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Analysis of lipid classes and the fatty acid composition of the salted fish roe food products, Ikura, Tarako, Tobiko and Kazunoko

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Abstract

This study was designed to clarify the content of lipid classes and the fatty acid composition of total lipids (TL), sterol esters (SE), triacylglycerols (TG), phospholipids (PL), phosphatidylcholine (PC), and phosphatidylethanolamine (PE) of the Japanese fish roe products, Ikura, Tarako, Tobiko and Kazunoko. The TL, total cholesterol, TG, and PL content of Ikura were higher than those of Tarako, Tobiko and Kazunoko. Kazunoko had the lowest cholesterol content among these roe products. PC was the main component in the PL class of each fish roe product. The main fatty acids of all roe products were 16:0, 18:1*n*−9, 20:5*n*−3, and 22:6*n*−3. Docosahexaenoic acid (22:6*n*−3) was rich in the TL, SE, TG, PL, PC and PE fractions of all roe products. In particulars the 22:6*n*−3 percentage of PC and PE fractions in Tobiko were higher than those of Ikura, Tarako and Kazunoko. These results indicate that the lipid from fish roe products may be a useful food source for maintaining human health.

Keywords: Fatty acid; Fish roe; Salted; Cholesterol; Phosphatidylcholine

1. Introduction

Fish roe is consumed throughout the world, and caviar is a well-known example. In Japan, the salted products of salmon, pollock, flyingfish, and herring roe are mainly consumed as Ikura, Tarako, Tobiko and Kazunoko, respectively. There have been some reports on the detailed composition of roe lipid. In general, fish roe contains large amounts of eicosapentaenoic acid (C20:5*n*−3) and docosahexaenoic acid (C22:6*n*−3) (Kaitaranta, 1980; Tocher & Sargent, 1984; Bledsoe, Bledsoe, & Rasco, 2003). These fatty acids play an important role in the prevention and treatment of cardiovascular diseases (Nordøy, 2001) and the improvement of learning ability (Yonekubo, Honda, Okano, Takahashi, & Yamamoto, 1994; Suzuki, Park, Tamura, & Ando, 1998). Furthermore, fish roe has a high percentage of phosphatidylcholine (PC) (Tocher & Sargent, 1984). PC is effective for the improvement of learning ability (Lim & Suzuki, 2002) and the lowering of plasma lipids (Iwata et al., 1992).

Generally, Japanese fish roe products, such as Ikura, Tarako, Tobiko and Kazunoko, are salted for increased preservation and then consumed (Bledsoe et al., 2003). However, little is known about the lipid components of these salted fish roe food products. Therefore, this study was designed to clarify the content of lipid classes and the fatty acid composition of the Japanese fish roe products Ikura, Tarako, Tobiko and Kazunoko.

2. Materials and methods

2.1. Sample

Ikura (salted salmon roe), Tarako (salted pollock roe) and Tobiko (salted flyingfish roe) were purchased from a

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Table 1
Lipid components of Ikura, Tarako, Tobiko and Kazunoko

	Ikura	Tarako	Tobiko	Kazunoko
Total lipid content (g/100 g tissue)	14.5 ± 0.7	3.7 ± 0.4	3.2 ± 0.2	3.0 ± 0.3
Cholesterol content (g/100 g tissue)	0.59 ± 0.10	0.35 ± 0.02	0.43 ± 0.01	0.26 ± 0.04
Triacylglycerol content (g/100 g tissue)	8.09 ± 0.68	0.64 ± 0.06	0.42 ± 0.01	0.54 ± 0.06
Phospholipid content (g/100 g tissue)	5.51 ± 0.12	2.28 ± 0.23	2.39 ± 0.19	2.14 ± 0.26
Unknown (g/100 g tissue)	–	0.18 ± 0.04	–	–
Phospholipid class (%)				
Lysophosphatidylcholine	1.5 ± 0.2	7.1 ± 0.4	4.2 ± 1.0	9.6 ± 1.5
Sphingomyelin	2.8 ± 0.1	1.3 ± 0.2	4.1 ± 0.6	2.9 ± 0.6
Phosphatidylcholine	77.9 ± 0.1	68.5 ± 0.5	76.6 ± 0.9	65.2 ± 5.8
LPE + PS	–	4.0 ± 0.0	2.8 ± 0.6	5.0 ± 0.6
Phosphatidylinositol	6.7 ± 0.4	3.8 ± 0.1	3.9 ± 0.0	4.9 ± 0.6
Phosphatidylethanolamine	11.0 ± 0.4	15.3 ± 0.9	8.4 ± 0.1	12.4 ± 2.5

LPE, lysophosphatidylethanolamine; PS, phosphatidylserine; Ikura, salted salmon roe; Tarako, salted Pollock roe; Tobiko, salted flyingfish roe; Kazunoko, salted herring roe.

supermarket in Tsukuba, Ibaraki, Japan. The Ikura and Tarako were processed in Hokkaido, Japan. The Tobiko was processed in Indonesia. Kazunoko (salted herring roe) that had been processed in Canada was supplied by Kato Suisan CO., LTD (Rumoi, Hokkaido, Japan). Four to eight lots of each sample were analyzed in double. All results were expressed as means ± SD.

