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Seasonal Variation in Lipids and Fatty Acids of Sardine, *Sardinops melanosticta*

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Abstract

The lipids in the tissues of sardine, *Sardinops melanosticta*, harvested between June and December in 1973, from the coastal region of Hakodate, Japan, were studied. The fatty acid compositions of non-polar lipids (NL) and polar lipids (PL) separated from total lipids by silicic acid columns were determined by gas-liquid chromatography.

The lipid contents in the tissues varied remarkably from 3.9 to 10.7% for the flesh and from 10.9 to 38.3% for the viscera through the sampling periods. The visceral lipids had strikingly high contents, something like 2.3–6.1 times those of the flesh. The ratios of NL to PL ranged from 3.9 to 10.5 for the flesh and from 1.4 to 3.9 for the viscera, and in both tissues the predominant parts of NL of the total lipids consisted chiefly of triglycerides.

The iodine values of NL for the flesh and viscera changed from 137.4 to 172.2 and from 108.8 to 136.9, respectively; and the values of the former were certainly higher than those of the latter.

The contents of fatty acid components for NL and PL in both tissues fluctuated slightly within the sampling season. The relatively large amounts of fatty acids for NL and PL in both tissues were 16:0, 18:1, 16:1, 14:0, 20:5 and 22:6; and the contents of C_{16} acid were the most predominant and C_{18} and C_{20} acid contents followed after. The variation in C_{16} and C_{14} acid of NL and PL for the flesh was relatively similar to that of the lipids; and C_{22} acid changed nearly in contrast to the variation of the lipids.

The seasonal variation in the contents of lipids and C_{16} or C_{14} acid for sardine were sufficiently attributed to the dietary phytoplankton.

Introduction

An adult sardine, more than 10 cm in body length, is a typical plankton feeder which fed mainly on phytoplankton by the filtration of its structural gill rakers.

The sardine fishery which was once important has declined tremendously. However, it has recently recovered with an increasing catch volume. The fishery is expected to recover with an increasing demand of the efficient utilization of the fish as a marine product for its high lipid contents. The coastal region of Hakodate, Japan, is a feeding ground of sardine between the months of June and December.

The lipid contents and iodine values of the lipids for sardine caught from the coast of Korea have been reported by Wada[1,2,3]. Yet, there was relatively little information available concerning the fatty acid components of sardine.

The present paper was undertaken to determine the seasonal variation of the lipids and fatty acid compositions of NL and PL for the flesh and viscera of sardine

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harvested between June and December in 1973, from the coastal region of Hakodate, Japan. The results obtained on the seasonal variation of lipids and fatty acid compositions were correlated with the variation in the seasonal growth of phytoplankton in the same area, as reported by Matsudaira *et al.*[4].

Materials

The samples used in this study were those which had been collected between June and December in 1973, from a set net located near Hakodate, Japan. Each sample was taken randomly out of fourteen to sixteen fishes of the same size, except for those taken in October and one sampling in November where the catch was very low.

Sampling dates, mean body length and weight, and fatness index of the samples are given in Table 1. Each sample was exmained irrespective of sex. The samples were divided into flesh and viscera, and then each tissue was used for the extraction of lipids. The samples taken in June till early August had matured ovaries.

Experimental Methods

Total lipids in the flesh and viscera were extracted by the methods of Bligh

Table 1. *Biological measurements of the examined sardine, and seasonal variation*

Catching day and month	June 28	July 13	July 27	Aug. 12
No. of fish	15	15	15	14
Body length cm, mean	17.7	17.7	18.0	17.1
Body weight g, mean	78.2	73.3	75.8	69.0
Fatness index mean	14.2	13.3	13.1	13.7
Lipid content %*				
Flesh	10.7	4.6	5.9	10.0
Viscera	24.2	10.9	20.0	27.7
Non-polar lipid %*				
Flesh	9.6	4.2	4.8	9.0
Viscera	15.7	6.3	14.6	19.4
Polar lipid %*				
Flesh	1.1	0.4	1.1	1.0
Viscera	8.5	4.6	5.4	8.3
Iodine value				
Flesh	158.3	163.8	172.2	153.0
Viscera	111.0	125.9	136.9	113.4

