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Fatty Acids of Lipids from Fish Testes with Particular Reference to Furan Fatty Acids

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Abstract

Lipid class and fatty acid analyses with particular reference to furan fatty acid were carried out on the testes of four marine fish (herring *Clupea pallasi*, chum salmon *Oncorhynchus keta*, rainbow smelt *Osmerus eperlanus mordax* and walleye pollock *Theragra chalcogramma*) and two reared freshwater fish (coho salmon *Oncorhynchus kisutch* and whitespotted char *Salvelinus leucomaenis*).

The total lipid content was between 1.2-4.1% of the testis wet weight. The major lipid class was phospholipids (PL) (55.5-69.4% of the total lipids), followed by free sterols (ST) (15.4-21.2%) and free fatty acids (FFA) (5.3-27.7%). Triacylglycerols (TG) were present with low levels (0.6-9.3%).

The fatty acid composition of TG differed from those of other lipid fractions, particularly with regard to the levels of total monounsaturated acids (of which there are more) and of total polyunsaturated acids (of which there are less). The sterol esters (SE), FFA and PL contained more polyunsaturated acids and less monounsaturated acids than the TG.

Furan fatty acids (F acids) were found in the lipid classes of the testis lipids of all fish other than walleye pollock and whitespotted char and were found mainly in the SE and TG with a range of 1.1 to 28.6% of the total fatty acids. They were found in much smaller amounts (up to 0.7%) in the FFA and PL.

The results suggest that the occurrence of F acids in fish testes is influenced by thier degree of maturation.

Introduction

Aquatic animals have a large number of structually unusual fatty acids[1~6]. Furan fatty acids (F acids) have also found in the lipids of aquatic organisms[7~12]. In freshwater fish, the F acids occur abundantly in the testis, liver and blood serum, and although in small amounts also in the muscle. Glass et al.[8] have reported that at spawning season, the F acids in the liver lipids decreased and on the contrary they increased in the testes lipids. The occurrence of F acids in fish organs is of interest in regards to their origin and function. Although the lipids of fish ovary have been examined in detail in connection to reproduction[13~16], in particular the polyunsaturated acids are known to be important for embryo growth and growth of the egg after fertilization, not much is known about lipid composition and fatty acid distribution in the lipid fractions of fish testis.

In this paper, the lipid class and fatty acid compositions of testes lipids from four marine fish and two reared freshwater fish were examined with particular reference to the F acids.

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Materials and Methods

Fish testes

Testes were excised from the following fish: herring (*Clupea pallasi*) (A) and walleye pollock (*Theragra chalcogramma*) obtained from the fish market; herring (B) caught at Bokkai bay; chum salmon (*Oncorhynchus keta*) captured in rivers (C: Abashiri, 1983 and D: Moheji, 1981) in Hokkaido and a river (E: Ozuchi, 1984) in Miyagi prefecture; rainbow smelt (*Osmerus eperlanus mordax*) caught off the coast of Southern Hokkaido; coho salmon (*Oncorhynchus kisutch*) and whitespotted char (*Salvelinus leucomaenis*) reared in freshwater ponds. All testes other than whitespotted char testis which was obtained at spermatogenic stage (Spermatogonium→ Spermatocyte) were obtained from fish at matured stage.

Extraction and fractionation of lipids

The lipids of testes were extracted by the method of Bligh and Dyer[17]. Fractionation of the total lipids into neutral lipids (NL) and phospholipids (PL) was carried out by column chromatography on silicic acid (Silica gel 60, Merck) using chloroform and methanol as solvents. The NL was separated into lipid classes by thin layer chromatography (TLC) on Silica gel 60G plates of 0.5 mm thickness using hexane/diethyl ether/acetic acid (85 : 15 : 1 by vol.) as a solvent.