2.2. Lipid extraction and lipid class analysis

The total lipids (TL) were extracted from the fish roe products by the method of Bligh and Dyer (1959). Each sample was combined with three volumes of chloroform/methanol (1:2) and homogenized for 2 min in a Waring blender. The various lipid classes were separated and fractionated by thin-layer chromatography (TLC, 0.25 mm silica Gel 60 F_{254}, Merck, Co, Ltd., Germany). The sterol esters (SE), triacylglycerols (TG), and phospholipids (PL) were separated using the solvent of petroleum ether/diethyl ether/acetic acid (80:20:1 by vol.), and some of the developed TLC plates were sprayed with 30% sulfuric acid solution, and then heated by a burner. PL classes were separated using chloroform/methanol/distilled water/acetic acid (65:45:2:1 by vol.), and some of the developed TLC plates were then sprayed with molybdenum and sulfuric acid reagent (Dittmer & Lester, 1964). The SE, TG, PC and phosphatidylethanolamine (PE) were recovered from the TLC plates by scraping off the appropriate bands and extracting them with chloroform/methanol (20:1). The total cholesterol (Chol), TG, and PLs content were quantified by the methods of Allain, Poon, Chan, Richmond, and Fu (1974), Spayd et al. (1978), and Rouser, Siakotos, and Fleischer (1966) after Tween 20 was added to the sample lipids. Each PL class percentage was determined by quantifying phosphates, using the method of Rouser et al. (1966) after each spot was scraped from the developed TLC plate.

Table 2
Fatty acid and dimethylacetal (DMA) composition of total lipids (TL) in the Ikura, Tarako and Kazunoko (%)

	TL			
	Ikura	Tarako	Tobiko	Kazunoko
SFA				
14:0	4.6 ± 0.1	2.4 ± 0.1	1.4 ± 0.0	2.3 ± 0.2
16:0	11.6 ± 0.2	21.8 ± 0.5	25.5 ± 0.2	26.3 ± 0.5
18:0	4.6 ± 0.1	2.4 ± 0.0	9.8 ± 0.1	2.6 ± 0.4
Others	0.9 ± 0.2	0.4 ± 0.0	2.9 ± 0.0	0.8 ± 0.2
Total	21.6 ± 0.2	26.9 ± 0.6	39.6 ± 0.3	32.0 ± 1.3
MUFA				
16:1*n*−9	0.4 ± 0.0	0.5 ± 0.0	0.3 ± 0.0	0.6 ± 0.0
16:1*n*−7	5.6 ± 0.1	3.3 ± 0.0	1.9 ± 0.0	4.8 ± 0.3
18:1*n*−12	1.9 ± 0.0	0.9 ± 0.0	–	0.5 ± 0.0
18:1*n*−9	17.9 ± 0.2	9.3 ± 0.1	8.9 ± 0.1	12.1 ± 1.0
18:1*n*−7	3.1 ± 0.1	5.4 ± 0.1	2.4 ± 0.0	5.2 ± 0.4
18:1*n*−5	0.6 ± 0.0	0.6 ± 0.0	–	0.5 ± 0.0
20:1	2.4 ± 0.0	3.1 ± 0.0	0.5 ± 0.0	0.7 ± 0.0
Others	1.3 ± 0.0	1.9 ± 0.0	0.5 ± 0.0	0.6 ± 0.0
Total	33.1 ± 0.4	25.0 ± 0.3	14.4 ± 0.1	25.0 ± 0.9
PUFA				
18:2*n*−6	1.0 ± 0.0	1.0 ± 0.0	1.1 ± 0.0	0.7 ± 0.1
18:3*n*−3	0.7 ± 0.0	0.4 ± 0.0	0.7 ± 0.0	0.4 ± 0.0
18:4*n*−3	0.8 ± 0.0	0.8 ± 0.0	0.4 ± 0.0	0.4 ± 0.0
20:4*n*−6	1.0 ± 0.0	1.3 ± 0.0	3.0 ± 0.1	1.1 ± 0.1
20:4*n*−3	2.1 ± 0.0	0.6 ± 0.0	0.5 ± 0.0	0.4 ± 0.0
20:5*n*−3	13.6 ± 0.1	18.8 ± 0.3	7.0 ± 0.1	15.0 ± 0.6
22:4*n*−6	0.2 ± 0.0	–	–	0.2 ± 0.0
22:5*n*−3	5.6 ± 0.0	1.0 ± 0.0	2.8 ± 0.0	1.3 ± 0.1
22:6*n*−3	17.4 ± 0.2	22.2 ± 0.4	27.9 ± 0.3	22.6 ± 1.0
Others	2.0 ± 0.2	1.5 ± 0.1	2.2 ± 0.0	0.6 ± 0.3
Total	44.6 ± 0.5	47.5 ± 0.9	45.5 ± 0.4	42.7 ± 0.3
16:0DMA	–	–	–	–
18:0DMA	–	–	–	–
18:1DMA*n*−9	–	–	–	0.3 ± 0.1
18:1DMA*n*−7	–	–	–	–
Unknown	0.7 ± 0.1	0.5 ± 0.0	0.6 ± 0.0	–

Ikura, salted salmon roe; Tarako, salted Pollock roe; Tobiko, salted flyingfish roe; Kazunoko, salted herring roe; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

Table 3
Fatty acid and dimethylacetal (DMA) composition of sterol ester (SE), triacylglycerol (TG), and phospholipids (PL) in the Ikura, Tarako, Tobiko, and Kazunoko (%)