* % to wet weight basis.

and Dyer[5]. NL was separated from PL by chromatography on a silicic acid (Mallinckrodt Co.,)-Celite (2:1) column. NL was eluted by passing chloroform through a column and PL was done with methanol. The iodine value of NL was determined in the usual way. The analysis of the components of NL was accomplished by thin-layer chromatography (TLC); a thin layer of 0.25 mm silicic acid (Wakogel B-5) activated at 110°C for 60 min, a developing solvent: petroleum ether-ethyl ether-acetic acid (90:10:1, v/v) or benzene, and a reagent: 15% phosphomolybdic acid in ethanol. The fatty acid compositions of NL and PL were determined by means of a Yanagimoto gas chromatograph (model G8) equipped with a dual hydrogen flame detector. The column used was 1.5×3 mm i.d., U shaped, of stainless steel, and was packed with 10% diethyleneglycol-succinate on Chromosorb W. The column temperature was 190°C and the inlet pressure of nitrogen 0.7 kg/cm². The fatty acid methyl esters prepared by boron trifluoride-methanol[6] were identified by comparison with commerical standard reagents (14:0, 16:0, 18:0, 16:1, 18:1, 18:2 and 18:3 acid). The identification of other fatty acids was accomplished by a log-plot of retention times against the number of carbons in the chain, and the comparison of ECL (equivalent chain length) values with those in literature. The percentage (in wt%) of each fatty acid was calculated by measuring the area of the peaks.

in lipid contents and characteristics of lipids of the flesh and viscera.

Aug. 25	Sep. 14	Sep. 26	Oct. 11	Oct. 31	Nov. 14	Dec. 11
16	15	15	7	2	6	15
17.9	18.5	17.8	17.8	19.2	18.1	17.9
79.3	87.4	73.0	75.8	83.0	77.8	80.3
13.7	13.8	13.0	13.5	11.7	13.1	13.9
10.0	6.8	5.9	5.2	3.9	4.9	9.3
31.9	30.9	31.8	31.6	23.5	19.7	38.3
9.1	5.9	5.1	4.4	3.1	4.0	8.3
21.1	18.0	20.0	25.1	16.3	12.1	27.3
0.9	0.9	0.8	0.8	0.8	0.9	1.0
10.8	12.9	11.8	6.5	7.2	7.6	11.0
153.7	167.8	145.6	137.4	151.7	150.0	153.1
116.4	123.0	115.3	130.6	131.7	108.8	123.2

Results and Discussion

Characteristics of lipids

The contents of the lipids and the proportion of NL and PL, and the iodine value of NL, for the flesh and viscera of the examined sardine are given in Table 1. Through the sampling periods, the lipid contents of the flesh and viscera varied between 3.9–10.7% and between 10.9–38.3%, respectively; and the visceral lipids had strikingly high contents when 2.3–6.1 times those of the flesh. The lipids showed high contents in June, August and December for the flesh, and in June, August to early October and December for the viscera.

The contents of NL changed from 3.1 to 9.6% for the flesh and from 6.3 to 27.3% for the viscera, and the ratios of NL to PL for the flesh and viscera ranged from 3.9 to 10.5 and from 1.4 to 3.9, respectively. In both tissues, NL including triglycerides mainly as determined by TLC occupied the greater part of the lipids, and accordingly followed the variation of the total lipids. The PL contents in the flesh were nearly constant between 0.8–1.1%, except for 0.4% of one sampling season (July 13), although those of the viscera changed from 4.6 to 12.9% being somewhat in the same pattern with the variation of the total lipids.

An adult sardine, more than 10 cm in body length, fed chiefly on phytoplankton by its structural gill rakers. The results, reported on the seasonal growth of phytoplankton at the sea water surface along the coastal region of Hakodate in 1962–1963 by Matsudaira *et al.*[4], showed the major peaks of phytoplankton consisting of diatoms, *Skeletonema costatum*, *Chaetoceros debilis* and *C. compressus*, in April, June and July, October and November. The period of high lipid contents for both examined tissues showed a resemblance with that of diatoms that followed one or two month later. Especially in the case of the viscera, the stored lipids in the body-cavity were maintained during the season when food was scanty. It was considered that the source of the stored lipids in sardine came from its diet.

