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Fatty Acid Composition of 35 Species of Marine Invertebrates

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Fatty acid compositions of 35 species of marine invertebrates (13 species of Bivalvia, 10 species of Gastropoda, 4 species of Cephalopoda, 4 species of Crustacea, 2 species of Ascidacea, 2 species of Holothuroidea) were studied using gas-liquid chromatography. Total lipids in all samples were very low, ranging from 0.24% to 1.96%. The prominent fatty acids were 16:0, 20:5 (n-3), 22:6 (n-3), 18:0, 16:1 (n-7), 20:4 (n-6), 18:1 (n-9) and 18:1 (n-7) in the majority of marine invertebrates. Polyunsaturated fatty acid (PUFA) was the richest fatty acid group in all invertebrates, accounting for 55.3 ± 6.70% of total fatty acids (TFA), followed by saturated (26.2 ± 4.33%) and monounsaturated fatty acid (18.5 ± 5.87 %). No correlation was found between total lipid content and each fatty acid group. Cephalopoda contained the highest level of n-3 PUFA (54.6 ± 5.17%), while Holothuroidea and Gastropoda contained the lowest level of n-3 PUFA, accounting for 26.5 ± 4.44% and 28.4 ± 4.04%, respectively. Bivalvia and Ascidacea are plankton feeders, which were rich in 20:5 (n-3) and 22:6 (n-3). Carnivorous species of Cephalopoda were prominently rich in 22:6 (n-3), ranging from 26.7% to 46.1% of the TFA. However, some species of Gastropoda are seaweed feeder (herbivorous), which contained high level of 20:4 (n-6) compared to plankton feeder and carnivorous species. In addition, blue and red colored sea cucumbers, and turban shells with and without apophyses belong to the same species, but they live in different habitats. These organisms were found to have different fatty acid compositions. Therefore, fatty acid compositions of these invertebrates might be affected by their different environments, particularly their diet.

Key words: fatty acid composition, n-3 PUFA, marine invertebrates

Introduction

The annual consumption of marine food in Korea has increased about 10 Kg/caput in the last 5 years (Korea Rural Economic Institute, 1996). This increase is thought to be highlighted in the viewpoint having beneficial effects to human health because sea food contains large amounts of n-3 fatty acids, such as eicosapentaenoic acid (EPA, 20:5 (n-3)) and docosahexaenoic acid (DHA, 22:6 (n-3)) (Lees, 1990). Marine invertebrates are a commercially important sea food in Korea. In particular, the production of cultured oyster in Korea was 185,000 M/T in 1997 (Ministry of Maritime Affairs and Fisheries, 1998). In addition to the oyster, blue mussel, ark shell, tiger prawn and ascidian have been cultured actively in Korea and the increase of their yield is expected. These invertebrates serve as intermediate producers in the marine food web, from the primary precursors, the phytoplankton, to the upper tropic levels, the carnivorous fish etc. (Joshep, 1982). Lipid content and fatty acid compositions of marine organisms are affected largely by their endogenous and exogenous factors. Their feeding habits are an especially important exogeneous factor and the habits vary by species such as plankton feeder, herbivorous and carnivorous species, and mud swallow etc. Marine invertebrates therefore are expected to show certain characteristic fatty acid compositions by their species. However, little information was available at the time on the fatty acid compositions of marine invertebrates in Korea (Jeong *et al.*, 1993a; Yoon *et al.*, 1986).

Authors have been studying functional lipid

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components of Korean sea food in order to obtain information for the food. As a result, we reported proximate composition, cholesterol, α-tocopherol content, and fatty acid compositions of 72 species of Korean fish (Jeong *et al.*, 1998a,b). We also reported proximate composition and sterol content of 35 species of marine invertebrates caught off the coast of Tongyeong, Korea (Jeong *et al.*, 1998c). In this study, we made information available on the fatty acid composition of 35 species of marine invertebrates in Korea. This work demonstrated a comprehensive survey of the fatty acid composition of the vast marine invertebrates for the first time in Korea.

Material and Methods

Lipid content and fatty acid composition were analyzed in 35 species of marine invertebrates. The samples were purchased from a fish market in Tongyeong city, Korea and transported to our laboratory in an ice box. Shell length, height and body weight of the samples were measured. Shells were removed from the shelled species, and the viscera was removed from sea cucumbers and sea hare (boiled). Approximately 300~500 g of the edible portion was removed from more than two individuals of each species and mixed by a speed cutter. Total lipid (TL) was extracted and purified according to the method of Bligh and Dyer (1959) and the content was determined gravimetrically. Phospholipid (PL) content in TL was obtained by multiplying total phosphorus content by 25 (Bartlett, 1959) and neutral lipid (NL) content was calculated from the difference between TL and PL content. Fatty acid was determined after methylation (AOCS, 1990). Fatty acid composition was analyzed with a gas-liquid chromatography (Shimadzu GC 14A, Shimadzu Seisakusho, Co. Ltd., Kyoto, Japan) fitted with an Omegawax 320 fused silica capillary column (30 m×0.32 mm, ID., Supelco Park, Bellefonte, PA, USA). The injector and the flame-ionization detector were held at 250 ℃ and the column was programed from 180℃ (initial time 8 min) to 230℃ at 3℃/min and final time set for 15 min. Helium was used as a carrier gas at the constant inlet pressure of 1.0 Kg/cm^2 with split ratio 1:50. Fatty acids were identified by comparison with authentic standards (Sigma Chemical Co., St. Louis, MO, USA) and a sample of oyster which had been analyzed by Koizumi *et al.* (1990). Data were calculated as the peak area percent of total peak area of fatty acids. Methyl tricosanoate (99%, Aldrich Chem. Co., Milw., WI., USA) was used as an internal standard for the quantitatve calculation of PUFA. All the data are presented as mean value of 4 determinations (2 group×2 times) for each species of fish. Standard deviation for these analyses was less than 0.90.