	SE				TG				PL			
	Ikura	Tarako	Tobiko	Kazunoko	Ikura	Tarako	Tobiko	Kazunoko	Ikura	Tarako	Tobiko	Kazunoko
SFA												
14:0	3.6 ± 1.0	2.1 ± 0.3	1.6 ± 0.2	1.6 ± 0.1	5.8 ± 0.0	4.8 ± 0.2	3.1 ± 0.0	4.9 ± 0.3	2.1 ± 0.0	1.1 ± 0.3	1.0 ± 0.0	2.4 ± 0.9
16:0	8.8 ± 0.6	14.3 ± 1.6	13.2 ± 2.7	10.0 ± 2.6	9.3 ± 0.1	14.6 ± 1.0	27.7 ± 0.0	18.7 ± 0.9	12.0 ± 0.9	10.4 ± 1.9	22.3 ± 0.3	25.5 ± 1.8
18:0	2.8 ± 0.3	1.6 ± 0.1	3.8 ± 0.2	1.8 ± 0.8	2.0 ± 0.0	2.8 ± 0.1	4.8 ± 0.0	1.1 ± 0.1	8.9 ± 0.1	1.5 ± 0.0	11.7 ± 0.5	3.2 ± 0.4
Others	1.2 ± 0.3	1.0 ± 0.1	3.1 ± 0.1	0.3 ± 0.1	0.8 ± 0.0	0.7 ± 0.0	4.1 ± 0.2	0.8 ± 0.5	0.8 ± 0.0	–	2.7 ± 0.0	0.9 ± 0.3
Total	16.4 ± 1.0	19.0 ± 1.8	21.7 ± 3.2	13.8 ± 3.4	18.0 ± 0.2	22.9 ± 0.9	39.7 ± 0.1	25.5 ± 1.2	23.7 ± 1.0	13.0 ± 1.6	37.7 ± 0.2	32.0 ± 2.7
MUFA												
16:1*n*–9	0.9 ± 0.1	0.8 ± 0.1	0.8 ± 0.1	1.3 ± 0.1	0.5 ± 0.0	0.2 ± 0.0	0.7 ± 0.0	1.2 ± 0.1	0.3 ± 0.0	0.5 ± 0.1	0.2 ± 0.0	0.6 ± 0.3
16:1*n*–7	4.4 ± 2.0	3.8 ± 0.6	4.1 ± 0.1	4.4 ± 1.1	7.5 ± 0.1	6.5 ± 0.2	5.5 ± 0.0	11.2 ± 0.3	2.0 ± 0.2	1.4 ± 1.0	1.1 ± 0.0	2.8 ± 0.2
18:1*n*–12	1.5 ± 0.5	0.7 ± 0.5	–	0.4 ± 0.5	2.2 ± 0.1	1.4 ± 0.1	–	–	1.1 ± 0.0	0.6 ± 0.1	–	0.3 ± 0.4
18:1*n*–9	16.7 ± 3.5	12.6 ± 1.9	16.5 ± 0.9	17.6 ± 0.4	20.8 ± 0.2	15.2 ± 0.2	12.3 ± 0.0	36.8 ± 0.6	10.7 ± 0.7	7.9 ± 0.2	6.7 ± 0.1	6.4 ± 0.4
18:1*n*–7	2.8 ± 0.3	5.7 ± 1.0	5.2 ± 0.2	5.4 ± 0.5	3.1 ± 0.1	6.1 ± 0.1	5.2 ± 0.0	4.6 ± 0.5	3.4 ± 0.2	4.6 ± 0.4	2.1 ± 0.1	6.7 ± 0.4
18:1*n*–5	0.5 ± 0.1	0.6 ± 0.1	0.1 ± 0.1	0.3 ± 0.0	0.6 ± 0.0	0.5 ± 0.0	–	0.2 ± 0.0	0.7 ± 0.0	0.4 ± 0.1	–	0.6 ± 0.0
20:1	3.2 ± 0.3	3.6 ± 0.7	1.8 ± 0.1	4.7 ± 0.5	2.2 ± 0.0	8.8 ± 0.1	1.1 ± 0.0	1.7 ± 0.0	2.7 ± 0.0	2.5 ± 0.1	0.4 ± 0.0	0.7 ± 0.1
Others	1.8 ± 0.0	1.8 ± 0.1	1.1 ± 0.0	2.7 ± 0.2	1.4 ± 0.0	5.7 ± 0.7	0.9 ± 0.0	1.2 ± 0.1	0.2 ± 0.0	0.3 ± 0.0	0.4 ± 0.0	1.4 ± 2.0
Total	31.7 ± 5.9	29.6 ± 5.1	29.7 ± 1.1	36.7 ± 2.3	38.3 ± 0.3	44.4 ± 0.7	25.7 ± 0.0	56.9 ± 0.5	21.3 ± 1.2	18.2 ± 1.2	10.9 ± 0.2	19.4 ± 2.2
PUFA												
18:2*n*–6	1.0 ± 0.1	1.3 ± 0.1	2.9 ± 0.1	0.9 ± 0.0	1.3 ± 0.0	1.4 ± 0.0	2.2 ± 0.0	2.0 ± 0.1	0.5 ± 0.0	1.0 ± 0.0	0.8 ± 0.0	0.4 ± 0.1
18:3*n*–3	0.6 ± 0.1	0.8 ± 0.1	1.8 ± 0.0	0.4 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	1.8 ± 0.0	1.1 ± 0.2	0.3 ± 0.0	0.3 ± 0.0	0.4 ± 0.0	–
18:4*n*–3	0.5 ± 0.2	1.1 ± 0.2	0.7 ± 0.0	0.4 ± 0.1	1.2 ± 0.0	3.0 ± 0.1	0.8 ± 0.0	0.9 ± 0.1	0.3 ± 0.0	0.6 ± 0.2	0.3 ± 0.0	–
20:4*n*–6	1.1 ± 0.2	0.9 ± 0.0	1.9 ± 0.2	0.9 ± 0.0	0.7 ± 0.0	0.3 ± 0.0	0.8 ± 0.0	0.2 ± 0.0	0.9 ± 0.0	1.3 ± 0.1	3.4 ± 1.0	0.9 ± 0.1
20:4*n*–3	3.0 ± 0.5	1.1 ± 0.2	2.2 ± 0.2	9.3 ± 0.1	2.7 ± 0.0	0.8 ± 0.1	1.2 ± 0.0	0.8 ± 0.1	1.1 ± 0.1	0.6 ± 0.0	0.3 ± 0.0	–
20:5*n*–3	18.6 ± 4.7	24.4 ± 4.5	11.1 ± 0.5	17.8 ± 2.9	14.9 ± 0.1	14.1 ± 0.7	4.2 ± 0.0	6.8 ± 0.7	16.1 ± 0.2	24.5 ± 2.2	7.1 ± 0.3	15.3 ± 0.5
22:4*n*–6	1.2 ± 0.7	0.4 ± 0.0	0.4 ± 0.0	9.4 ± 0.9	–	–	0.4 ± 0.0	–	0.4 ± 0.0	–	–	0.2 ± 0.3
22:5*n*–3	4.0 ± 0.5	0.8 ± 0.1	4.2 ± 0.3	1.0 ± 0.1	5.5 ± 0.1	0.9 ± 0.1	5.4 ± 0.0	0.9 ± 0.1	6.2 ± 0.1	2.1 ± 0.4	2.6 ± 0.0	1.5 ± 0.0
22:6*n*–3	18.7 ± 3.8	19.3 ± 1.9	15.1 ± 0.0	8.2 ± 1.1	14.3 ± 0.1	8.1 ± 0.4	13.9 ± 0.1	3.4 ± 0.1	27.9 ± 0.4	36.7 ± 0.2	33.4 ± 1.4	29.0 ± 4.7
Others	1.7 ± 0.2	1.7 ± 0.4	5.5 ± 0.4	1.0 ± 0.3	1.9 ± 0.3	2.3 ± 0.1	3.6 ± 0.0	1.2 ± 0.7	0.8 ± 0.3	1.4 ± 0.2	2.1 ± 0.2	0.4 ± 0.0
Total	50.4 ± 8.8	51.8 ± 7.3	45.8 ± 1.3	49.3 ± 1.4	43.7 ± 0.5	32.0 ± 1.5	34.3 ± 0.1	17.5 ± 1.9	54.7 ± 0.2	68.6 ± 3.0	50.5 ± 0.3	47.7 ± 5.7
16:0DMA	–	–	–	–	–	–	–	–	–	–	–	–
18:0DMA	–	–	–	–	–	–	–	–	–	–	–	–
18:1DMA*n*–9	–	–	–	–	–	–	–	–	–	0.1 ± 0.2	–	0.9 ± 0.2
18:1DMA*n*–7	–	–	–	–	–	–	–	–	–	–	–	0.2 ± 0.2
Unknown	2.1 ± 1.6	0.1 ± 0.1	2.8 ± 0.8	0.2 ± 0.3	0.3 ± 0.0	0.7 ± 0.2	0.2 ± 0.0	0.1 ± 0.1	0.3 ± 0.0	–	1.0 ± 0.1	–