Wada[1,2] studied on the lipids of sardine collected along the coastal region of Korea, and observed that the lipids in the tissues of the whole body, flesh or liver decreased from the middle of March to early April after spawning season, and increased to a higher level in July and August after much feeding activity in May. He also reported that the seasonal changes in the lipids of sardine nearly agreed with those of the lipids found in the stomach contents. About the seasonal changes of the flesh lipids in sardine[2], it was considered that the decreasing periods of the lipids coincided with the spawning season, when the gonads are matured utilizing flesh lipids. However, the decreasing tendency from September to November for the flesh lipids of the examined sardine may be caused by the scanty supply of food in the environment.

The iodine values of NL for the flesh and viscera changed between 137.4–172.2 and between 108.8–136.9, respectively. The values for the flesh were certainly high as compared with those of the viscera through the sampling season, and those of the flesh showed a higher value in July and October when its lipid contents were at a relatively low level.

Table 2. *Seasonal variation in the fatty acid compositions of the non-polar lipids of the flesh of the examined sardine.*

Fatty acid	June 28	July 13	July 27	Aug. 12	Aug. 25	Sep. 14	Sep. 26	Oct. 11	Oct. 31	Nov. 14	Dec. 11
12:0	0.4	0.5	0.5	0.2	0.2	0.4	0.3	0.2	0.1	0.1	0.2
13:0	0.1	tr*	tr	tr	tr	tr	0.1	tr	tr	tr	0.1
14:0	7.0	7.0	8.9	9.5	10.2	9.4	10.7	7.7	6.7	6.8	10.0
15:0	0.8	0.6	0.6	0.4	0.6	0.9	0.9	0.7	1.0	1.4	0.8
16:0	18.7	20.0	21.4	21.4	21.2	20.0	24.2	21.5	22.2	22.7	22.6
17:0	1.4	1.5	1.5	1.3	2.0	2.0	2.4	1.8	2.9	2.7	2.1
18:0	2.4	3.3	4.1	4.5	4.2	6.1	5.2	3.8	5.1	5.6	4.6
19:0	2.8	1.9	1.4	0.6	1.7	0.5	2.6	1.1	0.4	0.6	0.8
12:1	tr	0.1	tr	tr	tr	tr	0.1	tr	tr	tr	tr
13:1	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
14:1	2.1	0.8	0.5	0.8	0.7	0.3	1.0	1.4	0.6	0.8	0.8
15:1	tr	tr	tr	tr	tr	tr	tr	0.1	tr	0.4	tr
16:1	13.1	9.9	11.6	11.7	12.4	9.2	8.4	9.0	8.9	9.6	11.2
17:1	0.9	1.0	1.0	1.4	1.0	0.8	0.7	0.5	0.8	0.7	1.1
18:1	12.8	16.5	12.9	15.7	14.1	10.9	14.4	13.5	16.6	13.4	14.8
19:1	0.4	0.6	0.1	0.1	0.2	0.2	0.3	0.4	0.2	0.4	0.3
20:1	4.4	5.1	3.8	3.9	1.9	2.2	6.1	8.5	4.5	6.4	4.9
21:1	0.6	tr	tr	0.4	0.1	0.1	1.1	0.6	0.1	1.3	0.1
22:1	1.8	5.7	3.0	2.9	1.5	2.4	0.1	1.6	6.8	0.7	3.7
24:1	0.2	0.2	0.4	0.2	0.3	4.4	0.9	1.0	0.8	0.8	0.3
18:2	1.4	1.4	1.6	4.2	1.8	2.7	0.9	1.1	1.6	2.6	1.6
18:3	0.5	0.6	0.1	0.3	4.1	0.1	0.9	0.4	0.1	1.6	0.8
18:4	3.8	3.2	2.6	2.3	1.9	1.0	1.3	2.1	0.6	1.3	1.0
20:2	0.2	0.2	0.3	1.9	0.6	0.3	0.4	0.1	0.1	0.5	0.7
20:4	9.0	2.3	2.6	1.5	2.2	3.5	5.5	9.0	3.5	5.6	1.5
20:5	10.4	11.5	12.5	11.5	11.3	11.4	5.6	6.9	7.0	5.2	8.1
21:5	0.2	0.4	1.0	0.3	0.6	0.7	0.2	1.0	0.3	0.2	0.2
22:2	0.2	0.1	0.1	0.1	0.4	0.2	0.3	0.2	0.2	0.1	0.1
22:5	0.5	0.8	1.1	0.4	0.6	0.7	1.0	1.0	0.5	0.6	0.8
22:6	3.9	4.7	6.3	2.4	4.1	9.5	4.4	4.8	8.3	8.0	6.7
Saturates	33.6	34.8	38.4	37.9	40.1	39.3	46.4	36.8	38.4	39.9	41.2
Monoenes	36.3	39.9	33.3	37.1	32.2	30.5	33.1	36.6	39.3	34.5	37.2
Polyenes	30.1	25.2	28.2	24.9	27.6	30.1	20.5	26.6	22.2	25.7	21.5

