Fatty Acid Compositions of the Lipids Obtained from Commercial Salmon Products

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The fatty acid compositions of total lipids from the raw fillets of four species of salmon, the salted fillet and the canned fillets from sockeye salmon were investigated with open-tubular gas-liquid chromatography. The major components of fatty acids of the present samples were similar to those of masu salmon, pink salmon and chum salmon studied previously. Each sample showed the characteristic pattern of the fatty acids. Food products of sockeye salmon have high contents of 20:1 (n-11) and 22:1 (n-11 and n-13). The raw fillet of coho salmon has higher contents of polyunsaturated fatty acids than other samples. Moreover, the contents of 18:2 (n-6) in the raw fillets of rainbow trout and chinook salmon were apparently higher than those of other fish studied. It was inferred that these characters of fatty acid compositions were influenced by the fatty acid patterns of dietary lipids.

Salmons are representative edible fish in Japan, and eaten in various forms (raw, salted, canned and smoked, etc.). Recently, salmon culture industry becomes active, and cultured salmon as well as wild salmon are eaten. Moreover, a large quantity of salmon is imported from foreign countries (USA, Canada, Norway, Chile, New Zealand, Australia, etc.). Therefore, it is assumed that the lipids of commercial salmon products have variable properties according to the fishing area, the culture condition and the species of salmon.

It is known that fish lipids are rich in n-3 polyunsaturated fatty acids (PUFA) which are epidemiologically important substances.¹⁾ Dietary consumption of fish lipids containing n-3 PUFA such as eicosapentaenoic acid and docosahexaenoic acid was found to change the fatty acid compositions of total cardiac lipid.²⁻⁴⁾ Many studies emphasized the importance of ingesting fish oil and fish products.⁵⁾

There are some reports on the fatty acid compositions of the lipids from salmon.⁶⁻¹¹⁾ The fatty acid compositions of the lipids from masu salmon, pink salmon and chum salmon were elucidated in detail by using open-tubular gas-liquid chromatography (GLC) in our laboratory.^{12,13)}

The purpose of the present study was to investigate fatty acids of the lipids obtained from

the raw fillets of four species of salmon, the salted fillet and the canned fillets from sockeye salmon, and to indicate significant differences in the fatty acid compositions of commercial products from salmon.

Materials and Methods

Materials

The raw fillets of four species of salmon, the salted fillet and the canned fillets from sockeye salmon were bought at food markets in Hakodate. The characteristics of samples are shown in Table 1.

Lipid Extraction and Preparation of Fatty Acid Methyl Esters (FAME)

Total lipids (TL) were extracted from 2-4 fillets (200-500 g) by the method of Bligh and Dyer.¹⁴⁾

Preparations and purifications of FAME were carried out as described previously.¹⁵⁾

Analysis of Lipid Class Composition

The analysis of lipid class compositions of TL was carried out using thin-layer chromatography-flame ionization detector system (TLC-FID) (Iatron Laboratories, Tokyo) as described previously.¹⁶⁾ The rods used were Chromarods-SII. The rods were scanned through the Iatroscan FID immediately before applying the lipid samples. The chloroform solutions of lipids were prepared

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Table 1. Characteristics of samples

Common name (Scientific name)	Form	Habitat	Place of production or producer	Date of purchase or production
Rainbow trout (<i>Salmo gairdneri</i>)	raw	cultured	New Zealand	April 13, 1989.
Chinook salmon (<i>Oncorhynchus tshawytscha</i>)	raw	cultured	Scotland in England	April 13, 1989.
Coho salmon (<i>Oncorhynchus kisutch</i>)	raw	cultured	Miyagi prefecture in Japan	April 28, 1989.
Sockeye salmon (<i>Oncorhynchus nerka</i>)	raw	wild	Northern Pacific Ocean	April 30, 1989.
	salted	wild	Northern Pacific Ocean	May 22, 1989.
	canned A	—	Nichiro Gyogyo kaisha, Ltd.	Dec. 15, 1988.
	canned B	—	Kyokuyo Co., Ltd.	Summer, 1988.