Ikura, salted salmon roe; Tarako, salted Pollock roe; Tobiko, salted flyingfish roe; Kazunoko, salted herring roe; SFA, saturaed fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

2.3. Fatty acid analysis

The TL was saponified with 0.5 M NaOH in methanol for 15 min at 100 °C. TG and PL were transesterified with 0.5 M NaOH in methanol for 30 s at 100 °C. The fatty acids were methylated with 14% BF_3 in methanol for 20 s at 100 °C, and then measured on a gas chromatograph (Shimadzu GC-18A) equipped with a fused silica capillary column, SUPELCOWAX 10 (30 m × 0.25 mm i.d.). The carrier gas was helium (flow 1 ml/min) with a split injection of 40:1. The temperature profiles were as follows: initial temperature, 175 °C; heating rate, 1 °C/min; final temperature, 220 °C (final time, 20 min); injector temperature, 250 °C; and detector temperature, 270 °C. The fatty acids were identified by comparison of the retention times with those of standard purified fatty acids (Shirai, Suzuki, Tokairin, & Wada, 2001).

3. Results

The lipid components of Ikura, Tarako, Tobiko and Kazunoko are shown in Table 1. The TL, Chol, TG and PL contents of Ikura were higher than those of Tarako, Tobiko and Kazunoko. In particular, Kazunoko had the lowest cholesterol content among these roe products. PC was the main component in the PL class of each fish roe product. The LPC percentages were higher in Tarako and Kazunoko than in Ikura and Tobiko.