Fatty acid analyses

The separated lipid classes were saponified by refluxing with 1N KOH ethanol for 1 hr and the unsaponifiables were extracted with diethyl ether. Following acidification with 2N HCl, the fatty acids were recovered by extraction with diethyl ether and subsequently converted to methyl esters by heating with 7% BF_3-methanol at 100°C for 10 min.

The concentration of furan fatty acid fraction from TG fatty acid methyl esters (FAME) was carried out by urea adduct fractionation (9 vol. urea and 50 vol. methanol) and $AgNO_3$-TLC on Silica gel 60G plates (0.5 mm thickness) impregnated with 10% $AgNO_3$ using hexane/benzene (1 : 1 v/v) as a solvent.

The FAME were analyzed by gas liquid chromatography (GLC) carried out in a Yanagimoto G80 gas chromatograph with a flame ionization detector. Two glass columns (1.5 m×3 mm i.d.) packed with 10% DEGS on Chromosorb WAW (100-120 mesh) and with 15% BDS on Chromosorb WAW (80-100 mesh) were used. The columns were held at 190°C and/or 210°C.

Component peaks were identified by comparison with standards[11] and quantified by a Shimadzu Chromatopac ElA.

Results and Discussion

Table 1 shows the lipid content and lipid class composition of the testes.

The lipid contents of testes ranged between 1.2-4.1% wet weight and no significant difference in lipid content among the testes except for walleye pollock was observed.

In all species, the major lipid class was phospholipids, amounting to 55.5-69.4% of the total lipids. In the neutral lipids, free sterols (ST) were the major lipid class

Table 1. Lipid content and lipid class composition of fish testes.

	Herring		Chum salmon			Rainbow smelt	Walleye pollock	Coho Salmon	Whitespotted char
	A*1	B*1	C*1	D*1	E*1				
Lipid content (%)	4.1	3.2	2.0	2.4	2.8	3.5	1.2	2.6	2.2
Lipid class (% of total lipids)									
Sterol esters*2	0.5	0.7	0.8	0.9	0.8	0.5	0.8	0.8	2.7
Triacylglycerols	1.3	0.6	4.0	4.1	6.6	6.9	2.7	1.3	9.3
Free fatty acids	12.5	27.7	9.2	13.5	17.5	11.0	18.3	14.0	5.3
Sterols	16.2	15.4	17.6	20.3	17.2	16.2	21.2	18.0	18.8
Phospholipids	69.4	55.5	68.0	60.7	57.6	65.4	57.1	65.9	64.0
Others*3	—	—	0.4	0.5	0.4	—	—	—	—

*1 See text for materials.
*2 Includes a small amount of hydrocarbons.
*3 Mainly partial glycerides.

(15.4-21.2%). Low values (0.6-9.3%) of triacylglycerols (TG) were determined. On the contrary, the testes lipids of all fish other than whitespotted char contained relatively high amounts (9.2-27.7%) of free fatty acids (FFA). The testes lipids of whitespotted char collected at early spermatogenic stage contained more TG and less FFA than those of other species.

Generally, FFA of fish muscle are considered to arise from hydrolysis of PL during storage. However, as described below, the fatty acid composition of FFA is not necessarily the same as those from the PL. Hence, it was considered that this fraction was partly metabolites of specific lipid metabolism in the testes during maturation. The ST and PL in fish testes were considered to be important components as structural elements in membranes. These results may indicate a characteristic pattern in the lipid composition of mature testes of fish. Furthermore, the high content of FFA may also be characteristic of matured testes of fish.

The fatty acid compositions of individual lipid classes from the testes are shown in Tables 2, 3 and 4. The analyses of fatty acids indicated different fatty acid compositions for the PL and TG.

In marine species, the fatty acids of PL which are most predominant in the testes contained relatively high contents of 16 : 0, 20 : 5 (n-3) and 22 : 6 (n-3) as compared to TG. On the contrary, the TG contained more long-chain monounsaturated acids (20 : 1 and 22 : 1) and less 20 : 5 (n-3) and 22 : 6 (n-3) than other lipid classes except for in the case of rainbow smelt. The fatty acid compositions of the FFA and SE tended to have higher amounts of 18 : 0 and 20 : 5 (n-3) than that from the TG. Similar results were obtained from the testes lipids of reared freshwater species.