Results and Discussion

The content of TL, NL and PL are shown in Table 1. TL content ranged from 0.24% (blue colored sea cucumbers) to 1.96% (ascidian), the mean value was about 1%, described in the previous paper (Jeong *et al.*, 1998c). The proportion of NL to TL was the highest in Holothuroida (80.0%), but the lowest in Cephalopoda (33.3%). On the contrary, the proportion of PL to TL showed the highest level in Cephalopoda (66.7%), but the lowest level in Holothuroida (20.0%). Marine invertebrates therefore contained a relatively high level of PL compared to that of fish. The proportion of PL showed a similar value to that of demersal fish, which contained low levels of TL in other fish groups such as mid-surface dwelling and migratory fish, and reef dwelling fish (unpublished data).

Table 2 shows fatty acid compositions of 35 species of marine invertebrates. Approximately 60 different types of fatty acids were detected in all samples. Prominent fatty acids were 16:0, 20:5 (n-3) (EPA), 22:6 (n-3) (DHA), 20:4 (n-6), 18:0, 16;1 (n-7), 18:1 (n-9), which were similar to those of fish (Jeong *et al.*, 1998b), except that of 20:4 (n-6). Polyunsaturated fatty acids (PUFA) showed the highest level (55.3 ± 6.70%) in all samples, followed by saturated fatty acids (SFA) (26.2 ± 4.33 %), and finally monounsaturated fatty acids (MUFA) (18.5 ± 5.87%). Cephalopoda contained the highest PUFA, 61.4 ± 1.46%, of all the species. The PUFA level of Bivalvia (55.2 ± 3.90%) was similar to that of Gastropoda (57.9 ± 7.73%). However, Ascidacea, Crustacea and Holothuroida showed relatively low levels of PUFA, ranging from 48.2 to 49.6%. In this study, PUFA level of marine invertebrates was approximately 17%

Table 1. Lipid content of 35 species of marine invertebrates (g/100 g edible portion)

Species (Korean name)	Lipids*			Species (Korean name)	Lipids*		
	TL	NL	PL		TL	NL	PL
Bivalvia				Cephalopoda			
1. Blue mussel (Jin-ju-dam-chi)	1.43	1.01	0.42	24. Poulp squid (Nag-ji)	0.82	0.12	0.71
2. Mussel (Cham-dam-chi)	0.89	0.32	0.57	25. (Ju-ggu-mi)	1.26	0.51	0.76
3. Babyneck clam (Ban-ji-rag)	1.73	1.12	0.61	26. Cuttle fish (Cham-o-jing-eo)	1.28	0.40	0.88
4. Oyster (Cham-gul)	1.84	1.10	0.74	27. Common octopus (Mun-eo)	0.73	0.32	0.41
5. Cockle (Sae-jo-gae)	1.17	0.93	0.24	Mean	1.02	0.34	0.69
6. Purplish (Gae-jo-gae)	0.55	0.32	0.23	SD	0.29	0.16	0.20
7. Korean scallop (Bi-dan-ga-ri-bi)	1.06	0.64	0.42				
8. Bloody clam (Sae-go-mag)	1.07	0.67	0.40	Crustacea			
9. Gaper (U-reog)	0.96	0.52	0.45	28. Tiger prawn (Bo-ri-sae-u)	0.90	0.32	0.59
10. Venus clam (Sal-jo-gae)	0.67	0.49	0.18	29. (Wang-bam-song-i-ge)	0.87	0.36	0.51
11. Tellin (Bi-dan-jo-gae)	0.46	0.31	0.15	30. Blue crab (Ggoch-ge)	0.89	0.37	0.52
12. Pen shell (Ki-jo-gae)	0.69	0.35	0.34	31. (Min-ggoch-ge)	0.85	0.40	0.45
13. Ark shell (Pi-jo-gae)	1.51	1.17	0.35	Mean	0.88	0.36	0.52
Mean	1.08	0.69	0.39	SD	0.02	0.03	0.06
SD	0.44	0.34	0.17				
Gastropoda				Ascidacea			
14. Turban shell (So-ra) (A)**	1.37	1.07	0.30	32. Ascidian (Meong-ge)	0.71	0.21	0.50
15. Turban shell (So-ra) (B)**	0.90	0.34	0.56	33. (Mi-deo-deog)	1.35	0.78	0.58
16. Top shell (Bo-mal-go-dung)	0.98	0.61	0.37	Mean	1.03	0.50	0.54
17. Whelk (Mae-ggeun-i-go-dung)	0.81	0.53	0.28	SD	0.37	0.21	0.17
18. Abalone shell (Cham-jeon-bog)	0.71	0.11	0.60				
19. Murex shell (Maeb-sa-ri)	1.87	1.36	0.51	Holothuroida			
20. Whelk (Gag-si-su-rang)	1.88	1.19	0.69	34. Sea cucumbers			
21. Moon snail (Keun-gu-seul-u-reong-i)	0.82	0.41	0.41	(Hong-sam) (C)**	0.45	0.38	0.07
22. Triton shell (Na-pal-go-dung)	0.60	0.18	0.42	35. Sea cucumbers			
23. Sea hare (Gun-so)	1.63	0.93	0.70	(Cheong-sam) (D)**	0.24	0.18	0.06
Mean	1.13	0.63	0.50	Mean	0.35	0.28	0.07
SD	0.51	0.44	0.15	SD	0.15	0.14	0.01

* TL, total lipid; NL, neutral lipid; PL, phospholipid.
** A, with apophyses on the shell; B, without apophyses; C, red colored; D, blue colored.

higher than that of fish (Jeong *et al.*, 1998b). This shows that marine invertebrates contain a higher proportion of PL as shown in Table 1, compared to that of fish. In general, PL is richer in PUFA than triglycerides (Belling *et al.*, 1997; Jeong *et al.*, 1998b). The proportion of n-3 PUFA was the highest in Cephalopoda (54.6 ± 5.17%), but the lowest in Gastropoda (28.4 ± 4.04%) and Holothurida (26.5 ± 4.44%). However, Bivalvia, Ascidacea and Crustacea showed similar levels of n-3 PUFA, 42.1 ± 3.26%, 41.5 ± 0.13% and 37.2 ± 5.68%, respectively. High level of n-3 PUFA in Cephalopoda particularly was due to a high proportion of DHA, ranging from 26.7% to 46.1%, as shown in Table 2. On the other hand, the level of EPA was higher in most of marine invertebrates (except that of Cephalopoda) than that of DHA. These results differed from those of most fish, which contained more DHA than EPA (Jeong *et al.*, 1998).