The fatty acid compositions of TL from Ikura, Tarako, Tobiko and Kazunoko are presented in Table 2. The predominant fatty acids were 16:0, 18:1*n*−9, 20:5*n*−3, and 22:6*n*−3 in the TL. The 20:5*n*−3 + 22:6*n*−3 percentages of all roe products exceeded 30%. Ikura was lower in 16:0 and higher in 18:1*n*−9 percentages of TL than the other fish roe products. Tobiko had a lower 20:5*n*−3 and higher 22:6*n*−3 percentage than the other

Table 4
Fatty acid and dimethylacetal (DMA) composition of phosphatidylcholine (PC), phosphatidylethanolamine (PE) and unknown fraction in the Ikura, Tarako, Tobiko and Kazimoko (%)

	PC				PE				Unknown
	Ikura	Tarako	Tobiko	Kazunoko	Ikura	Tarako	Tobiko	Kazunoko	Tarako
SFA									
14:0	2.9 ± 0.2	1.8 ± 0.4	1.2 ± 0.1	1.7 ± 0.1	0.4 ± 0.1	0.6 ± 0.2	0.6 ± 0.0	1.4 ± 0.7	1.9 ± 0.1
16:0	22.9 ± 3.6	23.3 ± 1.4	26.3 ± 0.5	29.0 ± 2.6	6.4 ± 1.2	12.9 ± 0.6	13.3 ± 0.5	16.2 ± 0.6	7.3 ± 1.3
18:0	9.1 ± 0.2	2.4 ± 0.9	8.8 ± 0.0	2.7 ± 0.3	11.5 ± 0.0	2.9 ± 0.3	19.4 ± 0.2	3.3 ± 1.4	0.7 ± 0.1
Others	2.4 ± 1.2	0.9 ± 0.4	2.6 ± 0.1	0.9 ± 0.2	0.8 ± 0.1	0.5 ± 0.4	3.0 ± 0.0	1.1 ± 0.5	0.3 ± 0.0
Total	37.3 ± 5.1	28.4 ± 3.0	38.9 ± 0.5	34.3 ± 2.7	19.0 ± 1.4	17.0 ± 1.5	36.3 ± 0.7	22.0 ± 0.7	10.2 ± 1.5
MUFA									
16:1*n*−9	4.5 ± 3.3	1.7 ± 0.8	1.1 ± 0.2	1.3 ± 0.4	0.5 ± 0.3	0.9 ± 0.3	1.7 ± 0.1	1.1 ± 0.3	0.8 ± 0.1
16:1*n*−7	1.3 ± 0.1	1.6 ± 0.0	1.2 ± 0.0	2.5 ± 0.3	0.5 ± 0.0	0.8 ± 0.0	0.3 ± 0.0	3.1 ± 2.7	4.1 ± 0.4
18:1*n*−12	2.8 ± 1.3	1.1 ± 0.3	–	0.4 ± 0.5	0.7 ± 1.0	1.1 ± 0.1	–	0.3 ± 0.5	0.6 ± 0.1
18:1*n*−9	8.0 ± 0.5	7.1 ± 0.8	7.1 ± 0.1	5.0 ± 0.1	13.1 ± 1.2	9.9 ± 0.3	4.4 ± 0.1	12.8 ± 7.3	6.7 ± 1.3
18:1*n*−7	2.2 ± 0.3	4.1 ± 0.2	1.5 ± 0.0	4.3 ± 0.3	5.5 ± 0.0	8.0 ± 0.2	3.0 ± 0.1	9.5 ± 1.9	3.4 ± 0.7
18:1*n*−5	0.2 ± 0.3	0.5 ± 0.1	–	0.5 ± 0.0	0.9 ± 0.0	0.7 ± 0.0	–	0.6 ± 0.1	0.3 ± 0.0
20:1	1.4 ± 0.7	1.7 ± 0.2	0.3 ± 0.0	0.2 ± 0.3	4.4 ± 0.3	2.9 ± 0.1	0.5 ± 0.0	1.5 ± 0.2	1.8 ± 0.2
Others	0.8 ± 0.3	0.1 ± 0.2	0.3 ± 0.0	0.1 ± 0.2	0.4 ± 0.2	0.2 ± 0.0	0.4 ± 0.0	0.5 ± 0.4	1.6 ± 0.7
Total	21.2 ± 3.2	18.0 ± 1.2	11.4 ± 0.1	14.3 ± 0.6	26.1 ± 0.3	24.6 ± 0.4	10.4 ± 0.1	29.4 ± 8.6	19.5 ± 1.8
PUFA									
18:2*n*−6	0.9 ± 0.3	1.2 ± 0.5	0.9 ± 0.0	0.4 ± 0.1	0.7 ± 0.0	1.2 ± 0.3	0.6 ± 0.0	0.8 ± 0.3	1.1 ± 0.1
18:3*n*−3	–	0.3 ± 0.0	0.5 ± 0.0	–	–	0.3 ± 0.0	0.2 ± 0.1	0.3 ± 0.4	0.6 ± 0.0
18:4*n*−3	–	0.4 ± 0.0	0.3 ± 0.0	0.1 ± 0.2	0.1 ± 0.2	–	–	0.2 ± 0.2	1.0 ± 0.0
20:4*n*−6	0.2 ± 0.3	0.8 ± 0.1	1.9 ± 0.0	0.8 ± 0.1	1.2 ± 0.0	0.7 ± 0.0	2.2 ± 0.1	0.7 ± 0.1	2.0 ± 0.0
20:4*n*−3	0.4 ± 0.6	0.4 ± 0.1	0.3 ± 0.0	0.1 ± 0.2	0.7 ± 0.0	0.4 ± 0.0	0.3 ± 0.0	0.4 ± 0.2	0.5 ± 0.0
20:5*n*−3	10.0 ± 2.1	20.6 ± 2.0	7.6 ± 0.1	17.2 ± 1.3	20.0 ± 0.7	15.0 ± 0.6	4.3 ± 0.1	12.6 ± 1.0	35.7 ± 1.8
22:4*n*−6	0.3 ± 0.4	–	–	0.3 ± 0.4	–	–	–	–	–
22:5*n*−3	4.7 ± 0.9	0.6 ± 0.1	2.4 ± 0.1	1.4 ± 0.3	5.1 ± 0.0	1.1 ± 0.1	2.0 ± 0.0	1.6 ± 0.3	1.2 ± 0.1
22:6*n*−3	24.5 ± 3.7	27.4 ± 2.3	33.7 ± 0.3	30.8 ± 0.4	25.2 ± 0.5	37.3 ± 0.9	39.8 ± 0.6	27.2 ± 6.5	23.3 ± 0.7
Others	0.1 ± 0.2	1.4 ± 0.5	2.1 ± 0.1	0.3 ± 0.5	1.4 ± 0.3	0.8 ± 0.3	2.6 ± 0.1	0.6 ± 0.0	2.0 ± 0.6
Total	41.2 ± 7.9	53.2 ± 4.7	49.7 ± 0.6	51.4 ± 3.3	54.3 ± 1.4	56.8 ± 1.6	52.0 ± 0.6	44.4 ± 6.7	67.4 ± 3.0
16:0DMA	–	–	–	–	–	0.5 ± 0.1	1.4 ± 0.0	–	0.4 ± 0.0
18:0DMA	–	–	–	–	–	–	–	0.1 ± 0.2	–
18:1DMA*n*−9	–	–	–	–	–	0.5 ± 0.4	–	3.3 ± 0.7	0.8 ± 0.1
18:1DMA*n*−7	–	–	–	–	–	0.1 ± 0.2	–	0.8 ± 0.3	0.4 ± 0.1
Unknown	0.3 ± 0.4	0.3 ± 0.5	–	–	0.6 ± 0.2	0.6 ± 0.8	–	–	1.3 ± 0.1