The high contents of 20 : 1 and 22 : 1 in the TG of the testes lipids from the two reared fish can be attributed to the large amounts of these acids in their diets since generally, such acids are contained less in the lipids of freshwater fish than in marine fish[18,19].

Table 2. Fatty acid composition of lipid classes from testes of herring (as % of total fatty acids).

Fatty acid	A[*1]				B[*1]			
	SE[*2]	TG[*2]	FFA[*2]	PL[*2]	SE	TG	FFA	PL
12 : 0	—	—	—	—	—	—	—	—
Iso 14 : 0	0.7	0.1	Tr[*3]	Tr	1.0	0.8	—	—
14 : 0[*4]	1.4	5.6	0.8	0.9	0.7	3.2	0.4	0.5
15 : 0	0.2	0.4	0.1	0.2	0.4	1.0	0.2	0.3
Pristanic	0.4	0.6	Tr	0.1	0.3	0.6	Tr	0.1
16 : 0	16.8	13.2	11.7	31.8	16.2	14.3	12.0	28.3
Phytanic	1.7	3.2	0.4	0.3	1.7	2.2	0.3	0.4
18 : 0	1.8	2.0	4.4	1.8	1.6	3.5	4.1	1.3
14 : 1	0.4	0.2	Tr	Tr	0.4	0.1	—	Tr
16 : 1	5.5	7.4	2.6	1.0	4.2	6.5	1.0	0.6
17 : 1	0.4	0.1	0.3	0.3	0.8	0.5	0.4	0.5
18 : 1	15.3	26.5	19.0	26.8	14.4	35.3	17.8	26.1
20 : 1	4.0	7.4	1.1	0.7	2.7	4.8	0.7	0.5
22 : 1	3.3	6.7	Tr	Tr	2.0	4.6	Tr	Tr
24 : 1	0.4	1.5	—	—	0.1	Tr	—	—
18 : 2 (n-6)	0.7	1.2	2.3	0.7	1.0	1.3	1.4	0.8
18 : 3 (n-6)	0.2	0.1	—	—	0.3	0.2	—	0.1
18 : 3 (n-3)	0.3	0.6	0.8	0.2	0.3	0.6	0.5	0.1
18 : 4 (n-3)	—	—	—	—	—	—	—	—
20 : 2 (n-6)	—	—	0.2	0.2	—	—	—	0.1
20 : 3 (n-6)	—	—	0.1	—	—	—	0.1	Tr
20 : 4 (n-6)	1.7	1.5	3.5	1.6	2.9	0.7	3.0	0.8
20 : 4 (n-3)	Tr	Tr	1.4	0.3	—	—	0.8	0.3
20 : 5 (n-3)	20.6	6.0	19.3	9.9	21.4	6.8	19.2	8.5
22 : 5 (n-6)	0.1	0.5	0.2	0.2	—	—	0.2	0.3
22 : 5 (n-3)	0.5	1.6	3.3	1.4	0.8	2.0	2.3	1.7
22 : 6 (n-3)	17.8	4.9	28.0	20.9	25.1	7.5	35.3	28.2
Total saturates	23.0	25.1	17.4	35.1	21.9	25.6	17.0	30.9
Total monoenes	29.3	49.8	23.0	28.8	24.6	51.8	19.9	27.7
Total polyenes	41.9	16.4	59.1	35.4	51.8	19.1	62.8	40.9
Furan fatty acids	5.6	8.5	—	—	1.2	3.4	0.4	—
Unknowns	0.2	0.1	0.5	0.7	0.5	—	—	0.5
(n-3)/(n-6) polyenes	14.5	4.0	8.4	12.1	11.3	7.7	12.4	18.5

[*1] See text for materials.
[*2] SE - Sterol esters, TG - Triacylglycerols, FFA - Free fatty acids, PL - Phospholipids.
[*3] Trace (less than 0.05%).
[*4] Includes a small amount of 4, 8, 12-trimethyltridecanoic acid.

