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Fatty Acids in Lipids of Mature Chum Salmon, *Oncorhynchus keta*, with Special Reference to Phytanic Acid

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Abstract

The component fatty acids of the lipid classes of serum, liver, and dorsal muscle from mature chum salmon, *Oncorhynchus keta*, were examined with special reference to phytanic acid.

The free fatty acids (FFA) in the serum contained more phytanic acid than sterol esters (SE), triacylglycerols (TG) and phospholipids (PL). Whereas, in the liver and dorsal muscle, this acid tended to be accumulated in the TG and SE.

A distinct difference in the phytanic acid content in the serum and liver was determined in salmon of different sex. The phytanic acid content in male serum and liver was 12 mg/100 ml and 22 mg/100 g, respectively. These levels were about twice as high as those of females.

It was assumed that the sex difference in the distribution of component fatty acids including phytanic acid in the lipid classes of mature chum salmon tissues was closely related to fish physiology in the spawning season, and also in the male the inactivation of lipid catabolism caused by completion of maturation took place in preference to that in the female.

Introduction

Three isoprenoid fatty acids [4, 8, 12-trimethyltridecanoic (4, 8, 12-TMTD), 2, 6, 10, 14-tetramethylpentadecanoic (pristanic) and 3, 7, 11, 15-tetramethylhexadecanoic (phytanic) acids] have been widely found in the marine organisms[1~3,6,7]. Their occurrence and biochemistry have been summarized by some authors in detail[1,4,5].

The isoprenoid fatty acids have been found to constitute between 0.42-0.65% of the total fatty acids in marine fish, 0.40-1.57% in whale and 0.04-1.49% in zooplankton[5].

In humans, especially, a close relationship between phytanic acid and Refsum's syndrome has been revealed[5,8,9]. It has been suggested that the high concentration of this acid in the tissues is due to a decline in the catabolic process (in particular, α-oxidation).

Chum salmon, *Oncorhynchus keta*, migrate into rivers from the ocean for spawning and after spawning they die. During this time, numerous physiological and biochemical changes occur: maturation, starvation and utilization of stored chemical components[10~14].

In order to clarify the relationship between the maturation and the lipid metabolism of chum salmon, it is necessary to investigate the lipid classes and fatty acid composition of the tissues in detail.

In the present study, the lipid class and fatty acid compositions of the dorsal

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muscle, liver and serum of mature female and male chum salmon were investigated with special reference to phytanic acid.

Materials and Methods

Materials

Mature chum salmon, *Oncorhynchus keta* (3 females and 5 males), with an average body length of 69 cm were captured from Shiriuchi River in south Hokkaido, in December, 1982. Blood was collected from the caudal vessels with a hypodermic syringe. The serum was separated after centrifugation at 3,000 rpm for 15 min.

Young chum salmon having an average total length of 36 cm were caught from the North Pacific Ocean in July, 1981 at 55°59′N, 179°59′W as materials for comparison with mature chum salmon.

Extraction and separation of lipids

The lipids in the dorsal muscle, liver and serum were extracted by the method of Bligh and Dyer[15]. 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 subsequently fractionated into the lipid classes by thin-layer chromatography (TLC) on silica gel plates (0.5 mm, Silica gel G) using hexane/diethyl ether/acetic acid (85 : 15 : 1, v/v) as the development solvent.

Fatty acid analysis

Fatty acid methyl esters (FAME) were prepared from the separated lipid classes by heating with 7% BF_3-methanol and/or 0.5N sodium methoxide-methanol followed by purification by TLC on silica gel plates (0.5 mm, Silica gel G, Merck) using hexane/diethyl ether (85 : 15, v/v) as the development solvent.

Separation of the isopreonoid fatty acid fraction from the total fatty acids for identification by gas chromatography-mass spectrometry (GC-MS) was carried out by argentation-TLC and urea fractionation.

