魚類筋原繊維の加熱変性に対する糖および糖アルコールの保護効果の定量的考察

大泉 徹*・橋本浩二*・小倉潤子*・新井健一*

(1981 年 3 月 19 日受理)

Quantitative Aspect for Protective Effect of Sugar and Sugar Alcohol against Denaturation of Fish Myofibrils

Tooru OORIZUMI*, Koji HASHIMOTO*, Junko OGURA*,
and Ken-ichi ARAI*

The effects of sugar and sugar alcohol on the thermal stability of myofibrils (chub mackerel and sardine) have been studied in terms of the first order rate constant (k_D) for inactivation of myofibrillar Ca-ATPase. The plots of the logarithm of k_D against the molar concentration (0-3 M) of sugar or sugar alcohol were linear for all sugars and sugar alcohols examined. The slope (denoted as E) of $\log k_D$ versus molarity of sugar or sugar alcohol was calculated using the following relation; $E=1/a (\log k_{Da}-\log k_{Do})$, where k_{Da} and k_{Do} are the first order rate constants for the inactivation of myofibrillar Ca-ATPase in the absence and presence of a M of sugar or sugar alcohol, respectively. Judged from these E values, the protective effect was found to become lower in the order of maltotriose, lactitol, sucrose, sorbitol=glucose=maltose, mannitol, mannose=fructose=xylitol, xylose, sorbitan, glycerol, sorbide. Furthermore, the temperature dependence of $\log k_D$ revealed that the protective effects of sugars and sugar alcohols were practically unchanged in the temperature range of 25-45°C at which the myofibrils were denatured.

シュクロースやソルビトールなどの糖類化合物が魚肉たんぱく質の変性を防止する事実は以前からよく知られており、その優れた実用例はスケトウタラ冷凍すり身の製造および貯蔵の場合に見られる。^{1,2)}

それ故、魚肉構造たんぱく質の主要成分であるアクトミオシンまたはミオシンを使って、その加熱^{3,4)}凍結^{5,6)}および乾燥^{7,8)}による変性に対する糖類化合物の保護作用をあきらかにしようとした研究が、従来いくつか行なわれてきた。しかし、糖の保護作用を定量的に数値として表す試みは未だなされていない。一方、最近になって魚類の筋原繊維の調製法⁹⁾やその生化学的性質¹⁰⁾に関する研究が行なわれた結果、筋原繊維標品はアクトミオシンよりもさらに筋肉に近い構造を保有し、魚肉構造たんぱく質の研究をする対象として適していることが示唆された。

著者らは、魚類の筋原繊維を使って、その Ca-ATPase を指標とし、先に、加熱変性について研究し報告したが、¹¹⁾本研究では加熱変性における各種糖類化合物の保護作用を検討した。まず、初めに筋原繊維の変性に対する糖の保護効果を定量的に表す方法を検討し、それによ

って各種の糖類化合物の保護効力を比較検討し、糖類化合物の構造と変性防止効果との関係を追究しようとした。

実験方法

筋原繊維懸濁液の調製 魚類の筋原繊維 (Mf と略す) は、すでに加藤らが報じた方法⁹⁾に従って、マイワシ, sardine *Sardinops melanosticta* およびマサバ, chub mackerel *Scomber japonicus* の新鮮な筋肉より調製し、0.16 M KCl-40 mM Tris-HCl, pH 7.5 溶液に懸濁させた。

糖類の共存下における筋原繊維の加熱変性 魚類 Mf の懸濁液に対して一定のモル濃度になるように糖類化合物を添加溶解した後、その 1.0 または 1.5 ml ずつを試験管に分取し、所定の温度に調節した恒温槽中に保持し、一定時間ごとに取り出して氷冷して、加熱変性を停止させた。

Mf Ca-ATPase 活性の測定法 Mf Ca-ATPase 活性 (Adenosinetriphosphatase, EC 3.6.1.3) は、0.1 M KCl, 5 mM CaCl₂, 25 mM Tris-maleate (pH 7.0) および 1 mM ATP の組成液で、25°C において反応させて遊離する無

* 北海道大学水産学部生物化学教室 (Laboratory of Biochemistry of Fisheries, Hokkaido University, Hakodate 041).