Ikura, salted salmon roe; Tarako, salted Pollock roe; Tobiko, salted flyingfish roe; Kazunoko, salted herring roe; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

fish roe products. The 22:5$n-3$ percentage of Ikura was the highest among the roe products.

The fatty acid compositions of SE, TG, and PL from Ikura, Tarako, Tobiko and Kazunoko are presented in Table 3. The predominant fatty acids of SE, TG, and PL were similar to those of TL. Although the 20:5$n-3$ percentages of TG and SE were equal to the 22:6$n-3$ percentage of TG and SE in Ikura, the 22:6$n-3$ percentage was higher than the 20:5$n-3$ percentage in PL. The 20:5$n-3$ percentage of Tobiko was also lower in the SE, TG and PL than were to the other roe products. The 20:4$n-3$ and 22:4$n-6$ were included in the SE of Kazunoko. In Tarako and Kazunoko, the 22:6$n-3$ percentage was larger than the 20:5$n-3$ percentage in PL while the 20:5$n-3$ percentage was higher than the 22:6$n-3$ percentage in TG and SE. The 22:5$n-3$ percentages in TG, PL and SE were higher in Ikura than in Tarako, Tobiko and Kazunoko also was TL.

The fatty acid composition of PC and PE from Ikura, Tarako, Tobiko and Kazunoko roe are shown in Table 4. The predominant fatty acids of PC were 16:0, 20:5$n-3$ and 22:6$n-3$. Tobiko had lower 20:5$n-3$ and higher 22:6$n-3$ percentages than the other roe products in PC as well as TL. The 22:6$n-3$ was the main fatty acid of PE in Ikura, Tarako, Tobiko and Kazunoko. In PE, Tobiko had higher 18:0 and 22:6$n-3$ percentages and lower 18:1$n-9$ and 20:5$n-3$ percentages than the other fish roe products as also TL. The unknown fraction in Tarako contained a high percentage of 20:5$n-3$ and 22:6$n-3$, and dimethylacetal was detected in the unknown fraction.

4. Discussion

The TL content of Ikura was higher than in the other roe products. Ikura also had a high amount of TG, which was about half the level of lipid, while the other roe products had a TG content of less than 20%. Perhaps these differences of TL and TG contents could be influenced by differences of species and egg size. The cholesterol content of roe products is higher than in fish flesh, pork, chicken, and beef, but the contents of Tarako and Kazunoko are lower than that of a whole chicken egg. There are conflicting reports in the literature with regard to the effect of whole egg intake on plasma cholesterol content in humans, and various studies have shown either an increase or no change (Liebman & Bazzarre, 1983; Roberts, McMurry, & Connor, 1981; Buzzard, McRoberts, Driscoll, & Bowering, 1982). However, some reports indicate that the consumption of up to one egg per day is unlikely to have substantial overall impact on the risk of cardiovascular disease among healthy men and women (Hu et al., 1999), and that dietary cholesterol makes no significant contribution to atherosclerosis and the risk of cardiovascular disease (McNamara, 2000). Moreover, fish roe will not raise plasma cholesterol content since it is different from whole egg in that it contains large amounts of 20:5$n-3$ and 22:6$n-3$.