The total FAME from chum salmon tissues was warmed with urea (9 parts) and methanol (50 parts) and this solution was stored at −20°C for 3 hrs and filtered. The non-urea complexing FAME was further fractionated by argentation-TLC (Silica gel G plates impregnated with 10% $AgNO_3$) using hexane/benzene (7 : 3 v/v) as the development solvent.

GC analysis of FAME was carried out on a Yanagimoto G80 gas chromatograph equipped with a flame ionization detector. Two glass columns (1.5×3 mm i.d.) with 15% BDS on Chromosorb WAW (80–100 mesh) at 215°C and 5% DEGS on chromosorb WAW (100–120 mesh) at 190°C, respectively, were used. Individual fatty acids were identified by comparison with known standards and equivalent chain length (ECL), and quantified using a Shimadzu Chromatopac E1A.

GC-MS analysis of isoprenoid fatty acids was performed with a Hitachi 60 M operated at 20 eV and equipped with a glass column (2 m×3 mm i.d.) packed with 3% Silar 10 C on Gas Chrom Q (100–120 mesh) at 150°C.

Results

Identification of isoprenoid fatty acids

The gas chromatogram of the methyl esters of the isoprenoid acid fraction concentrated from chum salmon tissue showed three peaks with ECL values of 14.05 (A), 15.52 (B) and 16.86 (C), respectively, on the BDS column (Fig. 1). As shown in Fig. 2, the mass spectrum of component C showed a molecular ion peak (M^+) at m/e 326 and the fragment peaks at m/e 101 (basepeak) characteristic of the 3-methyl substituent, m/e 143 and 171 characteristic of the 7-methyl substituent, m/e 213 and 241 characteristic of the 11-methyl substituent and m/e 283 and 311 (M-15) characteristic of the 15-methyl substituent. From these results component C was confirmed to be methyl phytanate[16]. Similarly, the mass spectra of components A and B showed characteristic fragment peaks for methyl esters of 4, 8, 12-TMTD and pristanic acids (data not shown).

Lipid content and lipid class composition

Table 1 shows the lipid content and lipid class composition of chum salmon tissues. Lipids from each tissue were rich in PL which constituted from 42.4 to 75.0% of the total lipids except for that of the female dorsal muscle. It was clear that the serum contained more SE and less FFA; the liver contained more FFA and free sterols (ST) and less TG; and the dorsal muscle contained more TG and less SE than the other tissues. The contents of TG and FFA as mg per 100 ml in the serum were 60–89 mg and 14–19 mg, respectively. These levels were similar to the values reported by Patton et al.[17] for pink salmon collected from their spawning ground.

In young chum salmon liver, the FFA content was unexpectedly high. This may be partly due to hydrolysis of the lipids during the longer storage of the sample on board ship.

In the serum, the SE content was higher in the male than the female. On the other hand, in the dorsal muscle, the TG content was higher in the female than the male. Such sex differences were also observed in the fatty acid composition of the individual lipid classes as described below.

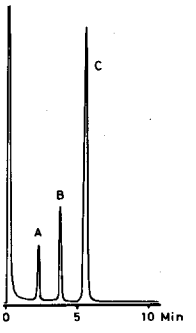

Fig. 1. Gas chromatogram on BDS column of methyl esters of isoprenoid fatty acid fraction.
ECL: A-14.05, B-15.52, C-16.86

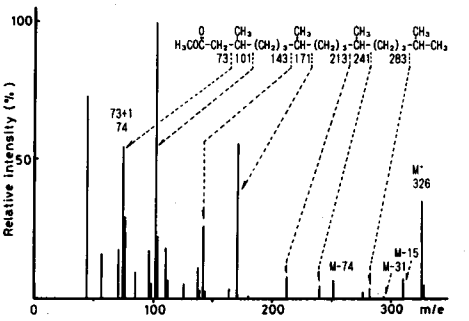

Fig. 2. Mass spectrum of methyl ester of isoprenoid fatty acid fraction C having ECL 16.86 on BDS column.

Table 1. Lipid content and lipid class composition of chum salmon tissues.