* Trace.

Table 3. *Seasonal variation in the fatty acid compositions of the polar lipids of the flesh of the examined sardine.*

Fatty acid	June 28	July 13	July 27	Aug. 12	Aug. 25	Sep. 14	Sep. 26	Oct. 11	Oct. 31	Nov. 14	Dec. 11
12:0	0.8	0.3	0.8	0.5	0.8	0.8	0.8	0.4	0.2	0.2	0.6
13:0	0.1	tr*	0.1	0.1	0.1	0.1	0.1	tr	0.1	0.1	0.1
14:0	11.5	6.4	8.1	11.6	13.7	11.7	9.0	6.9	5.0	5.9	7.3
15:0	0.7	0.6	0.7	0.7	0.7	0.9	0.8	0.7	0.7	1.0	0.7
16:0	27.0	23.7	24.7	26.5	21.7	24.3	26.0	27.6	29.9	29.6	28.0
17:0	1.1	1.3	1.7	0.8	1.0	1.8	2.0	1.8	2.0	1.8	1.3
18:0	3.8	3.9	5.2	5.0	4.2	4.4	5.3	5.0	4.6	5.2	6.9
19:0	2.9	1.7	2.2	4.4	3.5	1.5	1.7	1.6	0.6	1.1	2.6
12:1	0.1	tr	0.1	tr	tr	tr	0.1	0.1	tr	tr	tr
13:1	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
14:1	1.0	0.4	0.6	0.7	0.6	1.0	0.3	0.7	0.5	0.5	0.8
15:1	tr	tr	0.4	tr	tr	tr	tr	0.1	tr	tr	tr
16:1	11.3	9.4	10.0	13.5	14.2	10.8	11.1	8.2	8.0	9.2	12.0
17:1	1.2	0.9	1.5	1.3	1.3	1.0	1.9	1.2	0.8	0.9	1.6
18:1	11.2	7.0	8.3	10.4	9.2	6.9	9.1	10.4	9.9	9.7	10.1
19:1	0.4	0.5	0.2	0.2	0.1	0.2	0.5	0.4	0.4	0.5	0.5
20:1	1.8	0.9	1.3	1.3	0.7	0.5	1.0	2.9	1.3	0.9	1.1
21:1	0.1	0.1	0.2	tr	0.3	tr	0.3	0.2	0.1	0.2	0.3
22:1	0.7	0.6	0.3	0.3	tr	0.1	1.0	0.8	0.7	0.4	0.2
24:1	0.2	0.4	0.4	0.1	0.2	0.1	0.5	0.4	0.2	0.8	0.5
18:2	1.7	1.3	1.1	1.4	1.2	1.1	1.2	1.6	1.4	1.3	1.1
18:3	0.8	1.0	1.4	0.8	0.8	0.9	0.8	1.3	1.6	1.0	1.2
18:4	2.7	2.0	2.4	2.7	2.1	1.8	1.7	2.2	1.8	1.1	2.5
20:2	0.2	0.2	0.7	0.2	0.2	0.2	0.6	0.5	0.2	0.2	0.5
20:4	1.5	3.0	2.1	1.2	1.8	2.2	2.6	2.3	2.8	1.4	1.2
20:5	12.9	16.2	13.4	11.8	15.2	14.2	12.6	11.7	10.6	12.1	11.5
21:5	0.4	0.5	0.5	0.3	0.1	0.1	0.8	1.1	0.8	1.0	0.7
22:2	0.3	0.1	0.5	0.3	0.2	0.2	0.2	0.4	0.5	0.3	0.5
22:5	0.4	0.8	0.7	0.2	0.6	0.8	1.1	1.2	0.6	1.0	0.4
22:6	3.1	16.9	10.3	3.8	5.6	12.3	6.8	8.3	14.6	12.5	5.7
Saturates	47.9	37.9	43.5	49.6	45.7	45.5	45.7	44.0	43.1	44.9	47.5
Monoenes	28.0	20.2	23.3	27.8	26.6	20.6	25.8	25.4	21.9	23.1	27.1
Polyenes	24.0	42.0	33.1	32.7	27.8	33.8	28.4	30.6	34.9	31.9	25.3