Fatty Acids in Blood of Marine Little Toothed Whales *Stenella caeruleo-alba*

Hideaki MORII*

(Received March 23, 1981)

The compositions or quantities of free short-chain acids in plasma, of free and esterified short- and long-chain acids in plasma protein, and of long-chain acids in blood corpuscle lipids were studied with adult whales *Stenella caeruleo-alba* which were caught alive. The concentration of free short-chain acids in blood was about 0.97 meq/l, and that in plasma was low, being combined mainly with plasma protein. Free short-chain acids were composed mostly of acetic acid; isovaleric, propionic, isobutyric and *n*-butyric acids were also present in decreasing order. Several esterified short-chain acids were found in plasma protein; *n*-valeric and *n*-caproic acids were detected, in addition to those free short-chain acids observed in blood. The ratio of acetic acid in the esterified acids was very low compared to that in the free acids. In plasma protein, long-chain branched acids were rare in both free and esterified forms. These forms had different compositions. In particular, many branched-chain acids with carbon numbers lower than 13 were recognized in the free acids, but few in the esterified acids, where the composition was similar to that of fish oil. In the long-chain straight acids in plasma protein, the amount of saturated and monoenoic acids with carbon numbers lower than 16 and total saturated acids was greater in free form and total polyenoic acids in esterified form.

In the previous paper¹⁾, the author reported the possibility of biosynthesis of the short-chain branched acids in subcutaneous tissue lipids of the whales from branched-chain amino acids in the same subcutaneous tissue though not entirely eliminating the possibility from metabolic matters in muscle and organs, and also reported the possible derivation of the long-chain branched acids in muscle and organs from food. In order to clarify these problems, it is necessary at least to ascertain the quantity and composition of branched-chain acids in blood. Since the composition of branched-chain acids of the adult whales differed considerably from the fetus¹⁾, it was also necessary to study the composition of fatty acids in blood as the factors of such differences.

The author already reported the presence of free short-chain branched acids such as isovaleric acid in blood of the whales²⁾. However, this result was obtained from the whales fairly long after death and the presence of free short-chain branched acids in blood of the living whales was unknown. Also, the form and quantity of free short-chain branched acids and the composition of free long-chain branched acids in blood had not been studied. Accordingly, in this paper, the composition and quantity of free short-chain acids in plasma, of free and esterified short- and long-chain acids in

plasma protein of the living whales were examined. In addition, the composition of long-chain acids in blood corpuscle lipids were also studied.

Materials and Methods

Animals

The six adult whales *Stenella caeruleo-alba* (body length: 232-246 cm) used in the experiment were caught alive in Kawana Bay in Ito City, Shizuoka Prefecture, Japan in the middle of November 1974. These whales were chased to the bay and kept there overnight. Therefore, the stomach content was scarcely recognized.

Separation of Free Short-Chain Acids from Plasma

Blood of 1.0 to 1.5 liters was collected from carotid of the whales, added with 1 ml of heparin (5000 unit) per 200 ml of blood, placed in dry ice, and brought back to our laboratory on the same day. Immediately, blood corpuscles were removed from the blood by centrifuging for 30 minutes at 4000 rpm. Protein was removed by adding 25% phosphoric acid into the obtained liquid layer, and plasma was obtained by centrifuging for 15 minutes at 4500 rpm. Free short-chain acids from plasma were separated in the same manner as in the previous paper²⁾.

* Faculty of Fisheries, Nagasaki Univ., 14, Bunkyo-1, Nagasaki 852, Japan (森井秀昭: 長崎大学水産学部).

Separation of Free Short- and Long-Chain Acids from Plasma Protein

Chloroform-methanol (1:1) was added to the protein fraction obtained in the above procedure and the chloroform fraction was neutralized with 0.1 N-KOH alcohol solution. The salt produced was separated by washing with distilled water. Thus, the fatty acids present in the mixture of salt solution and methanol fraction were regarded as free acids in plasma protein. Free long-chain acids were separated from one half of the mixture by the usual method and free short-chain acids were separated from the other half by the method mentioned in the previous paper²⁾.