	Serum Mature		Liver Mature		Liver Young		Dorsal muscle Mature	
	Female	Male	Female	Male	Female	Male	Female	Male
Lipid content	mg/100 ml		%				%	
	1030	983	2.8	3.8	3.9	3.8	2.8	1.8
Lipid class (% of total lipids)								
Sterol esters*1	13.9	19.5	1.0	1.1	4.9	6.0	0.4	0.4
Triacylglycerols	8.6	6.1	0.9	1.8	1.6	1.6	62.6	43.2
Free fatty acids	1.4	1.9	14.1	12.5	39.8	41.0	5.2	7.2
Sterols	8.1	8.0	10.9	8.7	10.3	9.0	2.5	3.0
Phospholipids	67.5	64.1	72.4	75.0	43.3	42.4	27.0	44.0
Others*2	0.4	0.4	0.7	0.9	—	—	2.3	2.1

*1 Includes a small amount of hydrocarbons.
*2 Mainly mono-and di-acylglycerols.

Fatty acid composition

The fatty acid composition of the lipid classes of chum salmon tissues are shown in Tables 2, 3 and 4. In general, the predominant saturated fatty acid was 16 : 0 except for serum FFA. The main components in the mono- and poly-unsaturated fatty acids were 16 : 1, 18 : 1, 20 : 1, 22 : 1, 20 : 5 (n-3) and 22 : 6 (n-3). Furan fatty acids[18~20] (mainly F_6 and F_4 acids) which are fatty acids characteristically found in fish lipids, were found only in the serum SE of mature chum salmon with ca. 10% of the total fatty acids.

Isoprenoid acids tended to be concentrated mainly in the lipid classes of the serum and liver rather than those of the dorsal muscle.

The occurrence and distribution of isoprenoid fatty acids in marine organisms have been summarized by several authors[1,5]. In this study, the isoprenoid acids as the sum of pristanic and phytanic acids were found in the lipid classes of mature chum salmon tissues in the range 0.3-11.9% of the total fatty acids. These levels were relatively high as compared to those from marine fish lipids[20]. As shown in Table 3, relatively high amounts (ca. 5%) of these acids were found in the liver TG of young chum salmon that live on plankton and also, phytanic acid in the TG of *E. pacifica* constituted 6.0% of the total fatty acids (data not shown). Hence, these acids were assumed to be concentrated in chum salmon tissues from the diets rather than endogenous *de novo* synthesis as stated by Ackman et al.[1].

The distribution of phytanic acid in the lipid classes of serum was markedly different from those of the liver and dorsal muscle. This acid in the serum was found predominantly in the FFA, but accumulated in the TG or SE in the liver and dorsal muscle. Further, the comparison of the fatty acid composition of lipids in the male with that of the female definitely showed tht at the former TG and FFA contained more long-chain monounsaturated acids (20 : 1 and 22 : 1) as well as phytanic acid.

Table 2. Fatty acid composition of lipid classes of chum salmon serum (% of total fatty acids).