* Trace.

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Table 4. *Seasonal variation in the fatty acid compositions of the non-polar lipids of the viscera of the examined sardine.*

Fatty acid	June 28	July 13	July 27	Aug. 12	Aug. 25	Sep. 14	Sep. 26	Oct. 11	Oct. 31	Nov. 14	Dec. 11
12:0	0.3	0.2	0.7	0.1	0.2	0.4	0.3	0.2	0.1	0.2	0.2
13:0	0.1	0.1	0.1	tr*	tr	0.1	tr	0.1	0.1	0.1	0.1
14:0	9.9	8.4	12.0	8.7	9.2	8.4	8.5	9.0	7.7	7.6	9.0
15:0	0.8	1.0	1.2	0.6	0.7	1.3	1.0	0.9	1.1	1.7	0.8
16:0	24.4	21.4	23.5	20.0	20.4	25.2	22.2	10.7	21.7	25.8	23.2
17:0	1.8	2.7	2.0	1.7	2.4	2.9	2.4	2.0	2.7	2.3	1.4
18:0	4.0	4.1	4.3	4.0	4.3	6.1	5.0	4.0	5.2	5.7	5.2
19:0	1.0	1.8	1.1	2.5	1.5	1.0	1.7	1.6	2.0	0.7	1.0
12:1	tr	tr	tr	tr	0.1	tr	tr	tr	tr	tr	tr
13:1	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
14:1	1.2	1.6	1.6	1.5	1.0	1.4	1.0	1.1	1.1	1.0	0.9
15:1	tr	tr	tr	0.1	tr	0.2	tr	tr	tr	0.8	tr
16:1	10.2	17.8	12.0	12.0	14.8	12.2	11.1	10.8	9.2	9.8	9.5
17:1	1.0	1.3	1.0	1.0	0.9	1.1	0.9	0.8	0.9	0.8	1.1
18:1	18.5	14.7	14.5	18.7	16.2	13.9	13.9	11.7	14.2	14.3	14.6
19:1	0.5	0.6	0.3	0.6	0.2	0.7	0.4	0.5	0.1	0.5	0.5
20:1	8.4	3.7	3.1	4.5	2.4	3.4	7.0	9.5	5.9	6.1	6.2
21:1	0.1	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.1	0.2
22:1	4.8	3.4	1.9	4.4	2.7	1.6	6.0	9.9	3.5	4.5	5.4
24:1	0.5	0.3	0.7	0.4	0.3	0.9	1.0	0.9	1.1	1.3	1.0
18:2	1.0	1.6	1.8	2.2	0.8	2.0	1.9	1.6	0.5	1.4	1.3
18:3	0.4	0.4	0.7	0.4	3.7	1.4	0.2	1.0	2.7	1.1	0.6
18:4	1.7	1.4	1.6	1.9	2.1	1.5	1.8	3.2	1.8	1.1	1.9
20:2	0.6	0.6	1.0	2.2	0.9	1.0	0.5	0.6	0.6	0.4	1.0
20:4	1.0	2.3	1.9	1.8	3.1	2.5	2.7	4.1	3.3	1.7	1.8
20:5	4.4	6.3	7.6	6.2	7.0	4.9	4.5	8.4	6.2	4.2	6.8
21:5	0.7	0.4	0.1	0.1	0.6	0.4	0.9	0.5	0.7	0.4	0.7
22:2	0.2	0.4	0.4	1.0	0.6	1.0	0.6	0.5	0.1	1.0	1.2
22:5	0.4	0.3	1.0	0.5	0.6	0.5	0.8	1.6	0.7	0.6	0.9
22:6	2.1	3.2	3.8	2.7	3.2	3.8	3.3	4.8	6.6	4.7	3.6
Saturates	42.3	39.7	44.9	37.6	38.7	45.4	41.1	28.5	40.6	44.1	40.9
Monoenes	45.2	43.5	35.2	43.3	38.8	35.5	41.6	45.3	36.1	39.2	39.4
Polyenes	12.5	16.9	19.9	19.0	22.6	19.0	17.2	26.3	23.2	16.6	19.8

