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Fatty Acid Compositions of Cultured Oyster (*Crassostrea gigas*) from Korean and Japanese Spats

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Changes in lipid content, lipid class and fatty acid compositions of the cultured oysters in shallow-water, Bukman bay (Tongyeong, Korea), using both Korean and Japanese spats were investigated. The content of non-polar lipid (NL) comprised approximately 60~80% of total lipid (TL) in the cultured oysters. There was a positive correlation between NL content and meat weight, $y=0.2871x-15.309$ ($r=0.8341$, $p<0.001$). The prominent fatty acids of the oysters were 16:0, 20:5n-3 (eicosapentaenoic acid, EPA), 22:6n-3 (docosahexaenoic acid, DHA), 18:0, 18:1n-7, 18:1n-9, 16:1n-7, 14:0 and 16:4n-3. During the growth of the oysters, 16:4n-3 showed the highest coefficient of variation, accounting for 41.8% for the Korean oyster and 32.3% for the Japanese one, respectively. Both oysters showed low level of n-3 fatty acids such as DHA and EPA and high level of n-6 fatty acid, 20:4n-6, in the spawning period (August). During growth of the oysters, both EPA and DHA were the richest fatty acids in the harvest period (December, 314 mg/100 g sample) and in the pre-spawning period (July, 237~247 mg/100 g sample), respectively. Consequently, the cultured oyster with Japanese spat contained approximately two times more n-3 fatty acids per oyster individual than those with Korean one in the harvest season.

Key words: oyster, Korean and Japanese spat, culture, lipid class, n-3 fatty acids, coefficient of variation

Introduction

The production of the cultured oyster in shallow-sea was decreased markedly in 1994, approximately 172,000 M/T compared to that in 1993 (approximately 258,000 M/T) in Korea (Ministry of Maritime Affairs and Fisheries, 1998). This result might be derived of imperfection of natural oyster spats and it brought about import a number of oyster spats from Japan, accounting for about 2,300 of hanging rope for three years. Even though it is also considered by environmental pollution, the failure in controlling excellent mother oysters is thought to be the main reason for the imperfection of natural spats. However, it has been known that the breed improvement of oysters in Japan succeeded through both the hybrid seed production and the control of excellent mother oysters. Oyster is a commercially important seafood, which also contains a considerable amount of n-3 fatty acids such as eicosapentaenoic acid (EPA, 20:5n-3), docosahexaenoic acid (DHA, 22:6n-3), etc., typical fatty acids in seafood. These n-3 fatty acids have been known as biologically active materials for human being (Simopoulos, 1986: Lees, 1990). Previous studies (Jeong et al., 1990; Yoon et al., 1986) were reported on fatty acid compositions of oyster, but there was no information about changes in fatty acid compositions during growth from spat to the harvest period.

In the present study, changes in n-3 fatty acid and lipid class compositions were observed in the cultured oysters with Korean and Japanese spats during growth, until the harvest period.

Materials and methods

Samples

The oyster samples (*Crassostrea gigas*) were taken

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from the Korean spat, attached in Chinhae bay near Gaduk island in Korea and the Japanese spat, attached in Seto inland sea in Japan, which were suspended in Bukman bay (Tongyeong, Korea). The Korean and Japanese spats were reared from June, 1995 to January, 1996. The oysters were harvested at one month intervals from hanging rope in the sea and the meat (about 300 g) was removed from the shells, and minced with a speed cutter. Duplicate samples (groups 1 and 2, weighting about 150 g each) were subjected to analyses.

Lipid extraction

Total lipid (TL) was extracted and purified according to the method of Bligh and Dyer (1959), and the content was determined gravimetrically. Phopholipid (PL) content in the TL was determined by the method of Bartlett (1959). The non-polar lipid (NL) content in the TL was the difference between the TL and PL figures.