The prominent n-6 PUFAs were 20:4 (n-6) and 22:4 (n-6). The n-6 PUFAs were found in high levels in Gastropoda and Holothuroida, about 20 %, which contained low levels of n-3 PUFA. The ratio of n-3/n-6 in each species was relative proportion to their n-3 PUFA level. Cephalopoda showed the highest n-3/n-6 ratio, 1.55, followed by Ascidacea (8.31), Bivalvia (6.94), Crustacea (3.59), Gastropoda (3.59) and Holothuroida (1.33). There was no correlation between TL content and SFA, MUFA and PUFA. This is thought to be due to extremely low TL content in marine invertebrates.

Table 2. Fatty acid composition of 35 species of marine invertebrates (Area %)

Fatty acid	Bivalvia								
	1. Blue mussel	2. Mussel	3. Babyneck clam	4. Oyster	5. Cockle	6. Purplish	7. Korean scallop	8. Bloody clam	9. Gaper
12:0	tr***	0.13	–****	–	–	–	tr	–	–
14:0	0.90	2.97	1.41	3.34	5.29	1.41	3.42	3.39	2.87
15:0, iso	–	tr	tr	0.13	0.11	–	tr	tr	0.12
15:0	0.25	0.37	0.31	0.48	0.57	0.25	0.38	0.24	0.28
16:0, iso	tr	tr	0.30	0.12	tr	0.31	tr	0.11	0.24
pristanic	tr	0.10	0.12	0.22	0.15	0.59	0.20	1.46	0.40
16:0	13.6	17.2	14.7	15.2	12.5	16.1	18.6	12.7	13.7
17:0, iso	0.26	0.37	0.89	0.51	0.54	1.48	0.23	0.17	0.95
17:0, anteiso	0.13	0.33	0.62	0.40	0.24	0.34	0.26	0.60	0.58
phytanic	–	0.10	0.25	–	–	–	tr	–	0.15
17:0	0.50	0.73	0.90	1.00	0.62	1.10	0.51	1.08	0.66
18:0	3.69	3.36	5.41	3.14	4.24	5.00	4.67	4.91	3.64
19:0	0.10	0.13	tr	tr	0.12	–	0.14	0.10	–
20:0	tr	0.31	0.21	tr	0.33	0.25	0.10	0.19	0.11
22:0	–	–	–	0.15	–	–	–	tr	–
Σ Saturates	19.4	26.1	25.1	24.7	24.7	26.9	28.5	25.0	23.7
16:1 (n-9)	–	–	0.25	0.28	–	0.97	0.29	0.30	0.82
16:1 (n-7)	12.5	6.58	4.01	3.09	11.3	2.66	7.50	7.71	6.65
16:1 (n-5)	0.11	0.22	tr	0.95	0.38	0.31	0.17	0.43	0.56
17:1 (n-10)	–	–	–	0.23	0.49	–	0.66	0.67	0.25
17:1 (n-8)	tr	0.13	0.16	0.20	0.44	1.05	0.19	0.16	0.14
18:1 (n-11)	0.22	0.14	0.23	0.49	–	0.30	0.10	0.19	0.20
18:1 (n-9)	1.52	1.65	3.47	2.59	2.81	3.24	3.08	1.61	5.59
18:1 (n-7)	3.47	1.91	4.07	4.86	3.12	1.27	4.89	3.08	2.94
18:1 (n-5)	0.19	0.17	0.11	0.15	0.11	0.25	0.12	0.10	tr
20:1 (n-11)	0.94	1.00	1.82	1.19	0.45	3.13	1.19	2.49	4.33
20:1 (n-9)	1.64	1.68	2.01	0.49	1.58	0.70	0.71	0.81	1.57
20:1 (n-7)	1.41	1.02	1.35	3.48	0.81	2.60	1.13	1.72	1.68
22:1 (n-11)	–	–	–	0.15	–	–	–	0.20	–
22:1 (n-9)	tr	0.14	0.22	0.33	0.21	–	tr	0.11	0.18
Σ Monoenes	22.0	14.6	17.7	18.5	21.7	16.5	20.0	19.6	24.9
16:2 (n-7)	0.14	tr	–	–	0.12	0.71	tr	–	0.10
16:2 (n-4)	1.20	0.45	0.18	0.46	1.01	0.32	0.41	0.45	0.26
16:4 (n-3)	2.29	2.51	1.53	2.77	1.48	3.56	3.16	2.68	1.52
16:4 (n-1)	0.68	0.16	0.22	–	0.39	–	0.44	–	–
17:2 (n-8)	0.10	0.30	0.21	0.16	0.19	0.45	0.16	–	–
18:2 (n-6)	0.58	1.17	0.67	1.00	1.08	0.73	1.25	1.11	1.56
18:2 (n-4)	0.85	0.36	0.57	0.43	0.52	0.20	0.35	0.13	0.31
18:3 (n-4)	0.67	0.29	0.05	0.25	0.20	0.12	tr	–	–
18:3 (n-3)	0.90	0.71	0.28	0.67	1.15	0.45	1.35	0.73	0.20
18:3 (n-1)	0.10	tr	–	tr	–	–	–	–	–
18:4 (n-3)	3.18	1.48	1.02	1.63	3.31	1.12	3.21	1.20	0.57
18:4 (n-1)	0.64	0.20	–	0.10	0.12	–	tr	–	–
19:3 (n-6)	0.43	0.16	0.23	0.39	0.12	0.81	0.93	0.36	2.52
20:2NMID* (5,11)	1.10	1.93	0.27	0.56	0.11	–	0.28	0.13	0.28
20:2NMID (5,13)	0.63	0.46	0.28	tr	tr	–	0.18	0.31	0.18
20:2NMID	–	–	0.31	tr	–	–	tr	0.10	0.40
20:2 (n-6)	0.21	0.29	1.53	0.10	0.78	0.83	0.25	–	0.68
20:3 (n-6)	tr	0.12	0.15	0.13	0.16	–	0.18	tr	0.20
20:4 (n-6)	1.43	4.20	1.71	3.25	1.41	3.07	2.23	3.64	4.33
20:3 (n-3)	tr	tr	0.16	tr	0.20	0.14	0.12	tr	–
20:4 (n-3)	0.51	0.27	0.56	0.33	0.86	0.35	0.60	0.27	0.36
20:5 (n-3)	24.2	20.9	20.8	26.6	21.2	8.19	16.7	17.8	24.1
22:2NMID (7,13)	0.21	0.31	1.47	0.59	0.50	1.37	0.27	2.19	tr
22:2NMID (7,15)	2.58	2.74	2.27	2.96	0.48	4.99	0.38	6.00	0.15
22:2NMID	–	0.22	–	–	–	–	–	–	–
22:2 (n-6)	0.39	0.53	0.55	0.23	0.39	0.79	0.36	0.26	0.22
21:5 (n-3)	1.08	1.04	1.77	1.24	1.24	1.29	0.74	0.88	0.99
22:4 (n-6)	0.14	0.53	0.49	0.34	0.40	0.62	0.18	0.33	0.68
22:5 (n-6)	0.12	0.44	0.32	0.29	0.32	0.73	0.49	0.80	0.54
22:5 (n-3)	1.11	0.98	1.87	1.30	1.18	1.49	0.70	1.35	1.75
22:6 (n-3)	12.5	16.3	17.5	10.7	14.6	24.3	15.8	14.5	9.34
Σ Polyenes	58.0	59.0	57.0	56.5	53.5	56.7	50.8	55.3	51.2