Table 2. Lipid contents and lipid class compositions of the lipids from samples*

Fish	Form	TL (wt%)	Lipid (% in TL)				
			HC+SE	TG	FFA	ST	PL
Rainbow trout	raw	17.3	1.3	91.9	0.1	0.3	6.4
Chinook salmon	raw	8.7	2.0	86.5	0.1	0.9	10.5
Coho salmon	raw	18.1	2.2	89.9	—	2.3	5.6
Sockeye	raw	9.8	1.0	87.0	0.6	0.4	11.0
salmon	salted	5.7	0.4	76.2	8.3	0.6	14.5
	canned A	8.1	0.3	88.6	1.4	0.1	9.6
	canned B	6.8	1.8	86.2	—	0.7	11.3

* TL, Total lipids; HC+SE, Hydrocarbons+Sterol esters; TG, Triacylglycerols; FFA, Free fatty acids; ST, Free sterols; PL, Polar lipids.

in the concentration between 10 to 15 $\mu\text{g}/\mu\text{l}$. The chloroform solutions were spotted on the rods in the 1 μl size with a single spotting action using Drummond Microcap disposable pipets (Drummond Scientific Co., USA). The rods, after spotting, were developed with a developing solvent for a distance of 10 cm from the origin. The developing solvent was n-hexane/diethyl ether/formic acid (90:10:0.2, v/v). The rods were then scanned on the Iatroscan TH-10 (Iatron Laboratories, Tokyo). The scan speed was set at 30 sec/scan. Peak area percentages and retention data were obtained by a Shimadzu integrator C-R1A (Shimadzu Seisakusho Co., Kyoto). Each peak on the chromatograms was identified on the basis of the agreement with the retention data with those of the standard mixtures I and II prepared in our laboratory. The standard mixture I contained triacylglycerols, cholesterol and free fatty acids in the weight ratios of 52:43:10, respectively. The ratios of hydrocarbon + sterol esters, triacylglycerols, free fatty acids and free sterols in the standard mixture II were 15:30:5:50, respectively.

Open-tubular GLC

Open-tubular GLC of FAME was carried out

with a Shimadzu GC-6AM (Shimadzu Seisakusho Co., Kyoto) equipped with FID. The metal wall open-tubular column used was 50 m in length and 0.25 mm i.d., coated with Silar 5CP. The column temperature was 190°C. The detector and injector were held at 230°C. The carrier gas was H_2 . Peak area percentages were obtained with a Shimadzu integrator C-R6A (Shimadzu Seisakusho Co., Kyoto). Each peak on the gas chromatogram was identified as described previously.¹⁵⁾

Results and Discussion

Lipid Contents and Lipid Class Compositions

Table 2 shows lipid contents and lipid class compositions of TL. The raw fillets of rainbow trout (17.3%) and coho salmon (18.1%) have much higher lipid contents than those of chinook salmon (8.7%) and sockeye salmon (9.8%). The lipid contents of the flesh from masu salmon, pink salmon and chum salmon were 6.8%, 9.7% and 5.0%, respectively.^{12,13)} Salmons usually have seasonal cycles of lipid content associated with migration and spawning.¹⁷⁾ Yamaguchi *et al.* reported that the flesh of cultured coho salmon had higher lipid content than that of wild fish.¹⁰⁾