Fatty acid	Female				Male			
	SE*1	TG*1	FFA*1	PL*1	SE	TG	FFA	PL
12 : 0	—	—	—	—	—	—	—	—
Iso 14 : 0	0.1	0.2	0.2	—	0.2	0.1	0.1	—
14 : 0*2	0.4	2.9	2.6	3.4	0.6	4.4	2.0	4.3
15 : 0	0.2	0.2	0.3	0.4	0.3	0.1	0.2	0.5
Pristanic	Tr*3	0.1	1.6	Tr	0.1	0.7	1.6	0.1
16 : 0	23.7	7.9	10.1	23.4	32.8	5.8	6.9	26.9
Phytanic	0.7	1.6	5.8	0.7	1.0	4.4	10.3	1.7
18 : 0	5.3	1.0	4.9	8.9	1.8	1.6	3.3	2.7
14 : 1	—	Tr	Tr	Tr	—	—	Tr	Tr
16 : 1	1.4	10.6	4.5	3.6	1.4	9.1	2.9	4.0
17 : 1	0.4	0.8	0.3	0.4	0.3	0.2	Tr	0.2
18 : 1	15.0	41.9	17.9	18.8	11.3	33.2	13.2	12.7
20 : 1	0.6	2.1	8.2	1.5	1.1	7.1	14.4	1.7
22 : 1	—	0.9	13.3	0.6	0.2	6.2	26.2	1.2
24 : 1	—	—	3.2	—	—	—	5.1	—
18 : 2 (n-6)	0.2	0.9	0.3	0.2	0.4	1.1	0.3	0.5
18 : 3 (n-6)	Tr	—	0.1	Tr	0.2	0.2	0.1	—
18 : 3 (n-3)	0.1	1.2	0.3	0.2	0.3	1.2	0.2	0.6
18 : 4 (n-3)	0.2	1.1	0.4	0.2	0.5	1.5	0.2	0.6
20 : 2 (n-6)	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
20 : 3 (n-6)	—	0.1	0.2	0.1	—	0.1	0.2	0.1
20 : 4 (n-6)	0.8	0.7	1.0	1.4	1.5	0.2	0.2	1.5
20 : 4 (n-3)	0.4	1.8	0.7	0.6	1.0	2.2	0.5	0.9
20 : 5 (n-3)	23.1	13.5	10.9	11.8	16.8	12.5	4.2	15.8
22 : 5 (n-6)	Tr	Tr	—	0.1	0.1	0.2	—	0.2
22 : 5 (n-3)	2.1	4.6	2.8	5.3	1.9	3.4	1.7	5.2
22 : 6 (n-3)	14.7	4.8	10.1	17.2	14.8	2.6	5.3	16.7
Total saturates	30.4	13.9	25.5	36.8	36.8	17.1	24.4	36.2
Total monoenes	17.4	56.3	47.4	24.9	14.3	55.8	61.8	19.8
Total polyenes	41.7	28.8	26.9	37.2	37.7	25.3	13.0	42.2
Furan fatty acids	9.6	—	—	—	10.7	—	—	—
Unknowns	0.9	1.1	0.2	1.1	0.5	1.8	0.7	1.9

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

Table 3. Fatty acid composition of lipid classes of livers of mature and young chum salmon (% of total fatty acids).