Separation of Esterified Short- and Long-Chain Acids in Plasma Protein

In the lipids obtained after the removal of free acids from the chloroform fraction, the fatty acids were regarded as the esterified acids in plasma protein. The short- and long-chain acids from the lipids were separated in the same manner as in the previous paper¹⁾.

Separation of Long-Chain Acids from Blood Corpuscle Lipids

The long-chain acids of blood corpuscle lipids were separated by the usual method from the blood corpuscle obtained by the above procedure.

Preparation of Samples for Gas-Liquid Chromatography (GLC)·GLC Analysis

The same as in the previous paper¹⁾.

Results

The quantities per total volume of blood of free short-chain acids in plasma and plasma protein and of esterified short-chain acids in plasma protein are shown in Table 1.

It has been considered that, as in human blood where short-chain acids are bound weakly with

protein, the majority of free short-chain acids exist as sodium salt. In this study, however, the quantities of free short-chain acids existing as salt and combined with protein were about 0.12 meq and 0.85 meq per 1 liter of blood, respectively. When the total of these values is considered to be the whole amount of free short-chain acids in blood, it is much higher than that in human, i.e., 0.2 to 0.4 meq per 1 liter of plasma³⁾.

The REICHERT-MEISSL value of esterified lipids in plasma protein was about 20 being nearly equal to that of blubber lipids of the adult whales, and the quantity of esterified short-chain acids per 1 liter of blood was about 0.66 meq.

The composition of free short-chain acids in plasma is shown in Table 2. Major free short-chain acids recognized in plasma were acetic, propionic, isobutyric, *n*-butyric and isovaleric acids. Of these, acetic acid was the most dominant being followed by isovaleric and propionic acids.

Table 2. Composition (weight %) of free short-chain fatty acids in plasma of the whales *Stenella caeruleo-alba*

Fatty acid	Sample number					
	1	2	3	4	5	6
2:0	61.3	52.8	52.5	58.6	61.8	68.5
3:0	11.5	11.8	13.8	12.2	18.0	11.8
iso-4:0	4.1	3.7	3.2	3.8	4.6	3.6
<i>n</i> -4:0	1.2	1.4	0.8	1.0	2.8	1.3
iso-5:0	21.9	30.3	28.6	24.4	12.9	14.9
<i>n</i> -5:0	tr	tr	tr	tr	tr	tr
iso-6:0	nd	nd	nd	nd	nd	nd
<i>n</i> -6:0	nd	nd	0.4	nd	nd	nd
iso (total)	26.0	34.0	31.8	28.2	17.5	18.5

tr: trace. nd: not detected under the condition employed.

The composition of free short-chain acids in plasma protein is shown in Table 3.

In plasma protein, the same fatty acids found

Table 1. Contents of free short-chain fatty acids (FSCFA) in plasma and plasma protein and of short-chain fatty acids (SCFA) in plasma protein lipids of the whales, *Stenella caeruleo-alba*

Characteristic	Sample number						
	1	2	3	4	5	6	Mean
Plasma/Blood (Vol %)	29.4	38.8	36.4	25.4	28.7	28.5	31.2
Lipids in plasma protein (g/l Blood)	1.57	1.51	1.81	1.50	1.77	1.67	1.64
(Unsanifiable matter in the lipids, %)	(32.4)	(41.2)	(30.7)	(28.9)	(31.9)	(44.2)	(34.9)
FSCFA in plasma (meq/l Blood)	0.13	0.12	0.12	0.12	0.12	0.09	0.12
FSCFA in plasma protein (meq/l Blood)	1.14	0.87	0.78	0.90	0.58	0.82	0.85
SCFA in plasma protein lipids (meq/l Blood)	0.93	0.62	0.65	0.78	0.37	0.62	0.66
(REICHERT-MEISSL value of the lipids)	(29.6)	(20.5)	(16.4)	(24.9)	(9.8)	(18.6)	(20.0)