Table 2. (continued) (Area %)

Fatty acid	Bivalvia				Gastropoda				
	10. Venus clam	11. Tellin	12. Pen shell	13. Ark shell	14. Turban shell (A)**	15. Turban shell (B)**	16. Top shell	17. Whelk (C)**	18. Abalone shell
14:0	0.71	1.31	0.69	1.77	1.74	2.18	1.06	2.08	3.52
15:0, iso	0.37	0.28	tr	tr	tr	0.22	0.12	0.30	tr
15:0, anteiso	0.14	—	—	tr	tr	tr	—	—	—
15:0	0.33	0.42	0.43	0.21	2.05	0.49	0.63	0.16	tr
16:0, iso	0.59	0.29	0.18	tr	0.18	0.13	0.41	0.19	tr
pristanic	0.78	0.58	0.36	0.41	0.16	0.78	0.18	1.82	0.70
16:0	15.3	19.1	14.9	17.9	21.8	8.51	17.6	7.11	20.1
16:0, methyl	0.77	0.45	—	—	—	—	—	—	—
17:0, iso	1.82	1.34	0.30	0.21	0.25	0.70	0.67	0.27	tr
17:0, anteiso	1.36	0.23	0.61	0.37	0.75	0.69	0.86	0.62	0.53
17:0	1.24	1.49	0.94	1.15	3.09	0.80	2.03	0.63	0.92
18:0	4.70	6.05	5.60	6.24	4.23	6.30	4.32	6.94	4.67
19:0	—	—	—	0.13	—	tr	0.14	—	—
20:0	0.14	0.11	—	0.18	0.24	0.14	—	tr	—
Σ Saturates	28.2	31.7	24.0	28.6	34.4	21.1	28.0	20.1	30.5
16:1 (n-13)	—	—	—	—	—	0.86	—	—	—
16:1 (n-9)	1.99	1.24	0.50	—	0.32	0.97	0.66	0.57	0.55
16:1 (n-7)	1.41	1.88	0.81	8.06	1.02	0.44	1.18	0.63	1.49
16:1 (n-5)	0.85	1.01	1.31	0.41	0.25	0.67	0.19	1.37	0.99
17:1 (n-10)	—	1.28	0.79	0.59	0.19	0.51	0.54	0.40	tr
17:1 (n-8)	1.91	0.12	—	0.34	0.31	0.13	0.36	—	0.32
18:1 (n-11)	0.26	0.17	—	0.37	—	0.71	—	0.13	0.11
18:1 (n-9)	2.95	3.34	1.72	3.07	4.41	1.58	3.27	3.84	4.47
18:1 (n-7)	1.76	2.47	2.09	3.65	2.51	0.65	6.62	0.61	7.83
18:1 (n-5)	0.15	0.13	0.96	0.17	—	0.16	0.10	tr	tr
20:1 (n-11)	2.45	1.57	1.68	2.07	1.60	8.22	2.38	3.97	3.97
20:1 (n-9)	1.84	1.41	2.25	1.08	0.24	1.64	0.16	1.74	tr
20:1 (n-7)	1.54	1.17	0.67	2.80	0.05	1.94	0.51	0.39	0.45
22:1 (n-11)	—	—	—	—	—	—	—	0.11	tr
22:1 (n-9)	—	—	tr	0.19	1.13	0.53	0.23	0.28	tr
22:1 (n-7)	—	—	—		—	0.16	—	—	—
Σ Monoenes	17.1	15.8	12.8	22.6	12.0	19.2	16.2	14.0	20.2
16:2 (n-7)	—	0.76	0.25	—	—	—	—	—	—
16:2 (n-4)	—	0.34	—	0.69	—	0.50	tr	—	—
16:3 (n-3)	0.13	—	—	—	—	0.44	—	—	—
16:4 (n-3)	4.29	3.90	6.93	1.54	3.04	4.90	8.30	7.50	4.33
16:4 (n-1)	—	—	—	0.31	—	—	—	—	—
17:2 (n-8)	0.49	0.39	0.18	0.13	—	—	0.21	0.33	0.32
18:2 (n-6)	0.38	0.46	0.74	1.02	2.75	1.41	2.09	3.26	1.96
18:2 (n-4)	0.15	0.23	0.10	0.28	—	0.21	0.24	—	tr
18:3 (n-4)	0.17	0.19	0.29	0.12	—	0.30	—	—	0.13
18:3 (n-3)	0.15	0.13	0.32	0.77	1.18	0.12	1.32	0.22	2.80
18:4 (n-3)	0.33	0.42	0.42	1.25	0.17	0.07	0.69	—	0.49
19:3 (n-6)	0.29	0.36	1.04	0.20	0.49	0.94	1.66	0.45	1.59
20:2NMID (5,11)	0.17	0.23	1.07	0.42	tr	0.44	—	tr	tr
20:2NMID (5,13)	0.11	0.15	0.25	0.64	tr	0.97	—	tr	0.13
20:2NMID	0.13	—	0.42	0.11	—	0.40	0.19	—	0.37
20:2 (n-6)	1.05	0.84	0.37	0.12	1.38	1.47	0.12	1.30	0.26
20:2 (n-6)	0.17	0.16	tr	0.17	0.28	0.14	0.10	0.23	0.26
20:4 (n-6)	3.99	2.98	4.34	2.20	14.6	8.05	10.6	11.6	12.2
20:3 (n-3)	tr	tr	—	tr	—	—	—	—	0.23
20:4 (n-3)	0.18	0.19	0.22	0.38	0.20	0.11	0.20	0.17	0.21
20:5 (n-3)	7.68	7.32	14.3	19.5	6.93	7.80	8.98	4.19	7.35
21:5 (n-3)	0.88	0.97	2.22	0.92	0.67	0.99	0.58	0.42	0.32
22:2NMID (7,13)	1.91	1.15	3.84	0.33	1.78	4.71	1.25	6.84	4.38
22:2NMID (7,15)	4.18	2.01	2.91	3.39	2.14	7.77	4.60	5.89	0.60
22:2NMID	—	—	—	—	0.10	—	—	—	—
22:2 (n-6)	0.32	0.10	0.10	0.30	0.27	0.12	0.24	0.21	0.15
22:4 (n-6)	2.41	1.83	1.03	0.23	6.33	2.41	2.28	3.14	3.04
22:5 (n-6)	0.79	1.17	0.65	0.30	0.33	0.55	0.56	0.19	0.11
22:5 (n-3)	2.14	2.25	1.99	0.83	9.88	7.24	9.15	14.9	7.17
22:6 (n-3)	22.1	24.0	19.1	12.2	0.73	7.61	2.42	4.79	0.14
Σ Polyenes	54.6	52.5	63.0	48.4	53.3	59.7	55.8	65.6	48.5