Some reports indicate that the fatty acid composition of fish roe is influenced by diet but does not depend on the degree of maturation (Kaitaranta & Ackman, 1981; Shirai et al., 2001). In this study, the SFA percentage of Tobiko was higher than those of the other fish roe samples in TL and each lipid class fraction. The SFA percentage of fish lipid increases with rising water temperature (Reiser, Stevenson, Kayama, Choudhury, & Hood, 1963). Therefore, the fatty acid composition of Tobiko may differ from the other fish roe because it was caught in Indonesia. In the TG and SE fractions, the 20:5$n-3$ percentage was greater than the 22:6$n-3$ percentage in the Tarako and Kazunoko though the opposite occurred is in Tobiko. The fatty acid composition of TG is easily changed by diet (Lie, Hemre, & Lambertsen, 1992; Shirai, Terayama, & Takeda, 2002; Shirai, Suzuki, Tokairin, Ehara, & Wada, 2002), and plankton lipid contains a high percentage of 20:5$n-3$ (Linko, Kaitaranta, & Vuorela, 1985). Therefore, the fatty acid percentages of salted roe of pollock and herring may be a result of ingesting plankton on plankton-feeder fish. Kaitaranta (1980) indicated that the fatty acid pattern of TL from fish roe was similar to that of fish flesh. However, the 20:5$n-3$ and 22:6$n-3$ percentages tend to be higher in the TL of fish roe in this study than that of fish flesh (Kinsella, 1990). Perhaps this depends on the higher amount of PL in fish roe than in fish flesh.

The unknown fraction from Tarako contained a high percentage of 20:5$n-3$ and 22:6$n-3$. This fraction appeared between the TG and SE bands in TLC. The position where the band appeared is either wax ester or diacylglycerolether (DAGE) when the solvent ratio in this study was used. However, dimethylacetal, which was released from the lipid (Ohshima, Wada, & Koizumi, 1989), was detected in this fraction. Therefore, it is inferred from these facts that the unknown fraction may be DAGE. However, this result differs from the fatty acid composition of DAGE in the other fish, which contained a high percentage of monounsaturated fatty acids (Kang, Lall, & Ackman, 1997). Further study is needed to identify the unknown fraction.

The LPC percentage of fish roe products in this study was high compared to those of raw fish roe (Tocher & Sargent, 1984). The LPC increases with salting and storage period (Ohshima, Yankah, Ushio, & Kiozumi, 1998). The periods of the salting process in Kazunoko and Tarako are longer than that in Ikura. Therefore, the LPC percentages of Kazunoko and Tarako were higher than that of Ikura. Baskaran, Sugawara, and Nagao (2003) indicate that LPC may play an important role in the intestinal uptake of carotenoids solubilized in mixed micelles. These findings suggest that the influence of salted fish roe products on the intestinal absorption of nutritional components might differ from that of raw materials.

The results of this study demonstrate that each fish roe product contained a large amount of PC, and much 22:6$n-3$. Therefore, fish roe products are expected to be a source of PC containing a high percentage of 22:6$n-3$. Lim and Suzuki (2000) have already reported that PC and DHA intake is effective for the improvement of learning ability. Furthermore, Cansell, Nacka, and Combe (2003) show that marine PL may contribute to the improvement of PUFAs absorption. This indicates that fish roe lipid may be a useful food source for maintaining human health. Moreover, the lipids of fish roe products may be effective for the improvement of learning ability and plasma lipid content. However, further studies in both human and animal models are needed for determining the effect of fish roe lipid on brain function and plasma lipid levels.

In conclusion, this study indicates that lipids of Japanese fish roe products contain large amounts of 20:5$n-3$, 22:6$n-3$ and PC, and that these may contribute to an increase in learning ability and prevent diseases resulting from lifestyle. However, it is necessary to take care of an excessive intake of salted fish roe products because a large salt intake might be a danger to health.

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References

Allain, C. C., Poon, L. S., Chan, C. S. G., Richmond, W., & Fu, P. C. (1974). Enzymatic determination of total serum cholesterol. *Clinical Chemistry, 20*, 470–475.

Baskaran, V., Sugawara, T., & Nagao, A. (2003). Phospholipids affect the intestinal absorption of carotenoids in mice. *Lipids, 38*, 705–711.

Bledsoe, G. E., Bledsoe, C. D., & Rasco, B. (2003). Caviars and fish roe products. *Critical Reviews in Food Science and Nutrition, 43*, 317–356.

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology, 37*, 911–917.

Buzzard, I. M., McRoberts, M. R., Driscoll, D. L., & Bowering, J. (1982). Effect of dietary eggs and ascorbic acid on plasma lipid and lipoprotein cholesterol levels in healthy young men. *American Journal of Clinical Nutrition, 36*, 94–105.

Cansell, M., Nacka, F., & Combe, N. (2003). Marine lipid-based liposomes increase in vivo FA bioavailability. *Lipids, 38*, 551–559.

Dittmer, J. C., & Lester, R. L. (1964). A simple, specific spray for the detection of phospolipids on thin-layer chromatograms. *Journal of Lipid Research, 5*, 126–127.

Hu, F. B., Stampfer, M. J., Rimm, E. B., Manson, J. E., Ascherio, A., Colditz, G. A., et al. (1999). A prospective study of egg consumption and risk of cardiovascular disease in men and women. *JAMA, 281*, 1387–1394.

Iwata, T., Hoshi, S., Takehisa, F., Tsutsumi, K., Furukawa, Y., & Kimura, S. (1992). The effect of dietary safflower phospholipid and soybean phospholipid on plasma and liver lipids in rats fed a hypercholesterolemic diet. *Journal of Nutritional Science and Vitaminol (Tokyo), 38*, 471–479.

Kaitaranta, J. K. (1980). Lipid and fatty acids of a whitefish (*Coregonus albula*) flesh and roe. *Journal of the Science and Food Agriculture, 31*, 1303–1308.