Table 3. Composition (weight %) of free short-chain fatty acids in plasma protein of the whales *Stenella caeruleo-alba*

Fatty acid	Sample number					
	1	2	3	4	5	6
2:0	70.4	82.7	68.8	75.2	70.3	84.5
3:0	18.9	9.3	12.1	13.5	18.6	6.1
iso-4:0	5.0	3.0	2.6	3.4	2.8	1.7
<i>n</i> -4:0	1.8	1.6	1.1	1.3	1.3	0.8
iso-5:0	3.9	3.4	15.4	6.6	7.0	7.1
<i>n</i> -5:0	tr	nd	tr	nd	nd	nd
iso-6:0	nd	nd	nd	nd	nd	nd
<i>n</i> -6:0	nd	nd	nd	nd	nd	nd
iso (total)	8.9	6.4	18.0	10.0	9.8	8.8

tr: trace. nd: not detected under the condition employed.

Table 4. Composition (weight %) of short-chain fatty acids in plasma protein lipids of the whales *Stenella caeruleo-alba*

Fatty acid	Sample number					
	1	2	3	4	5	6
2:0	25.1	27.6	7.4	26.8	28.1	27.7
3:0	29.5	26.7	5.2	22.2	20.8	27.3
iso-4:0	2.4	3.1	3.1	4.1	5.2	3.3
<i>n</i> -4:0	2.1	0.9	0.4	1.1	1.6	0.8
iso-5:0	25.6	27.7	81.5	27.2	42.6	17.8
<i>n</i> -5:0	2.5	2.4	0.4	1.9	0.3	2.2
?:0	1.4	1.2	0.4	1.8	0.3	2.3
iso-6:0	nd	nd	nd	nd	nd	nd
<i>n</i> -6:0	11.6	10.4	1.5	14.8	1.1	18.6
iso (total)	28.0	30.8	84.6	31.3	47.8	21.1

nd: not detected under the condition employed.

in plasma existed in free form. However, plasma protein contained more acetic acid, less isovaleric acid and nearly equal amount of other acids compared with plasma.

The composition of esterified short-chain acids in plasma protein is shown in Table 4.

In plasma protein, *n*-valeric and *n*-caproic acids were recognized as the esterified short-chain acids in addition to those free fatty acids recognized in plasma and plasma protein. The composition of the esterified acids also differed considerably from that of the free acids. Although acetic acid was particularly abundant in free form, it was contained almost equally to propionic and isovaleric acids in esterified form. Thus the composition of esterified short-chain acids in plasma protein was considerably different from that in tissue and organ lipids.

The compositions of free and esterified long-

chain acids in plasma protein are shown in Tables 5 and 6, respectively.

The content of branched-chain acids in both the free and esterified long-chain acids in plasma protein was low in all the samples. The composition of branched-chain acids in free form differed remarkably from that in esterified form. That is, branched-chain acids with carbon number lower than 13 were more abundant in free form than in esterified form and iso-11:0 acid was the most dominant among all branched-chain acids. In esterified form, branched-chain acids with carbon number lower than 14 were scarce and iso-17:0 acid was the most dominant among all branched acids, being similar to the characteristics of common fish oil.

In straight-chain acids, the total amount of saturated acids was much greater in free form than in esterified form. As for individual fatty acids, *n*-15:0 acid was not so different in amount between free and esterified forms but fatty acids with carbon number lower than 17 including even such lower acids as *n*-12:0 and *n*-14:0 acids except for *n*-15:0 acid were more abundant in the former than in the latter. Fatty acids higher than *n*-18:0 acid hardly showed any difference between free and esterified forms. The total amount of monoenoic acids showed no considerable difference between free and esterified forms. As for individual fatty acids, however, 17:1 and 18:1 acids were rather less in free form than in esterified form but other fatty acids were more abundant in the former. Moreover, such lower fatty acids as 12:1 acid were recognized in free form. On the other hand, the total amount of polyenoic acids was much greater in the latter. As for individual fatty acids, 18:3 ω 3, 20:3 ω 6, and 22:3 ω 6 acids were more abundant in free form than in esterified form but other fatty acids, especially 20:4 ω 6, 20:5 ω 3, and 22:6 ω 3 acids, were less in the former.