Table 2. (continued) (Area %)

Fatty acid	Gastropoda					Cephalopoda			
	19. Murex shell	20. Whelk (D)**	21. Moon snail	22. Triton shell	23. Sea hare	24. Poulp squid	25. (Zug-gumi)	26. Cuttle fish	27. Common octopus
14:0	3.47	2.05	0.75	1.56	0.36	1.03	1.50	1.17	0.80
15:0, iso	tr	tr	tr	0.10	0.15	tr	tr	–	–
15:0	0.20	tr	0.22	0.65	0.23	0.26	0.41	0.33	0.21
16:0, iso	–	0.11	0.34	0.42	0.11	tr	tr	–	tr
pristanic	0.73	0.27	0.60	0.53	1.71	0.57	0.35	0.65	0.57
16:0	12.7	12.2	6.72	4.21	9.25	15.4	23.2	25.9	16.1
16:0, methyl	–	–	0.49	0.59	–	–	–	–	–
17:0, iso	0.16	0.54	0.44	0.68	tr	0.24	0.13	tr	0.17
17:0, anteiso	0.18	0.34	0.52	1.41	1.45	0.42	0.12	tr	0.49
phytanic	tr	0.13	–	–	–	–	–	–	–
17:0	0.28	0.80	0.83	1.39	0.99	1.45	0.78	0.51	1.17
18:0	4.31	5.19	9.07	7.52	6.16	8.26	4.19	4.20	7.61
19:0	–	tr	0.15	–	–	0.13	tr	–	–
20:0	tr	0.13	0.11	–	–	tr	tr	–	–
22:0	0.19	0.20	0.15	–	–	0.34	tr	–	–
Σ Saturates	22.2	22.0	20.4	19.1	20.4	28.1	30.7	32.7	27.1
14:1 (n-7)	0.14	tr	0.18	–	0.21	–	–	–	–
16:1 (n-9)	0.18	0.33	0.67	0.80	0.41	–	–	–	0.14
16:1 (n-7)	3.37	2.73	0.68	0.28	1.54	0.69	0.81	0.34	0.46
16:1 (n-5)	0.51	0.27	0.90	1.36	1.43	0.48	0.20	0.04	0.80
17:1 (n-10)	0.11	0.17	1.22	0.44	–	0.20	–	–	–
17:1 (n-8)	tr	0.21	0.15	0.30	0.36	0.15	tr	–	tr
18:1 (n-11)	1.51	0.36	–	–	0.12	0.42	0.14	–	0.34
18:1 (n-9)	3.18	8.17	2.32	0.35	4.41	2.13	1.79	1.32	2.05
18:1 (n-7)	5.27	4.24	0.67	0.84	2.84	2.42	0.97	0.86	1.28
18:1 (n-5)	0.25	0.24	0.13	0.15	0.31	0.32	0.13	tr	0.21
20:1 (n-11)	6.91	5.62	3.51	4.54	2.97	–	–	0.18	0.40
20:1 (n-9)	2.31	3.31	1.07	1.23	1.85	4.52	2.46	2.91	3.66
20:1 (n-7)	3.03	2.53	1.55	0.57	0.36	0.30	tr	tr	0.16
22:1 (n-11)	0.45	0.85	0.21	0.86	–	–	–	–	0.20
22:1 (n-9)	0.13	0.18	0.20	–	0.44	0.41	tr	0.11	0.38
22:1 (n-7)	0.26	–	0.12	–	–	0.18	–	–	–
Σ Monoenes	27.6	29.2	13.6	11.7	17.3	12.2	6.50	5.76	10.1
16:2 (n-4)	0.21	0.11	0.54	0.68	0.47	–	tr	–	–
16:3 (n-3)	–	–	tr	0.16	–	–	–	–	–
16:4 (n-3)	1.80	0.96	4.17	7.60	3.76	1.90	0.51	0.59	3.49
16:4 (n-1)	–	–	–	–	–	–	tr	0.13	–
17:2 (n-8)	tr	0.35	0.52	0.90	–	0.42	0.14	0.15	0.35
18:2 (n-9)	–	–	–	–	–	tr	–	–	–
18:2 (n-6)	1.04	1.40	4.29	2.54	1.15	0.38	0.18	0.11	0.28
18:2 (n-4)	0.21	0.39	0.17	–	tr	tr	tr	–	–
18:3 (n-4)	0.12	0.35	0.32	–	–	–	tr	–	–
18:3 (n-3)	tr	0.31	0.20	0.11	2.94	0.21	tr	–	tr
18:4 (n-3)	0.21	0.31	tr	–	0.23	tr	tr	–	–
19:3 (n-6)	0.84	0.99	1.87	0.15	–	0.13	tr	tr	–
20:2NMID (5,11)	1.55	0.42	0.38	0.25	tr	tr	tr	–	–
20:2NMID (5,13)	4.89	0.27	0.27	0.86	0.10	tr	–	–	–
20:2NMID	0.35	0.32	tr	–	0.19	tr	–	–	–
20:2 (n-6)	1.07	2.66	2.75	1.37	1.38	0.43	0.23	0.17	0.20
20:3 (n-6)	0.15	0.19	0.13	–	1.95	–	–	–	–
20:4 (n-6)	5.32	tr	10.4	21.0	13.6	6.91	1.30	1.45	8.13
20:3 (n-3)	–	0.23	–	0.17	1.43	0.54	0.39	0.30	0.20
20:4 (n-3)	0.13	0.47	tr	–	4.04	0.12	tr	tr	tr
20:5 (n-3)	16.8	15.2	13.2	3.96	7.79	16.5	11.6	11.2	15.6
21:5 (n-3)	0.62	0.67	0.82	0.42	0.81	0.40	0.12	0.10	0.13
22:2NMID (7,13)	–	3.06	5.30	7.32	2.98	–	–	–	0.21
22:2NMID (7,15)	2.63	1.84	4.07	1.03	1.62	0.27	tr	–	–
22:2NMID	2.96	–	–	–	–	–	–	0.46	–
22:2 (n-6)	tr	0.12	tr	–	0.10	0.46	0.17	–	0.10
22:3 (n-3)	–	–	–	–	0.62	–	–	–	–
22:4 (n-6)	0.90	1.28	2.31	6.11	13.8	0.83	0.28	–	1.17
22:5 (n-6)	tr	0.33	1.21	–	0.23	0.57	0.31	0.28	0.47
22:5 (n-3)	4.04	4.72	3.88	14.1	2.77	2.36	0.50	0.32	1.74
22:6 (n-3)	3.75	11.5	8.84	0.50	0.15	26.7	46.1	45.7	30.4
Σ Polyenes	49.6	48.4	65.7	69.2	62.1	59.1	61.9	61.0	62.5