Table 3. Fatty acid composition of lipid classes from testes of chum salmon (as % of total fatty acids).

Fatty acid	C*1				D*1				E*1			
	SE*2	TG*2	FFA*2	PL*2	SE	TG	FFA	PL	SE	TG	FFA	PL
12 : 0	0.1	0.1	—	—	0.1	0.1	—	—	0.1	Tr*3	—	—
Iso 14 : 0	0.7	0.2	0.1	Tr	0.4	0.1	0.1	Tr	1.8	0.6	0.2	Tr
14 : 0*4	1.8	2.7	1.2	2.6	1.3	4.0	1.6	3.1	2.0	4.8	1.5	3.8
15 : 0	0.7	0.1	0.2	0.5	0.5	0.2	0.2	0.6	0.4	0.2	0.2	0.6
Pristanic	0.5	1.9	0.2	0.1	0.4	1.7	0.5	0.1	0.6	3.2	0.4	0.1
16 : 0	27.6	3.4	11.4	24.6	24.1	5.9	9.1	24.4	23.0	4.0	8.4	24.4
Phytanic	2.0	7.0	0.9	0.8	1.9	7.0	1.4	0.6	1.4	10.9	1.0	1.0
18 : 0	3.0	0.5	5.2	2.9	2.6	1.2	3.9	2.3	2.2	0.6	3.8	2.7
14 : 1	0.7	0.1	Tr	Tr	0.3	0.1	Tr	Tr	0.1	0.1	0.1	0.1
16 : 1	7.5	7.6	4.0	3.5	5.4	6.2	4.1	1.3	6.1	8.9	4.2	3.9
17 : 1	0.5	0.2	0.3	0.4	0.8	0.3	0.5	0.4	0.4	0.2	0.6	0.4
18 : 1	12.4	22.1	21.7	22.6	13.6	18.4	18.3	18.4	12.0	16.9	16.2	21.0
20 : 1	0.4	3.0	2.1	1.2	1.0	3.7	3.1	1.5	1.7	5.6	3.3	1.8
22 : 1	—	1.5	1.3	0.9	Tr	2.6	2.5	0.5	0.7	3.6	1.6	0.6
24 : 1	—	Tr	Tr	—	—	0.4	1.0	—	—	Tr	0.3	Tr
18 : 2 (n-6)	1.9	1.6	1.4	0.6	2.3	1.5	2.4	0.8	1.6	1.7	2.2	0.7
18 : 3 (n-6)	0.8	Tr	Tr	Tr	0.3	Tr	Tr	Tr	0.1	Tr	Tr	Tr
18 : 3 (n-3)	0.7	2.1	1.1	0.3	1.9	1.8	2.0	0.4	1.6	2.0	1.6	0.3
18 : 4 (n-3)	1.5	1.3	0.9	0.2	1.6	1.5	1.4	0.2	0.8	1.1	0.9	0.1
20 : 2 (n-6)	0.1	0.2	0.2	0.2	0.1	0.3	0.3	0.2	0.1	0.4	0.3	0.2
20 : 3 (n-6)	—	0.2	0.1	Tr	0.2	0.2	0.2	0.1	Tr	0.2	0.1	Tr
20 : 4 (n-6)	1.7	0.7	2.8	2.4	2.1	0.8	3.0	2.5	2.2	0.7	3.1	2.4
20 : 4 (n-3)	1.0	0.8	1.2	0.3	1.7	1.3	1.8	0.6	1.4	1.0	1.5	0.4
20 : 5 (n-3)	17.4	5.5	23.2	17.3	22.7	6.5	21.2	22.2	25.4	6.9	28.4	16.5
22 : 5 (n-6)	—	Tr	0.3	0.1	0.1	Tr	—	0.2	0.1	—	0.2	0.1
22 : 5 (n-3)	0.8	1.5	3.4	1.8	1.3	2.0	3.8	1.9	1.5	2.3	3.3	2.5
22 : 6 (n-3)	11.6	7.1	16.4	14.3	11.2	9.2	17.1	16.9	10.5	7.3	15.7	14.3
Total saturates	36.4	15.9	19.2	31.5	31.3	20.2	16.8	31.1	31.5	24.3	15.5	32.6
Total monoenes	21.5	34.5	29.4	28.6	21.1	31.7	29.5	22.1	21.0	35.3	26.3	27.8
Total polyenes	37.5	21.0	51.0	37.5	45.5	25.1	53.2	46.0	45.3	23.6	57.3	37.5
Furan fatty acids	3.0	28.6	—	—	1.9	22.9	—	0.7	—	16.7	0.7	0.4
Unknowns	1.5	—	0.5	2.3	0.2	—	0.6	—	2.1	0.2	0.1	1.6
(n-3)/(n-6) polyenes	7.3	6.8	9.6	10.4	7.9	8.0	8.0	11.1	10.1	6.9	8.7	10.0