The composition of long-chain acids in blood corpuscle lipids is shown in Table 7.

The composition of long-chain acids in blood corpuscle lipids was similar to that in plasma protein lipids. However, *n*-16:0 and *n*-18:0 acids were more in blood corpuscles whereas 16:1 and 18:1 acids were less.

Discussion

Short-chain branched acids such as isobutyric and isovaleric acids were recognized in a fairly large amount in free and esterified forms in blood

Table 5. Composition (weight %) of free long-chain fatty acids in plasma protein of the whales
Stenella caeruleo-alba

Fatty acid	Sample number					
	1	2	3	4	5	6
iso-10:0	nd	nd	nd	nd	nd	nd
n-10:0	0.43	0.33	0.21	0.49	0.11	0.11
iso-11:0	0.38	0.33	0.23	0.55	0.26	0.19
anteiso-11:0	nd	nd	nd	nd	nd	nd
n-11:0	tr	0.09	0.02	tr	0.02	tr
iso-12:0	0.20	0.12	0.08	0.33	0.17	0.07
D(12):0	0.20	0.29	0.14	0.24	0.08	tr
n-12:0	3.84	4.26	2.62	5.43	2.71	2.30
A(13):0	0.21	0.11	0.20	0.41	0.22	0.15
iso-13:0	nd	tr	tr	nd	tr	tr
anteiso-13:0	0.22	0.05	0.20	0.29	0.21	0.20
n-13:0	tr	tr	0.10	0.11	0.06	0.05
iso-14:0	4.26	3.80	2.99	4.03	3.89	2.96
n-14:0	0.18	0.07	0.21	0.12	0.17	0.08
iso-15:0	nd	nd	0.11	0.12	0.12	0.12
anteiso-15:0	0.57	0.39	0.39	0.41	0.39	0.52
n-15:0	0.75	1.60	0.91	0.45	1.20	1.15
C(16):0	tr	tr	0.17	tr	0.21	tr
iso-16:0	22.15	17.63	15.50	17.29	16.61	17.72
n-16:0	0.17	0.19	0.24	0.07	0.16	0.16
iso-17:0	nd	nd	nd	nd	nd	nd
anteiso-17:0	2.30	2.59	2.00	2.00	1.93	2.55
n-17:0	0.77	1.00	0.62	0.47	1.12	0.98
C(18):0	0.19	tr	0.16	tr	0.13	tr
iso-18:0	10.62	6.00	6.82	8.91	6.79	10.71
n-18:0	0.04	nd	nd	0.06	0.19	tr
iso-19:0	0.13	0.02	0.07	0.06	0.13	0.15
n-19:0	nd	0.07	nd	tr	0.08	0.06
iso-20:0	0.33	0.16	0.27	0.37	0.24	0.28
D(20):0	1.46	1.11	1.27	1.89	1.38	1.03
E(20):0	0.27	nd	nd	nd	nd	nd
n-20:0	nd	nd	nd	nd	nd	nd
n-21:0	nd	nd	nd	nd	nd	nd
n-22:0	nd	nd	nd	nd	nd	nd
Total saturated	49.67	40.21	35.53	44.10	38.58	41.54
iso (total)	1.14	0.89	1.39	1.65	1.65	0.76
anteiso (total)	nd	nd	0.11	0.12	0.12	0.12
12:1	0.23	0.12	0.19	0.16	0.08	nd
14:1	0.23	0.14	0.12	0.29	0.07	0.15
14:1	0.69	0.39	0.73	0.60	0.17	0.10
15:1	0.37	0.08	nd	0.31	0.31	0.99
16:1	8.75	7.86	7.76	8.49	7.03	5.66
B(17):1	tr	0.35	0.53	0.29	0.49	0.41
17:1	0.39	0.12	0.15	0.68	0.16	0.14
18:1	27.06	31.76	29.31	30.17	32.69	30.75
19:1	0.11	0.05	0.16	0.11	0.11	0.09
20:1	3.13	4.60	3.27	3.27	5.15	3.20
22:1	2.35	3.72	2.99	2.66	4.69	2.37
Total monoene	43.31	49.19	45.21	47.03	50.59	43.86
12:2 ω ?	0.12	0.08	nd	0.23	nd	nd
16:2 ω 4	nd	nd	nd	nd	nd	nd