Table 3. Fatty acid compositions of the lipids from samples (wt%)*

Peak No.	Fatty acid	RRT	Rainbow trout raw	Chinook salmon raw	Coho salmon raw	Sockeye salmon			
						raw	salted	canned	
								A	B
1	12:0	0.133	0.07	0.10	0.14	0.05	0.00	0.04	0.05
2	13:0	0.187	0.03	0.04	0.03	0.02	0.03	0.02	0.03
3	iso-14:0	0.223	0.03	0.02	0.03	0.02	0.02	0.02	0.02
4	14:0	0.263	5.16	4.77	5.61	5.08	5.06	5.41	3.80
5	4, 8, 12-TMTD	0.273	0.11	0.14	0.12	0.08	0.06	0.08	0.08
6	14:1 n-7	0.283	0.07	0.05	0.04	0.04	0.04	0.04	0.03
7	14:1 n-5	0.298	0.04	0.03	0.06	0.03	0.03	0.03	0.02
8	iso-15:0	0.312	0.29	0.23	0.26	0.22	0.20	0.20	0.20
9	anteiso-15:0	0.331	0.07	0.06	0.08	0.08	0.07	0.07	0.09
10	15:0	0.367	0.35	0.37	0.45	0.34	0.40	0.38	0.42
11	iso-16:0	0.436	0.07	0.08	0.08	0.07	0.07	0.06	0.09
12	Pristanic	0.485	0.01	0.02	0.02	0.12	0.06	0.11	0.08
13	16:0	0.520	17.25	16.35	17.59	12.63	13.86	14.81	13.46
14	16:1 n-11	0.561	0.23	0.28	0.41	0.32	0.35	0.29	0.40
15	16:1 n-9	0.571	0.29	0.29	0.30	0.16	0.25	0.20	0.24
16	16:1 n-7	0.589	7.58	5.86	5.54	3.97	3.18	3.17	3.06
17	iso-17:0	0.608	0.37	0.33	0.43	0.43	0.47	0.46	0.47
18	anteiso-17:0	0.646	0.08	0.08	0.10	0.08	0.07	0.07	0.08
19	16:2 n-4	0.705	0.21	0.24	0.36	0.27	0.26	0.29	0.35
20	17:0	0.715	—	—	0.36	0.85	0.39	0.62	0.54
21	16:3 n-4	0.806	0.35	0.37	0.49	0.24	0.28	0.25	0.28
22	16:4 n-1	0.946	0.22	0.15	0.36	0.12	0.08	0.07	0.03
23	18:0	1.000	3.15	3.70	3.76	2.45	2.51	2.73	2.94
24	18:1 n-11	1.093	1.46	1.04	0.67	1.30	1.34	1.24	0.82
25	18:1 n-9	1.125	15.22	17.32	14.21	10.13	10.45	9.65	15.26
26	18:1 n-7	1.143	2.73	3.07	3.52	2.02	1.86	1.70	1.81
27	18:1 n-5	1.179	0.41	0.30	0.43	0.80	0.84	0.84	0.94
28	18:2 n-9	1.281	0.06	0.04	0.05	0.04	0.03	0.02	0.03
29	18:2 n-6	1.320	4.22	5.06	2.49	1.27	1.56	1.52	1.49
30	18:3 n-6	1.382	0.11	0.10	—	0.21	0.58	0.41	0.38
31	19:1 n-8	1.553	0.17	0.16	0.24	0.06	0.12	0.11	0.09
32	18:3 n-3	1.612	1.11	1.19	0.94	0.66	1.30	1.05	0.93
33	18:4 n-3	1.781	1.60	1.25	1.46	0.95	1.83	1.57	1.15
34	18:4 n-1	1.818	0.27	0.18	0.31	0.15	0.09	0.10	0.05
35	20:0	1.917	0.10	0.14	0.10	0.18	0.14	0.18	0.12
36	20:1 n-11	2.094	1.10	0.95	2.51	14.46	12.31	14.12	9.60
37	20:1 n-9	2.138	6.97	5.93	1.92	4.02	2.97	3.21	2.74
38	20:1 n-7	2.181	0.32	0.34	0.19	0.44	0.25	0.32	0.34
39	5, 11-20:2	2.264	0.04	0.04	0.05	0.17	0.11	0.15	0.15
40	20:2 n-6	2.514	0.33	0.44	0.28	0.36	0.40	0.43	0.42
41	20:4 n-6	2.931	0.23	0.52	0.95	0.33	0.37	0.41	0.48
42	20:3 n-3	3.079	0.13	0.16	0.15	0.17	0.25	0.25	0.24
43	20:4 n-3	3.387	1.08	1.11	1.44	0.90	1.33	1.11	1.17
44	20:5 n-3	3.599	4.76	4.58	8.14	6.65	7.07	6.87	6.88
45	22:1 n-11, n-13	4.002	6.60	6.57	2.21	11.56	8.04	8.88	6.75
46	22:1 n-9	4.055	0.93	0.90	0.36	1.02	0.60	0.69	1.15
47	22:1 n-7	4.165	0.11	0.09	0.06	0.15	0.08	0.10	0.11
48	21:5 n-3	5.550	—	0.05	—	—	—	—	0.03
49	22:4 n-6	5.992	0.08	0.20	0.24	0.10	0.16	0.11	0.23
50	22:5 n-6	6.392	0.06	0.07	0.07	0.05	0.06	0.05	0.06
51	22:5 n-3	6.966	1.56	1.96	3.22	1.83	1.98	1.34	1.81
52	22:6 n-3	7.389	8.71	8.75	12.50	7.80	11.97	10.36	13.73
53	24:1 n-9	7.674	0.51	0.79	0.72	0.93	0.71	0.80	1.15
Others			2.99	3.14	3.95	3.62	3.46	2.99	3.13
Total Sat.			27.14	26.43	29.16	22.71	23.41	25.26	22.47
Total Mono.			44.74	43.97	33.39	51.41	43.42	45.39	44.51
Total PUFA			25.13	26.46	33.50	22.27	29.71	26.36	29.89
n-3/n-6 ratio			3.77	2.96	6.91	8.17	8.22	7.70	8.48

* RRT, Relative retention time; 4, 8, 12-TMTD, 4, 8, 12-Trimethyltridecanoic acid; Pristanic, 2, 6, 10, 14-Tetramethylpentadecanoic acid; Sat., Saturated fatty acids; Mono., Monounsaturated fatty acids; PUFA, Polyunsaturated fatty acids; n-3, Fatty acids having n-3 structure; n-6, Fatty acids having n-6 structure.

The lipid contents of the salted fillet and the canned fillets from sockeye salmon ranged from 5.7% to 8.1%. There were no significant differences in lipid contents of food products from sockeye salmon.