* Trace.

Table 5. *Seasonal variation in the fatty acid compositions of the polar lipids of the viscera of the examined sardine.*

Fatty acid	June 28	July 13	July 27	Aug. 12	Aug. 25	Sep. 14	Sep. 26	Oct. 11	Oct. 31	Nov. 14	Dec. 11
12:0	0.6	0.4	0.8	0.5	0.8	0.8	0.9	0.5	0.4	0.3	0.5
13:0	0.1	0.2	tr*	0.1	0.1	0.1	0.1	0.3	0.2	0.1	0.1
14:0	8.9	6.5	7.5	13.3	15.7	8.6	11.4	11.9	9.9	9.4	11.6
15:0	0.7	1.1	1.1	0.8	1.1	1.8	1.2	1.4	1.3	0.6	1.2
16:0	18.6	15.8	13.6	22.2	20.6	16.0	18.7	19.4	21.9	21.0	17.4
17:0	1.1	3.8	2.2	2.1	2.8	3.9	1.7	2.2	2.2	2.3	1.7
18:0	3.8	3.5	3.9	4.6	4.4	4.3	4.1	4.3	5.2	4.2	4.3
19:0	4.0	4.2	2.7	3.6	2.5	2.4	3.1	2.5	1.8	1.0	2.7
12:1	tr	tr	0.1	0.1	0.1	0.1	0.1	0.1	tr	tr	tr
13:1	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
14:1	0.8	1.1	1.7	1.1	1.3	1.9	1.3	2.7	1.1	0.7	1.7
15:1	tr	tr	0.1	tr	tr	0.1	tr	0.3	tr	0.3	tr
16:1	11.1	16.1	12.8	17.4	16.7	14.0	14.7	14.4	11.1	10.6	14.2
17:1	1.4	2.9	1.6	1.6	1.6	1.8	1.6	1.4	1.5	1.3	2.0
18:1	12.3	11.4	8.6	15.2	11.9	8.8	10.1	11.0	10.1	10.8	9.3
19:1	0.7	1.0	0.7	0.6	0.7	0.7	0.5	1.0	0.4	0.6	0.7
20:1	2.8	2.1	3.4	1.5	1.6	1.2	2.7	3.0	2.7	2.2	2.2
21:1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.4	0.3	0.2	0.3
22:1	1.6	0.4	1.0	0.3	0.4	0.6	1.5	3.4	0.8	1.9	1.0
24:1	0.2	0.3	0.2	0.3	0.2	0.4	0.3	0.3	0.5	1.0	0.4
18:2	1.8	2.9	1.7	1.3	1.6	1.9	1.8	1.9	1.9	1.8	1.7
18:3	1.4	1.7	2.3	2.3	1.4	1.3	1.2	2.4	2.4	1.6	1.2
18:4	4.0	1.1	1.4	1.3	0.9	2.4	3.4	2.0	2.9	2.2	3.5
20:2	1.1	0.3	0.4	0.6	0.4	0.7	0.8	1.4	0.7	0.6	1.4
20:4	2.4	2.3	2.9	0.4	1.4	2.3	1.7	1.4	2.0	3.0	2.6
20:5	14.2	13.3	20.5	7.6	9.0	14.8	12.1	7.2	10.8	11.3	13.7
21:5	0.3	0.2	1.3	0.2	0.2	0.7	0.4	0.5	0.4	1.2	0.9
22:2	0.2	1.4	0.6	0.3	0.3	0.5	0.6	0.4	0.2	0.4	1.4
22:5	1.0	0.6	0.6	0.3	0.7	0.7	0.8	0.4	0.9	1.4	0.6
22:6	4.6	4.8	6.0	0.3	1.4	7.0	3.0	1.9	6.3	7.9	1.8
Saturates	37.8	35.5	31.8	47.2	48.0	37.9	41.2	42.5	42.9	38.9	39.5
Monoenes	31.1	35.8	30 4	38.3	34.7	29.7	32.9	37.9	28.5	29.6	31.8
Polyenes	31.0	28.6	37.7	14.6	17.3	32.3	25.8	19.5	28.4	31.4	28.8