Determination of Lipid class and fatty acid compositions

Lipid class compositions of PL and NL were determined as described in the previous paper (Jeong et al., 1990). Fatty acid was determined after methylation (AOCS, 1990) and those of TL were 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 ℃, the column oven temperature was programmed from 180℃ (the initial time 8 min) to 230℃ at 3℃/min, and the final time was 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 of 1:50. Fatty acids were identified by comparison with authentic standards (Sigma Chemical Co., St. Louis, MO, USA) and an oyster sample which had been analyzed by Koizumi et al. (1990). Data were calculated as the percentage of peak area against total area of fatty acids. Methyl tricosanoate (99%, Aldrich Chem. Co., Milw, WI, USA) was used as an internal standard for quantitative calculation of n-3 fatty acids.

Results and Discussion

Changes in lipid contents and lipid class compositions

Changes in meat weight, lipid content and lipid class compositions of the cultured oysters (using the Korean and Japanese spats during growth) in shallow-water were summarized in Tables 1 and 2. The increase of variable meat weights and TL contents in the oysters was demonstrated in the previous paper (Jeong et al., 1999a); briefly, the meat weights of the Korean and Japanese spats increased from 0.61g to 4.80 g/individual and from 0.33 g to 8.36 g/individual, respectively. Therefore, the growth rate of the Japanese spat was faster about as much as twice compared to that of the Korean one. Moreover, meat weight and TL content were decreased in the Korean spat in October whereas in the Japanese spat these were increased continuously to the harvest period (November). TL content in both oysters was increased exponentially with meat weight, $y=0.2081e^{1.5696x}$ ($r=0.8856$, $p<0.001$).

In the present study, NL contents in both oysters showed a low level from June to October (about 54~67% of TL content) and a higher level in the harvest period (71~78% of TL content). Changes in PL contents, however, were with contrast to changes in NL contents. In both oysters, the NL content (or percentages) and TL content were decreased especially in the spawning period (August). The Korean spat was also observed a decreased figure in NL, TL contents, and meat weight in October, which is thought due to be occurred spawning in a quit of individuals one more time. However, in case of the Japanese spat, spawning did not observed in October. The percentage of NL in TL content in both oysters was increased with TL while that of PL was decreased. There was a positive correlation between TL and NL content as the percentage, $y=12.511x+54.528$ ($r=0.7968$, $p<0.001$) while a negative correlation between TL and PL content as the percentage, $y=-12.511x+54.528$ ($r=-0.7968$, $p<0.001$) during growth of both oysters as shown in Fig. 1. These results indicate that the cultured oyster with the Japanese spat contained about twice more in lipid content per individual than that with the Korean spat in the harvest period.

The prominent lipid classes of NL and PL were triglycerides (TG), free sterol (ST), phosphatidylcholine (PC), and phosphatidylethanolamine (PE). The percentage of TG was the poorest in the spawning period (August), in both oysters while that of

Table 1. Monthly variation in lipid content and lipid class composition of the oyster cultured with Korean spat[1]