Fatty acid	Mature								Young							
	Female				Male				Female				Male			
	SE*1	TG*1	FFA*1	PL*1	SE	TG	FFA	PL	SE	TG	FFA	PL	SE	TG	FFA	PL
12 : 0	—	—	—	—	—	—	—	—	Tr*2	0.2	Tr	Tr	Tr	0.2	Tr	Tr
Iso 14 : 0	0.2	0.2	Tr	0.1	0.3	0.1	Tr	0.1	0.1	0.1	Tr	Tr	0.1	0.1	Tr	Tr
14 : 0*3	4.0	1.5	2.9	3.0	1.8	5.6	4.6	3.1	1.5	3.1	2.9	1.5	1.6	2.9	2.9	1.6
15 : 0	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.5	0.4	0.3	0.4	0.3	0.4	0.2	0.4	0.3
Pristanic	0.3	0.1	0.1	0.1	0.9	2.4	0.4	0.1	0.2	1.4	0.1	0.1	0.2	1.6	0.1	0.1
16 : 0	10.7	20.5	10.7	19.0	22.8	7.1	9.5	27.0	12.9	9.0	15.9	17.0	11.8	9.3	16.8	18.8
Phytanic	2.1	1.2	0.6	0.7	1.9	7.0	1.9	0.5	2.5	3.3	2.5	1.4	2.2	2.9	2.4	1.5
18 : 0	2.2	5.3	2.2	7.1	2.2	4.0	1.5	3.0	1.4	9.1	6.1	8.4	1.5	12.0	6.5	9.3
14 : 1	—	—	Tr	Tr	Tr	0.1	0.1	Tr	Tr	0.1	0.1	Tr	Tr	0.1	0.1	Tr
16 : 1	8.8	5.9	7.3	3.3	7.1	6.2	7.1	2.1	3.9	4.3	4.4	0.6	3.6	3.6	4.4	0.5
17 : 1	0.7	0.6	0.5	0.4	0.6	0.3	0.5	0.4	0.8	0.5	1.0	0.5	0.8	0.4	0.9	0.5
18 : 1	38.2	19.2	28.5	22.0	20.7	31.5	25.7	16.2	14.4	31.0	23.8	16.7	14.2	28.8	23.2	16.6
20 : 1	4.0	1.8	3.0	1.9	5.2	12.5	9.0	2.6	10.0	8.7	3.8	3.6	13.7	8.2	3.8	3.8
22 : 1	3.0	0.8	1.4	0.2	5.2	13.0	8.5	0.7	7.2	5.5	1.6	0.9	9.9	6.1	1.8	1.0
24 : 1	—	—	—	—	—	0.6	—	—	0.6	0.6	Tr	0.5	0.2	0.8	0.2	0.4
18 : 2 (n-6)	0.7	0.7	0.9	0.6	1.5	0.8	1.6	1.0	0.8	0.8	0.9	0.6	0.7	0.8	0.9	0.6
18 : 3 (n-6)	—	—	—	—	—	0.2	—	—	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.1
18 : 3 (n-3)	0.7	0.3	0.9	0.3	1.3	0.7	1.4	0.6	0.3	0.2	0.7	0.3	0.3	0.2	0.7	0.3
18 : 4 (n-3)	0.9	0.8	1.1	0.3	1.5	0.4	1.1	0.4	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1
20 : 2 (n-6)	0.1	0.1	0.2	0.2	0.2	0.1	0.3	0.2	0.4	0.4	0.4	0.5	0.5	0.3	0.4	0.5
20 : 3 (n-6)	0.1	0.1	0.2	0.1	0.1	0.2	0.3	0.1	0.3	0.3	0.1	0.1	0.2	0.5	0.1	0.1
20 : 4 (n-6)	0.7	2.2	3.1	3.4	0.8	0.2	1.0	2.1	1.6	1.3	2.4	2.6	1.1	1.2	2.2	2.3
20 : 4 (n-3)	0.6	1.1	1.7	0.6	2.0	0.8	2.3	0.7	1.6	0.7	1.2	0.1	1.5	0.6	1.2	0.7
20 : 5 (n-3)	11.7	18.3	16.4	15.9	12.1	1.6	9.6	18.3	14.3	5.7	12.2	12.2	10.7	6.4	12.6	12.1
22 : 5 (n-6)	Tr	0.1	0.1	0.1	0.1	0.1	—	0.2	0.3	0.2	0.2	0.3	0.4	0.1	0.1	0.3
22 : 5 (n-3)	4.6	3.6	5.3	4.9	2.7	2.2	5.8	5.0	2.8	2.3	2.9	3.6	4.3	0.8	2.2	3.5
22 : 6 (n-3)	4.1	13.1	12.7	13.7	7.0	1.7	7.3	13.2	14.2	9.1	14.1	26.3	15.1	7.8	13.9	23.1
Total saturates	19.8	29.1	16.7	30.3	30.1	26.4	18.1	34.3	19.0	26.5	27.9	28.7	17.8	29.2	29.1	31.6
Total monoenes	54.7	28.3	40.7	27.8	38.8	64.2	50.9	22.0	36.9	50.7	34.7	22.8	42.4	48.0	34.4	22.8
Total polyenes	24.2	40.4	42.6	40.1	29.3	9.0	30.7	41.8	37.1	21.4	35.5	47.0	35.2	19.0	34.6	43.7
Furan fatty acids	—	—	—	—	—	—	—	—	2.7	—	—	—	0.3	—	—	—
Unknowns	1.3	2.2	0.1	1.9	1.8	0.5	0.2	2.0	4.2	1.4	1.8	1.4	4.4	3.8	1.9	1.9

*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.