* Trace.

Table 6. *Seasonal variation in the fatty acids, on the main carbon numbers, of the non-polar and polar lipids of the flesh and viscera of the examined sardine.*

	June 28	July 13	July 27	Aug. 12	Aug. 25	Sep. 14	Sep. 26	Oct. 11	Oct. 31	Nov. 14	Dec. 11
Flesh	Non-polar lipid										
Fatty acid											
C14	9.1	7.8	9.4	10.3	10.9	9.7	11.7	9.1	7.3	7.2	10.8
C16	31.8	29.9	33.0	33.1	33.6	29.2	32.6	30.5	31.1	32.3	33.8
C18	20.9	25.0	21.3	27.0	26.1	20.8	22.7	20.9	24.0	24.5	22.8
C20	24.0	19.1	19.2	18.8	16.0	17.4	17.6	24.5	15.1	17.7	15.2
C22	6.4	11.3	10.5	5.8	6.6	12.8	5.8	7.6	15.8	9.4	11.3
	Polar lipid										
C14	12.5	6.8	8.7	12.3	14.3	12.7	9.3	7.6	5.5	6.4	8.1
C16	38.3	33.1	34.7	40.0	35.9	35.1	37.1	35.8	37.9	38.8	40.0
C18	20.2	15.2	18.4	20.3	17.5	15.1	18.1	20.5	19.3	18.3	21.8
C20	16.4	20.3	17.5	14.5	17.9	17.1	16.8	17.4	14.9	14.6	14.3
C22	4.5	18.4	11.8	4.6	6.4	13.4	9.1	10.7	16.4	14.2	6.8
Viscera	Non-polar lipid										
C14	11.1	10.0	13.6	10.2	10.2	9.8	9.5	10.1	8.8	8.6	9.9
C16	34.6	39.2	35.5	32.0	35.2	37.4	33.3	21.5	30.9	35.6	32.7
C18	25.6	22.2	22.9	27.2	27.1	24.9	22.8	21.5	24.4	23.6	23.6
C20	14.4	12.9	13.6	14.7	13.4	11.8	14.7	22.6	16.0	12.4	15.8
C22	7.5	7.3	7.1	8.6	7.1	6.9	10.7	16.8	10.9	10.8	11.1
	Polar lipid										
C14	9.7	7.6	9.2	14.4	17.0	10.5	12.7	14.6	11.0	10.1	13.3
C16	29.7	32.2	26.4	39.6	37.3	30.0	33.4	33.8	33.0	31.6	31.6
C18	23.3	20.6	17.9	24.7	20.2	18.7	20.6	21.6	22.5	20.6	20.0
C20	20.5	18.0	27.2	10.1	12.4	19.0	17.3	13.0	16.2	17.1	19.9
C22	7.4	7.2	8.2	1.2	2.8	8.8	5.9	6.1	8.2	11.6	4.8

Fatty acid composition

The fatty acid compositions of NL and PL in the tissues of the examined sardine are given in Tables 2–5. In addition, the variation of the fatty acids based on the main carbon numbers are listed in Table 6. As given in Tables 2–5, the contents of each fatty acid component of NL and PL for the flesh and viscera fluctuated somewhat during the sampling season. The relatively predominant fatty acids found in NL and PL of the flesh and viscera were 16:0, 18:1, 16:1, 20:5, 14:0 and 22:6 through the sampling season. The content of C_{16} acid based on the carbon atoms was the most predominant, and C_{18} and C_{20} acid contents followed after, in both NL and PL of the tissues, as given in Table 6.