Lipid[2]	Month (Jun 1995 - Jan 1996)							
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
TL (g/100 g sample)	0.52	1.84	1.52	1.70	1.55	1.87	1.93	2.05
NL (g/100 g sample)	0.28 (53.8)[3]	1.10 (59.7)	0.97 (63.8)	1.14 (67.0)	0.95 (61.2)	1.31 (70.0)	1.47 (76.1)	1.52 (74.1)
PL (g/100 g sample)	0.24 (46.1)	0.74 (40.2)	0.55 (36.1)	0.56 (32.9)	0.60 (38.7)	0.56 (29.9)	0.46 (23.8)	0.53 (25.8)
Meat weight (g/specimen)	0.61	1.82	2.60	3.34	2.78	4.18	4.80	NC[4]
NL class (% of NL content)								
ST	30.7 ± 0.20	16.9 ± 0.58	22.7 ± 1.77	23.7 ± 0.36	22.7 ± 0.33	15.6 ± 0.17	13.5 ± 0.20	16.0 ± 1.42
FFA	tr[5]	tr	tr	tr	tr	tr	tr	tr
TG	69.3 ± 1.26	72.8 ± 0.87	62.1 ± 2.53	66.7 ± 0.17	66.9 ± 1.71	68.4 ± 0.33	73.8 ± 1.28	64.8 ± 1.53
GE	tr	4.70 ± 0.81	4.64 ± 0.47	2.54 ± 0.27	3.84 ± 0.96	6.95 ± 0.10	4.97 ± 1.07	6.32 ± 0.77
SE	tr	5.66 ± 0.28	10.5 ± 1.06	7.06 ± 0.34	6.57 ± 2.14	9.06 ± 0.01	7.71 ± 1.29	12.9 ± 0.55
PL class (% of PL content)								
SPM	tr	tr	tr	tr	tr	tr	tr	tr
PC	62.0 ± 1.40	48.7 ± 0.89	42.1 ± 1.99	39.2 ± 0.73	43.0 ± 0.08	40.3 ± 1.95	31.7 ± 0.99	40.5 ± 1.53[6]
PS	10.9 ± 0.48	6.01 ± 0.11	9.58 ± 1.40	9.31 ± 1.37	8.11 ± 0.19	10.3 ± 0.34	12.9 ± 0.14	
PI	9.04 ± 0.35	8.23 ± 0.25	15.1 ± 1.14	11.6 ± 0.59	10.7 ± 0.56	11.8 ± 0.34	12.7 ± 0.78	16.5 ± 1.34
PE	18.1 ± 1.26	37.1 ± 0.75	33.2 ± 0.45	40.0 ± 1.23	38.2 ± 0.29	37.6 ± 1.27	42.7 ± 0.34	36.2 ± 1.50

[1]Data are presented as mean and/or ± standard deviation of 6 (2 groups x 3) determinations.
[2]TL, total lipid; NL, non-polar lipid; ST, free sterol; FFA, free fatty acid; TG, triglyceride; SE, steryl ester; GE, glyceryl ether; PL, phospholipid; SPM, sphingomyelin; PC, phosphatidylcholine; PS, phosphatidylserine; PI, phosphatidylinositol; PE, phosphatidylethanolamine.
[3]Figures in parentheses are presented as percent of TL content.
[4]NC, not checked. [5]tr, trace. [6]The data are presented as the sum of (PC+PS).

Table 2. Monthly variation in lipid content and lipid class composition of the oyster cultured with Japanese spat[1]