Fatty acid	Sample number					
	1	2	3	4	5	6
18:2 ω 6	0.59	1.08	1.01	0.88	0.65	0.84
18:3 ω 3	0.26	0.52	0.54	tr	0.39	0.21
18:4 ω 3	nd	0.17	nd	0.20	0.43	0.36
20:2 ω 6	0.26	tr	0.32	0.16	0.26	0.25
20:3 ω 6	0.15	0.11	0.21	0.17	0.22	0.26
20:4 ω 6	1.12	2.21	2.54	2.17	1.62	4.31
24:4 ω 3	0.48	0.44	0.82	0.98	1.31	0.39
20:5 ω 3	0.58	1.52	4.59	0.83	0.98	2.02
21:5 ω 2	1.58	1.29	0.90	0.74	0.58	0.62
22:3 ω 6	0.48	0.30	0.16	0.47	0.76	0.25
22:4 ω 6	0.25	0.24	0.49	0.35	0.58	0.41
22:5 ω 6	nd	0.20	0.81	0.22	0.33	0.28
22:5 ω 3	0.31	0.49	1.35	0.47	0.75	1.60
22:6 ω 3	0.84	1.95	5.52	1.00	1.61	2.80
Total polyene	7.02	10.60	19.26	8.87	10.47	14.60

tr: trace. nd: not detected under the condition employed. A-E: unknown. The same alphabets signify identical FCL (fractional equivalent chain length).

Table 6. Composition (weight %) of long-chain fatty acids in plasma protein lipids of the whales *Stenella caeruleo-alba*

Fatty acid	Sample number					
	1	2	3	4	5	6
iso-10:0	nd	nd	nd	nd	nd	nd
n-10:0	0.06	0.03	0.02	0.03	0.03	0.02
iso-11:0	0.05	0.04	0.02	0.02	0.01	0.02
anteiso-11:0	nd	nd	nd	nd	nd	nd
n-11:0	nd	nd	tr	nd	nd	tr
iso-12:0	nd	nd	0.03	0.02	tr	tr
D(12):0	nd	nd	nd	nd	nd	nd
n-12:0	0.09	0.24	0.20	0.09	0.09	0.18
A(13):0	0.09	0.32	0.10	0.09	0.08	0.08
iso-13:0	nd	tr	tr	nd	tr	tr
anteiso-13:0	nd	nd	tr	nd	nd	nd
n-13:0	0.06	tr	tr	nd	nd	nd
iso-14:0	tr	nd	0.04	tr	nd	0.04
n-14:0	2.08	2.12	2.34	1.95	1.87	2.00
iso-15:0	0.15	0.25	0.24	0.14	0.13	0.21
anteiso-15:0	nd	nd	0.04	tr	0.05	tr
n-15:0	0.53	0.48	0.60	0.41	0.42	0.39
C(16):0	0.17	nd	nd	0.23	0.09	nd
iso-16:0	0.14	0.10	0.24	0.14	0.11	0.16
n-16:0	15.29	12.63	12.05	13.25	13.30	11.00
iso-17:0	0.39	0.37	0.51	0.51	0.40	0.35
anteiso-17:0	nd	nd	nd	nd	nd	nd
n-17:0	1.87	1.60	1.02	0.98	1.33	0.71
C(18):0	nd	nd	nd	nd	nd	nd
iso-18:0	0.29	0.30	0.17	0.28	0.20	0.11
n-18:0	9.51	6.95	7.80	9.86	8.79	8.07
iso-19:0	nd	0.06	0.02	nd	tr	tr
n-19:0	0.03	nd	0.07	0.07	0.08	0.04
iso-20:0	nd	0.01	nd	nd	nd	nd
D(20):0	nd	0.56	0.04	nd	tr	0.08
E(20):0	0.75	0.06	0.64	0.66	0.94	0.63
n-20:0	0.14	nd	nd	nd	nd	nd