Table 4. Fatty acid composition of lipid classes of chum salmon dorsal muscle (% of total fatty acids).

Fatty acid	Female				Male			
	SE*1	TG*1	FFA*1	PL*1	SE	TG	FFA	PL
12 : 0	0.7	0.2	0.1	—	0.3	0.2	0.1	—
Iso 14 : 0	1.3	Tr*2	0.1	Tr	2.1	Tr	0.1	Tr
14 : 0*3	7.3	5.6	3.9	4.2	3.2	5.2	3.5	3.6
15 : 0	1.1	0.3	0.4	0.5	0.5	0.2	0.3	0.3
Pristanic	1.1	0.1	Tr	0.1	0.5	0.1	Tr	0.1
16 : 0	22.1	9.1	17.4	29.8	29.7	6.3	18.0	29.4
Phytanic	1.2	0.6	0.3	0.9	2.2	0.8	0.4	0.7
18 : 0	5.0	2.8	2.7	4.4	2.8	2.5	2.1	3.5
14 : 1	Tr	0.1	Tr	—	—	0.1	Tr	—
16 : 1	15.6	10.0	8.1	5.4	11.0	8.5	6.1	4.1
17 : 1	1.3	1.0	1.3	0.9	1.0	0.3	0.4	0.3
18 : 1	16.5	31.1	24.9	16.3	15.8	24.9	18.0	12.2
20 : 1	1.1	11.5	7.3	1.9	3.6	17.5	10.6	2.2
22 : 1	0.5	9.6	5.0	0.6	2.6	17.1	8.5	0.7
24 : 1	Tr	0.4	0.2	0.2	Tr	1.3	0.6	0.1
18 : 2 (n-6)	1.1	0.6	1.1	0.5	0.8	0.9	1.2	0.5
18 : 3 (n-6)	0.2	0.2	0.1	Tr	—	0.2	—	—
18 : 3 (n-3)	0.5	0.5	1.0	0.4	0.8	0.7	1.1	0.4
18 : 4 (n-3)	0.3	0.6	1.0	0.3	0.4	0.6	0.6	0.4
20 : 2 (n-6)	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1
20 : 3 (n-6)	—	0.1	0.2	0.1	—	0.1	0.2	0.1
20 : 4 (n-6)	0.6	0.2	0.4	0.6	0.4	0.1	0.4	0.7
20 : 4 (n-3)	0.5	0.7	1.3	0.6	1.3	0.5	1.1	0.4
20 : 5 (n-3)	13.9	4.0	9.8	12.2	9.4	2.4	7.8	11.1
22 : 5 (n-6)	—	0.1	0.1	0.1	Tr	0.1	0.1	0.2
22 : 5 (n-3)	1.1	3.5	3.4	2.6	2.0	3.7	3.7	2.5
22 : 6 (n-3)	3.7	6.5	9.6	16.6	6.5	5.0	14.5	26.1
Total saturates	39.8	18.7	24.9	39.9	41.3	15.3	24.5	37.6
Total monoenes	35.0	63.7	46.8	25.3	34.0	69.7	44.2	19.6
Total polyenes	22.0	17.2	28.2	34.1	21.7	14.5	30.9	42.5
Furan fatty acids	—	—	—	—	—	—	—	—
Unknowns	3.2	0.4	0.2	0.7	3.0	0.5	0.4	0.4

*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.

Discussion

In humans, a close relationship between the high accumulation of phytanic acid and Refsum's disease has been documented[5,8,21,22]. The high accumulation of this acid in the tissues of patients is considered to be due to the inactivation of lipid catabolism (particularly α-oxidation). In this study, the distribution of this acid among the lipid classes of mature chum salmon serum was different from that of the serum of patients with Refsum's disease in that this acid comprised 40% of the total fatty acids in the TG and 1% in the FFA[23].