Lipid[2]	Month (Jun 1995 - Jan 1996)							
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
TL (g/100 g sample)	0.45	1.92	1.44	1.58	1.84	2.02	1.96	2.01
NL (g/100 g sample)	0.27 (60.0)[3]	1.22 (63.5)	0.86 (59.7)	0.93 (58.8)	1.23 (66.8)	1.43 (70.7)	1.53 (78.0)	1.43 (71.1)
PL (g/100 g sample)	0.18 (40.0)	0.70 (36.4)	0.58 (40.2)	0.65 (41.1)	0.61 (33.1)	0.59 (29.2)	0.43 (21.9)	0.58 (28.8)
Meat weight (g/specimen)	0.33	1.62	2.30	2.64	4.22	8.36	7.53	NC[4]
NL class (% of NL content)								
ST	31.6 ± 0.13	15.6 ± 0.08	34.1 ± 0.85	22.5 ± 0.09	18.6 ± 0.89	13.9 ± 1.24	13.4 ± 1.65	20.1 ± 1.02
FFA	tr[5]	tr	tr	tr	tr	tr	tr	tr
TG	68.4 ± 2.21	74.6 ± 0.35	56.8 ± 0.85	68.3 ± 0.70	67.8 ± 0.70	67.1 ± 0.44	72.8 ± 0.98	63.3 ± 1.00
GE	tr	5.85 ± 0.22	3.06 ± 0.43	2.29 ± 0.35	5.96 ± 0.07	8.77 ± 1.12	6.21 ± 0.67	5.56 ± 0.87
SE	tr	4.00 ± 0.99	5.98 ± 0.67	6.89 ± 0.82	7.69 ± 0.79	10.3 ± 0.99	7.59 ± 1.78	11.0 ± 0.94
PL class (% of PL content)								
SPM	tr	tr	tr	tr	tr	tr	tr	tr
PC	47.9 ± 1.21	45.0 ± 0.18	43.3 ± 1.76	38.2 ± 0.18	44.3 ± 1.75	41.5 ± 2.68	36.5 ± 0.18	42.1 ± 1.13[6]
PS	6.58 ± 0.57	7.82 ± 0.23	10.2 ± 0.97	9.45 ± 0.12	8.70 ± 0.88	9.33 ± 0.56	10.6 ± 0.01	
PI	7.47 ± 1.60	9.63 ± 0.18	14.7 ± 0.77	12.2 ± 0.23	10.5 ± 0.76	13.0 ± 0.19	12.0 ± 0.37	15.9 ± 0.48
PE	38.1 ± 0.18	37.6 ± 0.22	32.0 ± 0.56	40.2 ± 0.53	36.5 ± 0.11	36.2 ± 1.93	40.9 ± 0.56	35.0 ± 1.20

[1]Data are presented as mean and/or ± standard deviation of 6 (2 groups x 3) determinations.
[2]TL, total lipid; NL, non-polar lipid; ST, free sterol; FFA, free fatty acid; TG, triglyceride; SE, steryl ester; GE, glyceryl ether; PL, phospholipid; SPM, sphingomyelin; PC, phosphatidylcholine; PS, phosphatidylserine; PI, phosphatidylinositol; PE, phosphatidylethanolamine.
[3]Figures in parentheses are presented as percent of TL content.
[4]NC, not checked. [5]tr, trace. [6]The data are presented as the sum of (PC+PS).

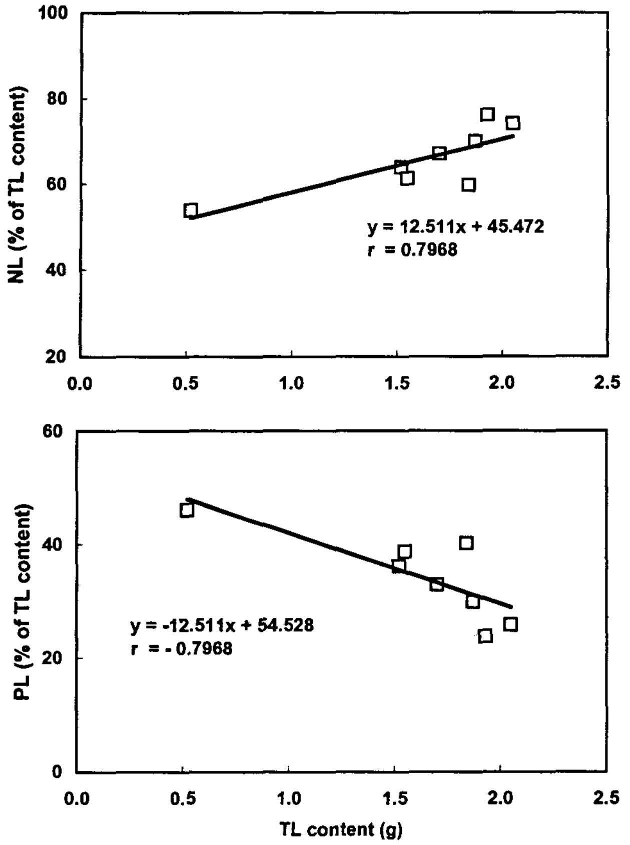

Fig. 1. Correlation between TL and NL, and PL contents of cultured oyster with the Korean spat.