Table 2. (continued) (Area %)

Fatty acid	Gastropoda				Ascidacea		Cephalopoda	
	28. Tiger prawn	29. (Wang-bamsongige)	30. Blue crab	31. (Ming-gochge)	32. Ascidian	33. (Mideo-deog)	34. Sea cucumbers (E)**	35. Sea cucumbers (F)**
12:0	tr	–	–	–	–	0.22	–	–
14:0	1.05	1.02	1.34	0.91	11.2	3.17	2.03	1.59
15:0, iso	0.29	tr	tr	tr	0.17	0.39	2.76	0.65
15:0, anteiso	0.23	–	tr	tr	tr	0.11	0.79	0.28
15:0	0.94	0.26	tr	tr	0.57	0.55	0.34	0.18
16:0, iso	0.45	tr	0.14	0.24	tr	0.30	0.57	0.10
pristanic	1.71	0.34	0.82	0.59	0.20	0.72	0.12	tr
16:0	14.4	14.0	16.0	14.9	16.5	14.0	9.92	8.19
17:0, iso	1.40	0.33	0.59	0.54	0.10	0.54	0.80	0.29
17:0, anteiso	0.14	0.24	0.37	0.29	tr	0.69	0.34	0.16
phytanic	–	0.14	–	–	tr	0.24	–	0.16
17:0	1.71	0.56	1.19	1.35	0.25	1.16	1.27	0.62
18:0	6.16	4.40	6.69	8.46	2.74	7.39	7.65	3.44
19:0	0.21	tr	0.17	0.17	0.23	0.26	0.83	0.37
20:0	0.18	0.16	0.22	0.20	0.22	0.33	1.32	1.18
21:0	–	–	tr	tr	–	–	0.68	1.19
22:0	0.14	0.15	0.21	0.18	tr	0.13	0.95	0.93
Σ Saturates	29.1	21.6	27.7	27.8	32.2	30.2	30.4	19.3
14:1 (n-7)	0.16	–	0.13	tr	–	–	–	–
16:1 (n-9)	0.38	0.31	–	–	0.63	0.59	–	–
16:1 (n-7)	6.54	2.12	5.62	3.45	1.82	8.12	11.5	2.98
16:1 (n-5)	0.36	0.47	0.33	0.61	0.21	0.63	1.27	1.12
17:1 (n-10)	–	–	–	–	–	0.11	0.75	–
17:1 (n-8)	tr	0.31	0.85	0.74	tr	0.17	tr	0.11
18:1 (n-11)	0.29	0.37	–	0.12	–	–	0.16	0.45
18:1 (n-9)	9.00	8.53	15.8	12.5	11.9	5.16	1.72	2.47
18:1 (n-7)	5.12	4.53	3.11	3.25	4.31	5.15	4.33	3.63
18:1 (n-5)	0.34	0.23	0.27	0.16	tr	0.16	0.23	–
20:1 (n-11)	1.37	0.80	0.42	0.66	–	tr	2.51	4.33
20:1 (n-9)	0.50	0.92	0.45	0.31	0.51	0.36	1.48	0.78
20:1 (n-7)	0.99	0.34	0.18	0.10	0.18	0.38	0.55	1.53
22:1 (n-11)	–	0.19	0.25	0.15	–	–	0.35	0.57
22:1 (n-9)	0.14	0.26	0.12	tr	–	–	0.82	0.56
22:1 (n-7)	0.16	–	0.11	–	–	0.16	1.45	1.78
24:1 (n-9)	0.23	–	–	–	–	–	1.55	1.87
Σ Monoenes	25.6	19.4	27.6	22.0	19.5	21.0	28.7	22.2
16:2 (n-7)	1.35	–	–	–	–	–	0.24	–
16:2 (n-4)	0.28	tr	0.35	0.37	0.47	0.19	0.94	0.24
16:4 (n-3)	1.40	0.97	0.96	1.69	1.06	3.29	2.19	4.55
16:4 (n-1)	–	–	–	–	0.54	–	–	–
17:2 (n-8)	0.49	0.26	0.76	0.23	0.15	0.15	0.24	–
18:2 (n-9)	–	–	–	–	–	0.10	–	–
18:2 (n-7)	–	0.10	–	0.12	–	–	–	–
18:2 (n-6)	1.31	1.27	1.37	1.09	2.65	1.40	0.93	0.96
18:2 (n-4)	0.25	0.13	0.11	0.18	0.51	0.23	0.15	0.24
18:3 (n-4)	0.39	–	0.23	0.21	0.12	0.10	0.20	–
18:3 (n-3)	0.49	0.86	0.25	0.17	2.41	0.53	0.32	0.36
18:4 (n-3)	0.17	0.32	0.11	tr	0.41	0.98	0.65	0.47
20:2NMID (5,11)	tr	0.79	–	–	–	–	0.13	0.28
20:2NMID (5,13)	0.17	0.31	–	–	–	–	–	0.25
20:2NMID	–	–	–	–	–	–	–	0.20
20:2 (n-6)	0.93	1.16	0.59	0.45	0.14	tr	0.73	0.74
20:3 (n-6)	0.22	0.24	tr	0.05	0.11	0.17	0.17	0.17