*1 See text for materials. *2 SE - Sterol esters, TG - Triacylglycerols, FFA - Free fatty acids, PL - Phospholipids.
*3 Trace (less than 0.05%). *4 Includes a small amount of 4, 8, 12-trimethyltridecanoic acid.

Table 4. Fatty acid composition of lipid classes from testes of rainbow smelt, walleye pollock, coho salmon and whitespotted char (as % of total fatty acids).

Fatty acid	Rainbow smelt				Walleye pollock				Coho salmon				Whitespotted char			
	SE*1	TG*1	FFA*1	PL*1	SE	TG	FFA	PL	SE	TG	FFA	PL	SE	TG	FFA	PL
12 : 0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Iso 14 : 0	1.3	0.1	0.1	Tr*2	0.2	Tr	—	Tr	0.2	0.1	—	—	0.7	0.1	0.2	0.1
14 : 0*3	0.6	3.0	0.6	1.4	1.2	4.2	0.9	1.4	1.2	2.6	1.4	1.9	1.7	2.6	0.9	1.3
15 : 0	0.3	0.3	0.1	0.4	0.4	0.3	0.1	0.3	0.5	0.7	0.1	0.2	0.5	0.2	0.3	0.2
Pristanic	0.3	0.2	0.1	0.1	0.4	0.8	0.1	0.1	0.3	0.6	0.1	Tr	0.5	0.1	0.1	0.1
16 : 0	7.7	11.1	12.5	27.6	7.3	11.3	9.1	29.0	24.8	10.1	13.7	34.0	19.9	16.2	24.5	25.7
Phytanic	1.0	0.7	1.1	1.1	0.9	2.3	1.0	0.9	0.5	0.5	0.2	0.2	0.5	0.3	0.4	1.0
18 : 0	1.3	2.1	3.3	2.1	1.5	2.3	6.5	2.8	2.7	2.3	3.4	3.5	2.1	3.8	6.4	5.1
14 : 1	—	0.3	Tr	0.1	—	0.2	Tr	—	0.3	0.1	—	—	0.5	0.1	Tr	—
16 : 1	5.1	10.2	3.8	4.6	4.8	8.9	2.7	1.6	8.8	7.9	6.4	1.0	7.0	7.2	4.1	4.5
17 : 1	0.3	0.3	0.7	0.5	0.2	0.1	0.1	0.3	0.3	0.2	0.1	0.2	0.4	0.2	0.3	0.4
18 : 1	13.2	24.8	16.9	15.6	10.6	19.9	14.9	24.4	22.6	29.7	26.6	17.7	18.6	30.1	18.1	20.9
20 : 1	1.1	2.1	0.7	0.4	2.1	11.4	3.7	5.9	3.3	11.1	5.1	1.6	2.6	6.4	1.5	1.1
22 : 1	Tr	Tr	Tr	0.1	0.9	10.9	1.0	1.2	1.0	4.8	0.9	Tr	Tr	2.5	—	0.3
24 : 1	—	—	—	—	Tr	1.1	Tr	Tr	—	—	—	—	Tr	0.4	—	—
18 : 2 (n-6)	0.5	0.4	0.7	0.6	0.9	1.1	0.4	0.3	8.4	7.2	8.9	1.6	10.0	19.9	8.7	5.9
18 : 3 (n-6)	0.1	0.1	—	—	Tr	Tr	Tr	0.1	—	0.1	Tr	0.1	0.4	0.2	0.3	0.1
