmed RT. Total n-3 PUFA, n-3 HUFA, α-linolenic acid, and DHA were higher in wild RT than in farmed RT whereas the ratio of n-3 to n-6 PUFA was similar in all trout samples. However, absolute concentrations showed that farmed RT provided threefold higher amounts of n-3 PUFA than wild RT (931 vs. 268 mg/100 g). PUFA were present in higher proportion in wild RT than in farmed RT. In contrast, SFA and MUFA were higher in farmed RT than in wild RT.

DISCUSSION

Although farmed salmonids generally display higher amount of lipids than wild fish (5,6), our results showed that the lipid content of farmed AS was lower than expected and similar to that of wild AS. Moreover, linoleic, α-linolenic, and arachidonic acids were, respectively, six-, three-, and twofold higher in farmed AS than in wild AS. The recent use of vegetable oils in feeds of farmed AS may explain these differences. It is well known that the FA composition of farmed fish greatly varies depending upon their diet (5,7). In the present study, the composition of the diets for the farmed fish was unknown, as they are mainly produced in Chile (Morin, R., unpublished data). Unexpectedly, the flesh of wild and farmed RT displayed a similar ratio of n-3/n-6 PUFA even though farmed RT contained more lipid and less n-3 and n-6 PUFA than wild RT. Moreover, the concentration of arachidonic acid was sixfold higher in wild RT than in farmed RT, probably reflecting the greater consumption of terrestrial insects by wild RT (8).

In 2004, for primary prevention of CHD, nutrition experts of the International Society for the Study of Fatty Acids and Lipids recommended 500 mg of EPA + DHA per day (1). Fortunately, our results show that the consumption of farmed salmonids provides high levels of n-3 HUFA and consequently may have beneficial health effects for consumers.

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