Kaitaranta, J. K., & Ackman, R. G. (1981). Total lipids and lipid classes of fish roe. *Comparative Biochemistry and Physiology, 69B*, 725–729.

Kang, S. J., Lall, S. P., & Ackman, R. G. (1997). Digestion of the 1-*O*-alkyl diacylglycerol ethers of Atlantic dogfish liver oils by Atlantic salmon Salmo salar. *Lipids, 32*, 19–30.

Kinsella, J. E. (1990). Sources of omega-3-fatty acids in human diets. In R. S. Lees & M. Karel (Eds.), *Omega-3-fatty acids in health and disease* (pp. 157–200). New York: Marcel Dekker Inc..

Lie, Ø., Hemre, G.-L., & Lambertsen, G. (1992). Influence of dietary fatty acids on the glycerophospholipid composition in organs of cod (*Gadus morhua*). *Lipids, 27*, 770–775.

Liebman, M., & Bazzarre, T. L. (1983). Plasma lipids of vegetarian and nonvegetarian males: effects of egg consumption. *American Journal of Clinical Nutrition, 38*, 612–619.

Lim, S. Y., & Suzuki, H. (2000). Effect of dietary docosahexaenoic acid and phosphatidylcholine on maze behavior and fatty acid composition of plasma and brain lipids in mice. *International Journal for Vitamin and Nutrition Research, 70*, 251–259.

Lim, S. Y., & Suzuki, H. (2002). Dose–response effect of egg-phosphatidylcholine on maze-learning ability and fatty acid composition of plasma and brain in aged mice fed an $n-3$ fatty acid-deficient diet. *Annals of Nutrition and Metabolism, 46*, 215–221.

Linko, R. P., Kaitaranta, J. K., & Vuorela, R. (1985). Comparison of the fatty acid in Baltic herring and available plankton feed. *Comparative Biochemistry and Physiology, 82B*, 699–705.

McNamara, D. J. (2000). Dietary cholesterol and atherosclerosis. *Biochimica et Biophysica Acta, 1529*, 310–320.

Nordøy, A., Marchioli, R., Arnesen, H., & Videbaek, J. (2001). $n-3$ polyunsaturated fatty acids and cardiovascular diseases. *Lipids, 36*, S127–S129.

Ohshima, T., Wada, S., & Koizumi, C. (1989). 1-*O*-alk-1'-enyl-2-acyl and 1-*O*-alkyl-2-acyl glycerophospolipids in white muscle of bonito *Euthynnus pelamis* (linnaeus). *Lipids, 24*, 363–370.

Ohshima, T., Yankah, V. V., Ushio, H., & Kiozumi, C. (1998). Antioxidizing potentials of BHA, BHT, TBHQ, tocopherol, and oxygen absorber incorporated in a Ghanaian fermented fish product. *Advances in Experimental Medicine and Biology, 434*, 181–188.

Reiser, R., Stevenson, B., Kayama, M., Choudhury, R. B. R., & Hood, D. W. (1963). The influence of dietary fatty acids and environmental temperature on the fatty acid composition of teleost fish. *Journal of American Oil Chemists Society, 40*, 507–513.

Roberts, S. L., McMurry, M. P., & Connor, W. E. (1981). Does egg feeding (i.e., dietary cholesterol) affect plasma cholesterol levels in humans. The results of a double-blind study. *American Journal of Clinical Nutrition, 34*, 2092–2099.

Rouser, G., Siakotos, A. N., & Fleischer, S. (1966). Quantitative analysis of phospholipids by thin-lyer chromatography and phosphorus analysis of spots. *Lipids, 1*, 85–86.

Shirai, N., Suzuki, H., Tokairin, S., Ehara, H., & Wada, S. (2002). Dietary and seasonal effects on the dorsal meat lipid composition of Japanese catfish Silurus asotus and (Thai catfish *Clarias macrocephalus* and hybrid: *Clarias macrocephalus* and *Clarias galipinus*). *Comparative Biochemistry Physiology, 132A*, 609–619.

Shirai, N., Suzuki, H., Tokairin, S., & Wada, S. (2001). Spawning and season affect lipid content and fatty acid composition of ovary and liver in Japanese catfish (*Silurus asotus*). *Comparative Biochemistry Physiology, 129B*, 185–195.

Shirai, N., Terayama, M., & Takeda, H. (2002). Effect of season on the fatty acid composition and free amino acid content of the sardine *Sardinops melanostictus*. *Comparative Biochemistry Physiology, 131B*, 387–393.

Spayd, R. W., Bruschi, B., Burdick, B. A., Dappen, G. M., Eikenberry, J. N., Esders, T. W., et al. (1978). Multilayer film elements for clinical analysis: applications to representative chemical determinations. *Clinical Chemistry, 24*, 1343–1350.

Suzuki, H., Park, S. J., Tamura, M., & Ando, S. (1998). Effect of the long-term feeding of dietary lipids on the learning ability, fatty acid composition of brain stem phospholipis and synaptic membrane fluidity in adult mice: a comparison of sardine oil diet with palm oil diet. *Mechanisms of Ageing and Development, 101*, 119–128.

Tocher, D. R., & Sargent, J. R. (1984). Analyses of lipids and fatty acids in ripe roes of some northwest european marine fish. *Lipids, 19*, 492–499.

Yonekubo, A., Honda, S., Okano, M., Takahashi, K., & Yamamoto, Y. (1994). Effects of dietary fish oil during the fetal and postnatal periods on the learning ability of postnatal rats. *Bioscience Biotechnology and Biochemistry, 58*, 799–801.