Table 2. (continued) (Area %)

Fatty acid	Gastropoda				Ascidacea		Cephalopoda	
	28. Tiger prawn	29. (Wang-bamsongige)	30. Blue crab	31. (Ming-gochge)	32. Ascidian	33. (Mideo-deog)	34. Sea cucumbers (E)**	35. Sea cucumbers (F)**
20:4 (n-6)	5.84	8.55	5.23	8.81	0.56	3.93	9.52	17.9
20:3 (n-3)	0.18	0.99	0.18	0.12	–	–	–	–
20:4 (n-3)	0.25	0.54	0.20	tr	0.16	0.18	0.20	0.15
20:5 (n-3)	15.4	25.9	14.4	18.0	11.5	19.7	13.0	17.1
21:5 (n-3)	0.31	0.22	0.11	0.14	0.43	2.41	0.43	0.52
22:2NMID (7,13)	–	tr	–	tr	–	–	0.19	0.36
22:2NMID (7,15)	0.14	0.25	–	tr	–	–	0.25	0.95
22:2NMID	–	–	–	–	0.37	–	–	–
22:2 (n-6)	0.11	–	–	tr	0.22	0.16	–	–
22:4 (n-6)	0.99	0.43	0.50	0.43	0.13	0.18	2.90	5.53
22:5 (n-6)	0.78	0.15	0.57	0.44	0.31	0.43	0.92	0.96
22:5 (n-3)	1.80	2.26	0.99	0.91	0.43	0.52	0.65	0.82
22:6 (n-3)	11.9	13.0	17.4	16.0	25.0	14.1	5.91	5.64
Σ Polyenes	45.1	58.7	44.3	49.4	47.7	48.7	40.9	58.4

*NMID, non-methylene interrupted diene.
**A, with apophyses on the shell; B, without apophyses on the shell; C, *Kelletia lischkei*; D, *Volutharpa ampullacea perry*; E, red collored; F, blue colored.
***tr, trace, less than 0.1%
**** –, not detected.

However, there were negative correlations between PUFA and MUFA ($r=-0.77$, $p<0.001$), and SFA ($r=-0.50$, $p<0.005$) (Fig. 1).

Fatty acid compositions of marine organisms are generally affected by their feeding habits (Stansby, 1986). This tendency may be strong in marine invertebrates compared to fish, because the former has a various food habit such as plankton feeder, sea weed (herbivorous) feeder, carnivorous feeder and mud swallow. The prominent fatty acids of Bivalvia, plankton feeder, were EPA, DHA, 16:1 (n-7), 18:1 (n-9) and 18:0, which resemble those of fish. However, Bivalvia was high in 16:1 (n-7), while fish was high in 18:1 (n-9). In addition to these fatty acids, marine invertebrates contained considerable amount of 16:4 (n-3), 18:4 (n-3) and 22:2 non-methylene interrupted diene (NMID) which were in found in trace amounts in fish. Gastropoda can be divided into herbivorous (sea weed) and carnivorous feeder. On the whole, Arceaogastropoda are herbivorous and are found in rocky environments. Mesogastropoda include both herbivorous and carnivorous species, while Neogastropoda, the most advanced species, are carnivorous (Joseph, 1982). Fatty acid compositions of Gastropoda were therefore different from those of Bivalvia, plankton feeder, and those of Gastropoda were also different from each other due to their feeding habits (Shimma and Taguchi, 1964; Hayashi and Yamada, 1975). Gastropoda contained 20:4 (n-6) and 20:5 (n-3) as major components, and 22:6 (n-3) and 16:1 (n-7) as minor components which are major components in Bivalvia. Particulalry, 20:4 (n-6) and 22:5 (n-3) were found in high levels, about 10%, in sea weed feeder such as turban shell (with apophyses), abalone, sea hare and top shell. These results were consistent with sea urchin (Jeong *et al.*, 1993a). This might be a result of their diets. In fact, brown algae, which are a major food source, contain high levels of 20:4 (n-6) and 20:5 (n-3), and low levels of 22:6 (n-3) (Jeong *et al.*, 1993b). On the other hand, carnivorous Gastropoda such as whelk (*Kelletia lischkei*), murex shell and moon snail contained high level of 22:6 (n-3) compared with herbivorous Gastropoda. Turban shell with apophyses inhabits like at intertidal zone and broken sea, but that of without apophyses inhabits at waveless (Kwon *et al.*, 1993). In this study, turban shells had similar patterns of fatty acids, but differed in their compositions. Turban shell with apophyses contained more 16:0, 20:4 (n-6) and 22:4 (n-6), while that with apophyses contained more 22:6 (n-3), 22:2 (NMID) and 20:1 (n-11). These turban shells with and without apophyses have the same scientific name, *Batillus cornutus*. This suggests that their diets existent in their habitats can bring about differences in their fatty acid compositions in spite of being the same species (Takagi *et al.*, 1982). Triton shell is known