In salmon, several physiological changes are known to occur during spawning. However, it is not clear whether or not the symptom (cerebellar ataxia and visual stenosis) similar to Refsum's disease occurs in mature chum salmon. The contents of the main fatty acids in the tissues of mature chum salmon are summarized in Table 5. The contents of phytanic acid in the liver and serum of the male were about twice as large as those of the female. These findings suggest that sex differences in the lipid metabolism of chum salmon occur during the spawning season.

As to the gonad development in salmonids, the gonadosomatic index of the testes of rainbow trout (*Salmo gairdneri*) reaches a maximum prior to spawning,

Table 5. Contents of major fatty acids in mature chum salmon tissues.

Fatty acid	Sex	Serum		Liver		Dorsal Muscle	
		mg/100 ml*1	Ratio*2	mg/100 g*1	Ratio	mg/100 g	Ratio
Phytanic	Female	5	0.42	12	0.55	14	1.40
	Male	12		22		10	
16 : 0	Female	119	0.91	279	0.54	305	1.47
	Male	131		515		208	
16 : 1	Female	25	1.14	71	0.95	195	2.22
	Male	22		75		88	
18 : 1	Female	123	1.60	389	0.92	602	2.35
	Male	77		422		256	
20 : 1	Female	9	0.69	36	0.38	201	1.37
	Male	13		96		147	
22 : 1	Female	6	0.43	8	0.13	162	1.21
	Male	14		61		134	
20 : 5 (n-3)	Female	75	0.93	263	0.73	133	1.66
	Male	81		362		80	
22 : 6 (n-3)	Female	86	1.12	221	0.84	192	1.08
	Male	77		263		178	

*1 The values were calculated from the contents of SE, TG, FFA and PL in the tissues and the ratios of fatty acids/fatty acid esters (0.4 for SE, 0.9 for TG and 0.6 for PL).

*2 Female/Male.

followed by a decrease. Whereas that of the ovary increases gradually and reaches a maximum during the late spawning period[24]. Such a difference in the procedure of gonad development between the female and male may affect the catabolism of the stored lipids. Hence, it can be suggested that the sex difference of the distribution of the lipid components as stated above is closely related to fish physiology during the spawning season. That is to say, the decline of lipid catabolism caused by completion of maturation in the male chum salmon occurs in preference to the female.

It is suggested that the isoprenoid acids have no important role as biomembrane constituents because of their low levels in the PL of the tissues examined (Tables 2, 3 and 4). It can be assumed that they are accumulated in the tissues when the normal oxidation process is blocked by inactivation of lipid catabolism in the late spawning season.

Selective utilization of lipids in fish under starvation, migration and maturation has been discussed by some authors. Ando et al.[25] reported that no selective consumption of the fatty acids of chum salmon muscle lipids occured during spawning migration. However, although the changes in the lipids of chum salmon during the spawning season are well investigated, sex difference in the fatty acid composition among lipid classes has not been appreciably studied. In spite of no significant differences in the FFA content of the serum between the female and male as shown in Table 1, a distinct sex difference in the fatty acid composition was observed in the FFA, that is, the metabolically active component of blood and a major source of energy. These findings suggest that lipid metabolism (transfer and oxidation of fatty acids) between the female and male is affected by their maturation and proceeds with different activity during the spawning season.

Isoprenoid fatty acids have been used as an indication on food web research in marine biochemistry[1]. In addition, phytanic acid may be available as an indication for physiological study in salmonids at spawning season.

The sex differences in the content of fatty acids in chum salmon tissues were also observed in the long-chain monounsaturated fatty acids. As shown in Table 5, the ratios of female to male of 20 : 1 and 22 : 1 in the serum were 0.69 and 0.43 respectively, and these levels were slightly low compared to those (0.91-1.60) of other fatty acids except phytanic acid. These results also suggest that the long-chain monounsaturated fatty acids as well as phytanic acid are not subject to oxidation compared to other fatty acids as described by Beare-Rogers[26].

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