Fatty acid	Sample number					
	1	2	3	4	5	6
<i>n</i> -21:0	nd	nd	nd	nd	nd	nd
<i>n</i> -22:0	nd	nd	nd	nd	nd	nd
Total saturated	31.69	26.12	26.19	28.73	27.92	24.09
iso (total)	1.02	1.13	1.27	1.11	0.85	0.89
anteiso (total)	nd	nd	0.04	nd	0.05	nd
12:1	nd	nd	nd	nd	0.06	nd
14:1	0.05	nd	0.34	0.01	0.04	nd
14:1	0.15	0.13	0.77	0.09	0.09	0.10
15:1	0.12	0.06	0.44	tr	0.05	nd
16:1	4.82	4.53	6.64	4.56	3.52	3.81
B(17):1	2.11	2.71	2.07	1.85	1.98	1.71
17:1	0.63	0.47	0.71	0.56	0.71	0.61
18:1	40.77	33.79	33.35	39.05	33.87	33.69
19:1	0.13	0.07	0.10	0.11	0.20	0.06
20:1	2.97	1.07	3.10	2.39	3.68	2.11
21:1	nd	nd	nd	nd	nd	nd
22:1	1.73	1.21	2.11	1.44	1.87	1.32
Total monoene	53.48	44.04	49.63	50.06	46.07	43.41
12:2 ω ?	nd	nd	0.08	nd	nd	nd
16:2 ω 4	1.27	1.38	1.38	1.52	1.36	1.07
18:2 ω 6	0.79	1.30	0.99	1.02	0.96	0.98
18:3 ω 3	0.16	0.12	0.21	0.18	0.21	0.07
18:4 ω 3	0.05	0.07	0.07	0.05	0.11	0.13
20:2 ω 6	0.12	0.16	0.12	0.04	0.17	0.33
20:3 ω 6	0.05	0.10	0.12	0.18	0.15	0.12
20:4 ω 6	4.99	9.74	7.24	8.29	8.08	11.99
20:4 ω 3	0.44	0.27	0.56	0.38	0.31	0.55
20:5 ω 3	3.61	11.31	7.89	5.91	8.65	10.43
21:5 ω 2	0.62	0.01	0.41	0.26	0.35	tr
22:3 ω 6	0.21	nd	nd	nd	nd	nd
22:4 ω 6	0.44	0.47	0.49	0.24	0.56	0.54
22:5 ω 6	nd	0.13	0.28	0.19	0.40	0.30
22:5 ω 3	0.49	0.84	0.63	0.76	1.13	1.02
22:6 ω 3	1.59	3.94	3.71	2.19	3.57	4.97
Total polyene	14.83	29.84	24.18	21.21	26.01	32.50

tr: trace. nd: not detected under the condition employed. A-E: unknown. The same alphabets signify identical FCL.

of the whales unlike in land mammals⁹⁻¹¹. Moreover, isovaleric acid was much more abundant than isobutyric acids in both forms. When these short-chain branched acids are considered to originate from metabolic matters of muscle (dorsal), organs and so on, the same acids in blood are considered as the origin of those in subcutaneous tissue lipids. Since free acids in blood are usually considered to be liberated from subcutaneous tissue, however, it may well be possible that the free short-chain branched acids in blood also originate from the short-chain branched acids in subcutaneous tissue.

Since the composition of at least the esterified acids among the long-chain branched acids in blood is similar to that of fish oil, it is most likely that the acids have originated from food. Moreover, the long-chain branched acids of lipids in tissue and organs such as muscle and liver may also have possibly originated from food in light of the similar composition to that of the esterified lipids in blood.