More than 85% of TL were triacylglycerols and the remainder were mostly polar lipids in other fillet samples except for the salted fillet from sockeye salmon. Although free fatty acids (FFA) could not be detected in all the samples except for the salted fillet from sockeye salmon, FFA in the salted fillet from sockeye salmon made up 8.3% of TL. FFA in the salted fillet from sockeye salmon was caused by the hydrolysis of esterified fatty acids by the activity of the enzyme.

Major Fatty Acid Components

Table 3 shows the fatty acid compositions of the lipids of samples. The major components were 14:0, 16:0, 16:1 (n-7), 18:0, 18:1 (n-9), 18:1 (n-7), 18:2 (n-6), 20:1 (n-11), 20:1 (n-9), 20:5 (n-3), 22:1 (n-11 and n-13), 22:5 (n-3) and 22:6 (n-3). These components were detected at the level above 3% of the total fatty acids in one or more samples. The total contents of major components were more than 80% in all samples. These major components were similar to those of masu salmon, pink salmon and chum salmon.^{12,13)}

Saturated Fatty Acids

The total saturated acids were 20–30% of total fatty acids in all samples. The most predominant saturated acid was 16:0, followed by 14:0 and then 18:0. Although branched-chain fatty acids and odd numbered fatty acids were also detected, the proportions of these fatty acids were less than 1.0% of total fatty acids.

Monounsaturated Fatty Acids

The total monounsaturated fatty acids exceeded 40% of total fatty acids in all the samples except for the raw fillet of coho salmon (33.39%). Especially, an half of total fatty acids were monounsaturated fatty acids in the raw fillet of sockeye salmon. While there were no significant differences in the contents of other monounsaturated fatty acids, the raw fillet and food products from sockeye salmon have much higher contents of 20:1 (n-11) and 22:1 (n-11 and n-13) than those of other species. It was reported that the contents of 20:1 (n-11) in masu salmon, pink salmon and chum salmon were 4.61%, 0.87% and 7.47% of

total fatty acids, and the contents of 22:1 (n-11 and n-13) were 2.93%, 1.03% and 5.83%, respectively.^{12,13)} Yamada and Hayasai reported that the contents of 20:1 and 22:1 in sockeye salmon were 17.0% and 10.3% of total fatty acids.¹⁸⁾ It is known that food habits of salmon are variable according to the species.¹⁰⁾ The main diets of sockeye salmon are copepods, euphausiids, amphipods and squid in which their lipids are rich in the wax esters.²⁰⁾ The major fatty alcohols of the wax esters in their lipids are alc 20:1 and alc 22:1.^{21,22)} Therefore, it was assumed that the lipids of sockeye salmon were rich in 20:1 (n-11) and 22:1 (n-11 and n-13). This character of sockeye salmon lipids may be due to their diet lipids.

PUFA

The total PUFA were less than 30% of total fatty acids in all the samples except for the raw fillet of coho salmon (33.50%). The major PUFA of samples were 20:5 (n-3) (4.58–8.14%) and 22:6 (n-3) (7.80–13.73%). The former is precursor of eicosanoids (prostaglandins and leukotrienes), and their biological activities have been noticeable in biochemistry and pharmacology. The raw fillet of coho salmon has higher contents of 20:4 (n-6), 20:5 (n-3), 22:5 (n-3) and 22:6 (n-3) than other samples. Yamaguchi *et al.* reported that the fatty acid composition of the lipids in cultured coho salmon were influenced by the patterns of fatty acids in their dietary lipid.¹⁰⁾ Their principal diets were mackerel and sardine in which their lipids were rich in PUFA. It was reported the contents of PUFA were 30–40% of total fatty acids in the sardine and mackerel.^{23,24)} The most of PUFA in these fishes comprised 20:5 (n-3) and 22:6 (n-3). The proportions of 18:2 (n-6) in the raw fillets of rainbow trout and chinook salmon were 4.22% and 5.06%, and were higher than those of coho salmon (2.49%) and sockeye salmon (1.27–1.56%). Suzuki *et al.* reported that the muscle lipids of cultured rainbow trout contained higher percentages of 18:2 (n-6) than those of wild fish.²⁵⁾ They indicated that the amount of 18:2 (n-6) of dorsal muscle lipids depended on the diet lipids. The contents of 18:2 (n-6) in masu salmon, pink salmon and chum salmon were less than 1% of total fatty acids.^{12,13)} It was inferred that these characters of fatty acid compositions were influenced by the fatty acid patterns of dietary lipids. The ratios of n-3 to n-6 PUFA ranged from 6.91 to 8.48 in other samples except

for rainbow trout (3.77) and chinook salmon (2.96). This ratio was markedly influenced by the content of 18:2 (n-6).

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