ST including steryl ester (SE) was the richest in the month, except that in June. These results indicate that sterol increased the production of sex hormone and resulted in the decrease of TG, which was also used partly for the development of gonad or spawning. On the other hand, the percentage of PC was decreased with growing in both oysters but that of PE was increased. Both PL classes were decreased a little amount in the spawning period with comparison to the pre-spawning and post-spawning. The percentage of phosphatidylinositol (PI) was also increased with growth of the oysters and was high somewhat in the spawning period, in the contrary to those of PC and PE. In general, PI that contained high proportion of 20:4n-6 (Okita et al., 1982; Bell, 1989) is mainly distributed in the inner layer of cell membrane and contributed to information for the transmission of cell (O'Flaherty, 1987). Therefore, high proportion of PI in August in both oysters may be need for an active information for the transmission between cells in the spawning period.

Changes in fatty acid compositions

Changes in fatty acid compositions of TL of the cultured oysters in the same sea with Korean and Japanese spats, were summarized in Tables 3 and 4. In the present study, reported by Jeong et al. (1998), the prominent fatty acids from the cultured oyster collected in December, were 16:0, EPA, DHA, 18:0, 18:1n-7, 18:1n-9, 16:1n-7, 14:0 and 16:4n-3 in both oysters. These results were similar to those reported by Jeong et al. (1990) but different from these reported by Yoon et al. (1986). This is thought to be due to differences from the sample size and collection season. Previous studies on fatty acid compositions of oysters had been only carried out on the samples collected at a temporary period. For example, Jeong et al. (1990) studied on the samples caught in December while Yoon et al. (1986) studied on the sample in April. In general, fatty acid compositions of marine organisms differ greatly by collection season, because it includes a number of factors such as differences in diet content, age, spawning, size, water temperature, salinity, etc. (Ackman, 1989; Vaskovsky, 1989; Joseph, 1989; Jeong et al, 1999b). During growth, both oysters were the richest in polyunsaturated fatty acids (PUFA), accounting for 52.8 ± 7.14% in the Korean oyster and 55.4 ± 3.81% in the Japanese one, and the poorest in monounsaturated fatty acids (MUFA), accounting for 18.3 ± 2.56% and 17.6 ± 2.43%, respectively. The Japanese oyster was more in PUFA and less in saturated fatty acids (SFA) and MUFA than that of the Korean oyster. In both oysters, PUFA decreased markedly in the spawning period (August), while SFA and MUFA increased in that time. The both oysters showed low levels of n-3 fatty acids such as 16:4n-3, 18:4n-3, EPA and DHA, and high level of n-6 fatty acid, 20:4n-6, in the spawning period (August) compared to those in pre-spawning period (July). These fatty acids were associated with PC, PE and PI compositions as described above. These results were similar to the results of cod roe by Bell (1989). He reported that PC and PE are richer in n-3 fatty acids (EPA and DHA) in cod roe while PI is richer in n-6 fatty acid (20:4n-6). In general, 20:4 n-6 produces a number of prostaglandin, potent hormone-like materials, which has known to be involved in reproductive function in vertebrates. Although its action is obscure yet in invertebrates, it is interested that 20:4n-6 was contains relatively

Table 3. Monthly variation in fatty acid composition of the oyster cultured with Korean spat[1] (Area %)