It is considered that the branched-chain acids in blood of the mother supplying nutrients to the fetus may exert some effect on the composition of fatty acids of lipids in the fetus. However, the results in this study were insufficient to explain the

Table 7. Composition (weight %) of long-chain fatty acids in blood corpuscle lipids of the whales *Stenella caeruleo-alba*

Fatty acid	Sample number	
	1	4
iso-10:0	nd	tr
n-10:0	0.03	0.02
A(11):0	0.02	0.02
iso-11:0	nd	nd
anteiso-11:0	nd	nd
n-11:0	0.02	tr
A(12):0	0.16	0.05
iso-12:0	nd	nd
D(12):0	0.04	0.02
n-12:0	0.25	0.05
A(13):0		
iso-13:0	tr	nd
anteiso-13:0	nd	nd
n-13:0	nd	tr
A(14):0	0.03	0.04
iso-14:0	tr	0.03
n-14:0	1.20	1.00
B(15):0	0.20	0.05
iso-15:0	0.20	0.05
anteiso-15:0	nd	0.06
n-15:0	0.30	0.27
A(16):0	0.16	0.34
iso-16:0	0.11	0.08
n-16:0	14.52	17.43
B(17):0	0.55	0.21
iso-17:0	0.82	0.23
anteiso-17:0	nd	0.18
n-17:0	1.28	0.76
A(18):0	0.33	0.44
iso-18:0	0.76	0.45
n-18:0	12.58	14.85
C(19):0	0.17	nd
iso-19:0	nd	nd
n-19:0	0.46	0.09
A(20):0	nd	0.12
C(20):0	nd	0.11
D(20):0	tr	0.21
n-20:0	0.57	0.49
C(22):0	1.14	nd
n-22:0	nd	nd
Total saturated	36.25	37.58
iso (total)	1.89	0.85
anteiso (total)	nd	0.18
14:1	0.01	0.05
14:1	nd	nd
15:1	0.02	nd
16:1	3.76	2.62
17:1	0.26	0.11

Fatty acid	Sample number	
	1	4
18:1	27.89	22.45
19:1	0.48	0.34
20:1	2.77	4.71
22:1	2.14	2.49
Total monoene	37.33	32.77
18:2 ω 6	0.94	0.73
18:3 ω 3	0.25	0.11
18:4 ω 3	0.07	tr
20:2 ω 6	nd	nd
20:3 ω 6	nd	nd
20:4 ω 6	10.68	13.37
20:4 ω 3	0.19	0.08
20:5 ω 3	8.47	8.93
21:5 ω 2	tr	0.10
22:3 ω 6	nd	nd
22:4 ω 6	0.49	0.70
22:5 ω 6	0.01	0.13
22:5 ω 3	1.28	1.31
22:6 ω 3	4.04	4.09
Total polyene	26.41	29.53

tr: trace. nd: not detected under the condition employed. A-E: unknown. The same alphabets signify identical FCI.

reason for the difference in the composition of fatty acids between the fetus and adult. Further studies are awaited.

Acknowledgements

The author expresses here his sincere thanks to Prof. Dr. T. KANEDA, Faculty of Agriculture, Tohoku University, who kindly gave valuable suggestions.

References

- 1) H. MORII: *Bull. Fac. Fish., Nagasaki Univ.*, **49**, 35-52 (1980).
- 2) H. MORII and R. KANAZU: *Bull. Japan. Soc. Sci. Fish.*, **38**, 1035-1039 (1972).
- 3) Y. MUTO: in "Clinical lipids Biochemistry" (ed. by I. HARA, N. HOSOYA, Y. TAKAHASHI, and C. NAITO), Igaku Shoin Ltd., Tokyo, Japan, 1972, pp. 333.
- 4) E. S. ERWIN, G. J. MARCO, and E. M. EMERY: *J. Dairy Sci.*, **44**, 1708-1711 (1961).
- 5) C. REMESY and C. DEMIGNE: *Biochem. J.*, **141**, 85-91 (1974).