18 : 3 (n-3)	0.3	0.2	0.3	0.1	0.3	0.5	0.1	Tr	0.7	0.6	0.7	0.2	0.3	0.8	0.3	Tr
18 : 4 (n-3)	—	—	—	—	0.8	1.4	0.4	0.1	—	—	—	—	—	—	—	—
20 : 2 (n-6)	0.1	0.4	0.3	Tr	0.1	0.3	0.3	0.2	—	0.2	0.4	0.2	1.4	0.9	0.7	0.4
20 : 3 (n-6)	—	0.4	0.2	Tr	—	—	0.1	Tr	—	0.2	0.4	0.2	1.9	0.4	1.4	0.9
20 : 4 (n-6)	3.9	7.8	7.8	4.6	3.6	0.3	4.6	1.2	1.8	1.2	2.1	3.7	3.3	0.5	10.1	8.2
20 : 4 (n-3)	Tr	1.6	1.1	0.1	0.7	0.4	0.6	0.3	—	—	—	Tr	0.3	0.2	0.2	—
20 : 5 (n-3)	37.1	20.5	30.4	17.0	31.6	13.7	28.6	13.2	5.9	1.8	9.2	14.6	9.3	1.6	7.7	3.5
22 : 5 (n-6)	—	0.4	0.1	0.1	0.3	0.1	0.2	0.1	1.5	1.0	0.2	0.2	0.3	0.1	0.2	0.3
22 : 5 (n-3)	3.5	5.8	6.2	4.4	1.9	1.1	2.6	1.5	2.7	7.4	2.8	0.8	1.0	0.8	0.9	1.2
22 : 6 (n-3)	20.7	6.1	12.4	18.5	26.3	5.0	21.3	14.1	6.5	4.4	16.6	16.9	15.3	3.9	11.9	18.6
Total saturates	12.5	17.5	17.8	32.7	11.9	21.2	17.7	34.5	30.2	16.9	18.9	39.8	25.9	23.3	32.8	33.5
Total monoenes	19.7	37.7	22.1	21.3	18.6	52.5	22.4	33.4	36.3	53.8	39.1	20.5	29.1	46.9	24.0	27.2
Total polyenes	66.2	43.7	59.5	45.4	66.5	23.9	59.2	31.1	27.5	24.1	41.3	38.5	43.5	29.3	42.4	39.1
Furan fatty acids	1.1	0.8	0.2	—	—	—	—	—	3.3	3.0	0.4	—	—	—	—	—
Unknowns	0.5	0.3	0.5	0.7	2.9	2.4	0.8	1.1	2.6	2.2	0.2	1.2	1.5	0.4	0.8	0.2
(n-3)/(n-6) polyenes	13.4	3.6	5.5	7.6	12.6	12.3	9.6	15.4	1.4	1.4	2.4	5.4	1.5	0.3	1.0	1.5

*1 SE - Sterol esters, TG - Triacylglycerols, FFA - Free fatty acids, PL - Phospholipids. *2 Trace (less than 0.05%). *3 Includes a small amount of 4, 8, 12-trimethyltridecanoic acid.

In this study, the fatty acid composition of the total lipids was not determined. However, a composition similar to that from the PL is expected because of the most predominant component in the testes lipids.