Fatty acid	Month (Jun 1995 - Jan 1996)							
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
14:0	6.04 ± 0.11	3.25 ± 0.10	4.61 ± 0.15	2.55 ± 0.26	2.10 ± 0.13	2.94 ± 0.47	3.34 ± 0.15	3.91 ± 0.07
15:0 iso	0.12 ± 0.01	0.06 ± 0.01	0.11 ± 0.01	0.08 ± 0.03	0.07 ± 0.02	0.10 ± 0.01	0.13 ± 0.02	0.21 ± 0.02
15:0	0.57 ± 0.03	0.41 ± 0.02	0.58 ± 0.02	0.44 ± 0.06	0.53 ± 0.05	0.50 ± 0.02	0.48 ± 0.02	0.53 ± 0.03
16:0 iso	0.10 ± 0.01	0.05 ± 0.00	0.11 ± 0.02	0.07 ± 0.01	0.10 ± 0.01	0.10 ± 0.01	0.12 ± 0.01	0.16 ± 0.00
Pristanic	0.11 ± 0.00	0.16 ± 0.02	0.15 ± 0.01	0.21 ± 0.02	0.34 ± 0.01	0.30 ± 0.02	0.22 ± 0.01	0.22 ± 0.02
16:0	26.4 ± 0.30	19.8 ± 0.58	20.1 ± 0.54	17.7 ± 0.63	15.0 ± 0.72	15.0 ± 0.26	15.2 ± 0.34	16.3 ± 0.07
17:0 iso	0.61 ± 0.03	0.34 ± 0.04	0.48 ± 0.00	0.43 ± 0.02	0.49 ± 0.02	0.50 ± 0.05	0.51 ± 0.02	0.59 ± 0.01
17:0 anteiso	0.33 ± 0.04	0.28 ± 0.13	0.44 ± 0.02	0.42 ± 0.05	0.49 ± 0.07	0.55 ± 0.07	0.40 ± 0.11	0.51 ± 0.01
Phytanic	tr[2]	0.27 ± 0.34	0.09 ± 0.06	0.92 ± 0.09	tr	0.30 ± 0.02	0.22 ± 0.01	0.01 ± 0.00
17:0	1.15 ± 0.10	0.68 ± 0.31	1.10 ± 0.01	tr	0.95 ± 0.13	1.11 ± 0.06	1.00 ± 0.09	1.05 ± 0.01
18:0	4.69 ± 0.02	4.31 ± 0.10	4.36 ± 0.06	4.29 ± 0.09	3.87 ± 0.07	3.48 ± 0.04	3.14 ± 0.02	3.14 ± 0.01
19:0	0.12 ± 0.03	0.10 ± 0.03	0.23 ± 0.00	0.13 ± 0.01	0.12 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.16 ± 0.01
20:0	0.16 ± 0.01	0.22 ± 0.14	0.07 ± 0.00	0.02 ± 0.01	tr	0.05 ± 0.04	0.03 ± 0.02	0.07 ± 0.01
22:0	tr	tr	0.11 ± 0.02	tr	tr	0.13 ± 0.02	0.15 ± 0.02	0.17 ± 0.03
24:0	tr	tr	0.01 ± 0.00	tr	tr	0.06 ± 0.01	0.06 ± 0.01	0.08 ± 0.02
ΣSaturates	40.4	29.9	32.6	27.3	24.1	25.2	25.0	27.1
16:1n-9	tr	0.25 ± 0.09	0.38 ± 0.01	0.32 ± 0.12	0.41 ± 0.05	0.48 ± 0.04	0.28 ± 0.06	0.01 ± 0.00
16:1n-7	5.12 ± 0.31	1.83 ± 1.11	3.90 ± 0.12	2.24 ± 0.13	1.97 ± 0.07	2.51 ± 0.08	3.09 ± 0.07	3.58 ± 0.03
16:1n-5	0.43 ± 0.01	0.25 ± 0.11	1.11 ± 0.04	0.89 ± 0.28	0.87 ± 0.11	0.59 ± 0.07	0.95 ± 0.10	0.74 ± 0.06
17:1n-10	0.04 ± 0.01	tr	0.31 ± 0.03	0.13 ± 0.17	0.02 ± 0.00	0.38 ± 0.04	0.23 ± 0.04	0.28 ± 0.01
17:1n-8	0.13 ± 0.06	0.21 ± 0.12	0.27 ± 0.01	0.24 ± 0.10	0.32 ± 0.07	0.19 ± 0.03	0.20 ± 0.03	0.29 ± 0.01
18:1n-11	0.55 ± 0.01	0.33 ± 0.02	0.40 ± 0.01	0.22 ± 0.02	0.36 ± 0.01	0.52 ± 0.01	0.49 ± 0.02	0.68 ± 0.02