As compared to the contents of the major fatty acids and/or saturates, monoenes and polyenes between NL and PL in the flesh, the former consisted in significant amounts: 18:1 acid and monoenes, and the latter: 16:0, 20:5 and 22:6 acid and saturates and polyenes. In the case of viscera, it was the same: 18:1 acid and monoenes of NL, and 20:5 acid and polyenes of PL. The differences between the flesh and viscera showed a tendency of the comparatively large contents of 20:5 acid and polyenes for NL in the former, and of 16:0 acid and saturates for NL in the latter. The contents of C_{16} and C_{14} acid of NL and PL in the flesh varied

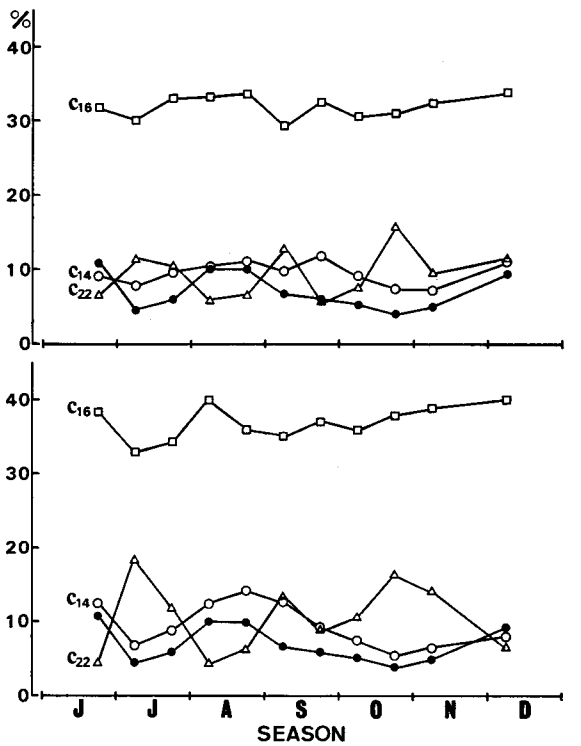

Fig. 1. Seasonal variation in lipid contents (•——•) and C_{14}, C_{16} and C_{22} acid contents of the non-polar and polar lipids, of the flesh of the examined sardine.

nearly in accordance with the change of the lipids in the flesh, while C_{22} acid content did inversely (Fig. 1). It showed the same tendency between C_{14} and C_{22} acid in the PL of the viscera.

Along the coastal region of Hakodate, Japan, diatoms have been observed to be composed mainly of *C. debilis* and *C. compressus* in April and July, and *S. costatum* in August, October and November[4]. The fatty acid compositions of diatoms, *S. costatum*[7,8,9], and *Chaetoceros spp.* of six or seven species were characterized to contain relatively large amounts of acid: 14:0, 16:0 and 20:5. The acid variations of 14:0, 16:0 and 16:1 which were correlated to those of the lipids for the examined sardine were considerable due to the amounts of lipids in the dietary diatoms. The saturates of larger components in the lipids of the examined sardine through the sampling season were different from the results on fishes, zooplankton feeder and carnivore, which contained the most predominant components of monoenes in the fatty acid composition[11]. High levels of polyenes such as 20:5 acid in NL and 22:6 acid in PL for the flesh during the season of low lipid contents for the exmained sardine suggest that the more saturated fatty acids were preferentially utilized. It has been well known that the fatty acid composition of the fish lipids was considerably affected by compounded factors: the fish diet or maturity, environmental temperature, individuality of species, and what not[12]. It was also reported that fatty acids derived from dietary sources or by biosynthesis can be altered by chain elongation or desaturation in the production of the lipids of fish[13]. Recently, Ueda[14,15] has studied on the correlation between fatty acid composition of mackerel, *Scomber japonicus*, and probably related factors such as: influence of the season, body length and lipid contents. He has reported that the variation in the fatty acids was related to that in the lipid contents of the fish.

In the examined sardine, it was observed that dietary fatty acids such as 14:0, 16:0 and 16:1 acids were directly deposited in their tissues. In conclusion, the seasonal variation in the contents of lipids and C_{16} or C_{14} acid of sardine was sufficiently attributed to their dietary phytoplankton.

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