The ratios of total fatty acids (n-3) to (n-6) in the TG and PL showed higher levels in those from marine species than in the freshwater species. The low value of this ratio in rainbow smelt as compared to those of other marine species is due to high amount of 20 : 4 (n-6) and suggests a different food habit between the former and the latter.

F acids were found in the testes lipids of four fish except for walleye pollock and whitespotted char, and were concentrated mainly in the TG and SE. Very little (less than 0.7% of the total fatty acids) were found in the FFA and PL. Gunstone et al. have reported that high amounts (84.3%) of F acids occurred in the liver SE of starved cod (*Gadus morhua*)[9]. However, F acids were found at low levels (up to 5.6%) in the SE fatty acids.

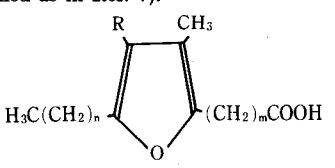
Table 5 shows F acid composition of the TG from testes lipids. In the F acid found, F_6 acid was almost always the major component having 50-94% of the total F acids. The next most common F acid was F_4 acid followed by F_5 acid. These results were similar to those of the testes lipids of freshwater fish[8]. However, F acid

Table 5. Furan fatty acid composition of triacylglycerols from fish testes.

				Herring		Chum salmon			Rainbow smelt	Coho salmon
				A*1	B*1	C*1	D*1	E*1		
% of total fatty acids				8.5	3.4	28.6	22.9	16.7	0.8	3.0
% of total F acids*2										
	m	n	R							
F_1	8	2	CH_3	2.4	—	0.3	0.6	0.2	12.5	—
F_2	8	4	H	7.1	—	0.9	2.2	1.0	Tr*3	3.3
F_3	8	4	CH_3	3.5	3.0	0.5	0.6	0.2	12.5	—
F_4	10	2	CH_3	22.4	Tr	19.2	21.5	22.1	Tr	36.7
F_5	10	4	H	11.8	3.0	7.4	10.7	11.6	—	10.0
F_6	10	4	CH_3	52.9	93.9	61.8	58.1	59.1	75.0	50.0
$F_{6'}$*4	12	2	CH_3	Tr	—	2.5	2.0	2.3	—	—
F_7	12	4	H	—	—	0.6	0.2	0.7	—	—
F_8	12	4	CH_3	Tr	—	6.4	3.3	2.0	—	—
Unknowns				—	—	0.4	0.8	0.8	—	—

*1 See text for materials.

*2 Named as in Ref. 7).



*3 Trace (less than 0.05%).

*4 14, 17-epoxy-15, 16-dimethyleicosa-14, 16-dienoic acid[11].

composition of rainbow smelt was slightly different from other testes in terms of their high contents of F_1 and F_3 acids.

The absence of F acids in the testis lipids of whitespotted char may be closely related to the degree of maturation, while in the walleye pollock the F acids may be preferentially concentrated in other tissues (for example, in the liver) as observed in starved cod[9].

In chum salmon, all of the testes collected from different locations and years contained F acids at relatively high amounts (about 20% of the total fatty acids).

The origin and function of F acids in aquatic organisms remain obscure. As shown in Table 3, the TG of chum salmon testes also contained a high amount of phytanic acids compared to other lipid classes.

High accumulation of this acid in the TG of chum salmon testes may be closely related to the decay of lipid catabolism since this acid is not subject to catabolism compared to other straight chain fatty acids[6]. Similarly, it can be considered that the accumulation of F acids in the testes TG is markedly controlled by fatty acid catabolism during the spawning season rather than by dietary habit.

Very few studies if any, have been made of testes lipids where lipid class analyses was conducted together with fatty acid analyses of individual lipid classes.

Our data in this study indicates that the lipids of mature fish testes had a characteristic lipid composition composed of high amounts of ST, PL and FFA, and of higher amounts of F acids in the TG than in other organs.

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