18:1n-9	4.42 ± 0.04	2.90 ± 0.06	2.16 ± 0.06	1.79 ± 0.11	1.95 ± 0.04	2.07 ± 0.01	2.59 ± 0.04	4.63 ± 0.03
18:1n-7	5.38 ± 0.07	3.33 ± 0.06	5.36 ± 0.06	4.42 ± 0.16	3.98 ± 0.14	4.78 ± 0.02	4.86 ± 0.02	4.70 ± 0.03
18:1n-5	0.11 ± 0.11	0.17 ± 0.10	0.15 ± 0.01	0.13 ± 0.13	0.27 ± 0.10	0.12 ± 0.01	0.15 ± 0.02	0.22 ± 0.01
20:1n-11	1.80 ± 0.35	1.60 ± 1.07	2.82 ± 0.08[3]	2.84 ± 0.22	2.50 ± 0.26	2.17 ± 0.01[3]	1.19 ± 0.02	2.10 ± 0.01[3]
20:1n-9	0.22 ± 0.27	0.76 ± 0.81		0.25 ± 0.27	0.34 ± 0.22		0.49 ± 0.02	
20:1n-7	3.00 ± 0.03	2.21 ± 1.11	3.64 ± 0.09	3.58 ± 0.10	3.47 ± 0.11	3.09 ± 0.02	3.48 ± 0.04	2.80 ± 0.03
22:1n-11	tr	tr	0.02 ± 0.03	tr	tr	0.15 ± 0.03	0.15 ± 0.02	0.28 ± 0.05
22:1n-9	0.34 ± 0.09	0.15 ± 0.02	0.17 ± 0.01	0.18 ± 0.07	0.14 ± 0.06	0.19 ± 0.03	0.33 ± 0.02	0.27 ± 0.01
22:1n-7	tr	tr	0.18 ± 0.02	tr	tr	0.06 ± 0.03	0.04 ± 0.03	0.01 ± 0.00
ΣMonoenes	21.5	14.0	20.9	17.2	16.6	17.3	18.5	20.6
16:2n-7	tr	tr	tr	0.05 ± 0.04	0.06 ± 0.03	tr	tr	tr
16:2n-4	0.20 ± 0.10	0.08 ± 0.03	0.28 ± 0.04	0.14 ± 0.03	0.14 ± 0.04	0.35 ± 0.06	0.46 ± 0.07	0.49 ± 0.01
17:2n-8	0.22 ± 0.03	0.29 ± 0.01	0.24 ± 0.02	0.11 ± 0.05	0.13 ± 0.02	0.21 ± 0.09	0.16 ± 0.06	0.32 ± 0.03
16:4n-3	2.45 ± 0.16	5.34 ± 0.65	3.01 ± 0.18	6.37 ± 0.71	5.84 ± 0.27	5.02 ± 0.25	2.77 ± 0.21	2.03 ± 0.15
18:2n-9	0.16 ± 0.02	0.14 ± 0.03	0.10 ± 0.01	0.09 ± 0.04	0.08 ± 0.02	tr	tr	0.08 ± 0.00
18:2n-6	1.48 ± 0.04	1.04 ± 0.03	1.08 ± 0.01	1.27 ± 0.09	1.11 ± 0.03	0.92 ± 0.03	1.00 ± 0.06	1.46 ± 0.01
18:2n-4	0.19 ± 0.02	0.15 ± 0.01	0.30 ± 0.00	0.26 ± 0.03	0.19 ± 0.01	0.28 ± 0.04	0.43 ± 0.02	0.40 ± 0.03
18:3n-4	tr	0.15 ± 0.04	0.26 ± 0.01	0.22 ± 0.02	0.16 ± 0.02	0.21 ± 0.03	0.25 ± 0.01	0.28 ± 0.01
18:3n-3	1.46 ± 0.11	0.69 ± 0.42	0.75 ± 0.02	0.90 ± 0.12	0.70 ± 0.07	0.75 ± 0.03	0.67 ± 0.01	1.26 ± 0.02
18:4n-3	3.03 ± 0.02	1.80 ± 0.67	1.29 ± 0.04	1.34 ± 0.04	1.14 ± 0.04	1.41 ± 0.01	1.63 ± 0.02	2.93 ± 0.01
18:4n-1	tr	tr	tr	tr	tr	0.05 ± 0.02	0.10 ± 0.03	tr
19:3n-6	0.23 ± 0.00	0.97 ± 0.76	0.53 ± 0.04	0.49 ± 0.08	0.54 ± 0.04	0.54 ± 0.04	0.39 ± 0.05	0.31 ± 0.05
20:2NMID (5,11)[4]	0.08 ± 0.07	0.37 ± 0.17	0.01 ± 0.00	0.11 ± 0.07	0.10 ± 0.06	0.06 ± 0.02	0.05 ± 0.01	0.28 ± 0.00
20:2NMID (5,13)	0.89 ± 0.25	0.80 ± 1.31	0.74 ± 0.01	0.40 ± 0.05	0.41 ± 0.07	0.55 ± 0.06	0.56 ± 0.06	0.65 ± 0.01
20:2	tr	tr	0.13 ± 0.01	0.09 ± 0.01	0.09 ± 0.02	0.10 ± 0.02	0.02 ± 0.00	0.13 ± 0.01