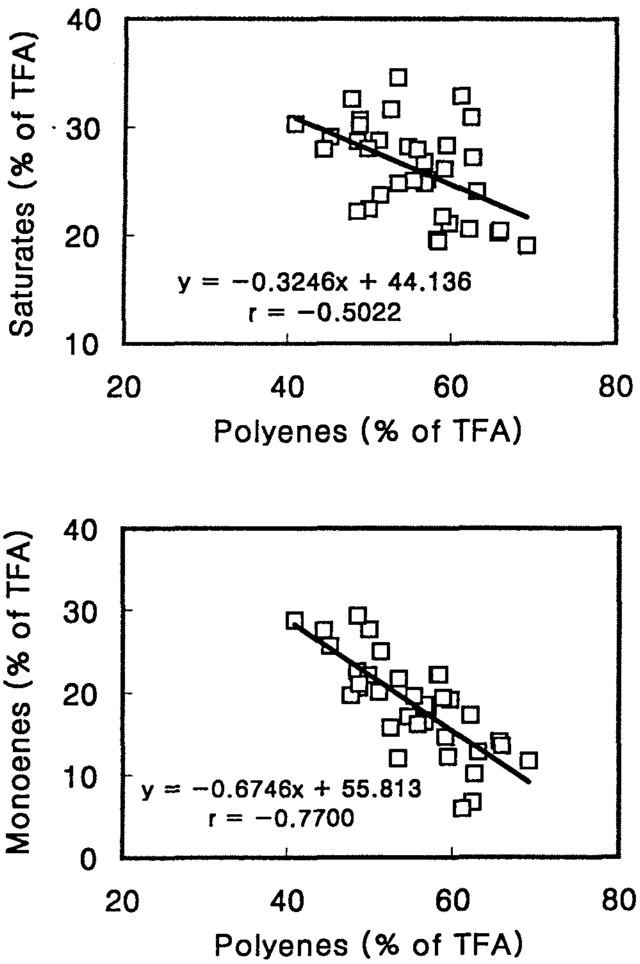

Fig. 1. Correlation between polyenes and saturates, and monoenes in 35 species of marine invertebrates.

to be a carnivorous species (Kwon *et al.*, 1993), but fatty acid composition showed consistency with that of a typical fatty acid compositions of herbivorous Gastropoda (sea weed feeder). Turban shell with apophyses, abalone, sea hare and triton shell showed the tendency of sea weed feeder, while turban shell without apophyses, murex shell, moon snail and whelk (*Kelletia lischkei*) showed a carnivorous habit. The prominent fatty acids of Cephalopoda resembled those of Bivalvia, except that of DHA, which contained 2~3 times more than the latter. Tests of 4 species of Cephalopoda, resulted in, poulp squid and common octopus being similar in their fatty acid compositions, while ju-ggu-mi (*Octopus ocellatus*) resembled cuttle fish in fatty acid compositions. This Cephalopoda is carnivorous, but has a different diets. Poulp squid and common octopus are demersal and eat shellfish, crab and shrimp. Ju-ggu-mi (*Octopus ocellatus*) and cuttle fish are surface fish and eat some small fish such as sardine. Accordingly, demersal Cephalopoda contained considerably 20:4 (n-6), 22:5 (n-3), 20:1 isomers and 16:4 (n-3) derived from their diets. Surface dwelling Cephalopoda contained high levels of DHA, more than 45%, which is a characteristic fish fatty acid. The prominent fatty acids of Crustacea were similar to those of Bivalvia. This is thought that their fatty acid compositions are directly related to their diets, mainly Bivalvia. Ascidacea are filter feeder as the same as Bivalvia. The prominent fatty acids of ascidian were therefore similar to those of mi-deo-deog (*Stylea clava*), but their proportions of fatty acids were considerably different in both species. The former was higher in 14:0, 16:0, 18:1 (n-9) and DHA, while the latter was higher in 18:0, 16:1 (n-7), 16:4 (n-3), 20:4 (n-6) and EPA. Holothuroida are mud swallow, these species swallow whole sand or mud, and ingest nutrients from them. They then excrete unused substances (Yun and Hong, 1995). Sea cucumbers, *Stichopus japonicus*, are divided into 2 species. One is blue or black in color (cheong-sam), and inhabits sand or mud in inner bay. The other is red and brown in color (hong-sam), and inhabits rocky area in outer bay (Kwon *et al.*, 1993). The prominent fatty acids were similar in both species, but proportions of their fatty acids were considerably different. The red colored sea cucumbers had higher levels of 18:0 and 16:1 (n-7), while the blue colored sea cucumbers had higher levels of 20:4 (n-6), 16:4 (n-3), 20:1 isomers, 22:4 (n-6) and EPA. Both species of sea cucumbers were also different in their fatty acid compositions. This is also thought to be due to the difference of their major diets as in case of both turban shells.

Consequently, fatty acid compositions of marine invertebrates are dependant on their diets and differ depending on their habitats. This is well demonstrated in two marine invertebrates, the same species but different habitats, such as turban shells with and without apophyses, and blue and red colored sea cucumbers.

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