Table 3. 〈Continued〉

Fatty acid	Month (Jun 1995 - Jan 1996)							
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
20:2n-6	0.13 ± 0.00	0.20 ± 0.15	0.12 ± 0.01	0.12 ± 0.01	0.14 ± 0.02	0.14 ± 0.04	0.10 ± 0.01	0.21 ± 0.01
20:3n-6	0.04 ± 0.01	0.10 ± 0.02	0.18 ± 0.00	0.12 ± 0.01	0.13 ± 0.01	0.13 ± 0.01	0.13 ± 0.00	0.16 ± 0.00
20:4n-6	1.23 ± 0.03	1.30 ± 0.82	3.33 ± 0.04	3.65 ± 0.12	3.82 ± 0.07	3.64 ± 0.08	3.25 ± 0.06	2.71 ± 0.02
20:3n-3	0.04 ± 0.01	0.47 ± 0.81	0.06 ± 0.01	tr	tr	0.04 ± 0.05	0.04 ± 0.02	0.13 ± 0.02
20:4n-3	0.42 ± 0.04	0.34 ± 0.02	0.37 ± 0.04	0.26 ± 0.01	0.27 ± 0.02	0.31 ± 0.01	0.33 ± 0.00	0.49 ± 0.02
20:5n-3	11.7 ± 0.18	13.5 ± 0.08	15.9 ± 0.20	15.7 ± 0.23	17.8 ± 0.46	22.7 ± 0.71	26.6 ± 0.82	19.6 ± 0.14
22:2NMID (7,13)	0.60 ± 0.02	0.95 ± 0.02	0.60 ± 0.03	0.68 ± 0.02	0.80 ± 0.05	0.64 ± 0.02	0.59 ± 0.06	0.52 ± 0.05
22:2NMID (7,15)	2.98 ± 0.07	3.52 ± 0.02	4.30 ± 0.14	4.55 ± 0.07	4.13 ± 0.05	3.40 ± 0.07	2.96 ± 0.02	2.82 ± 0.25
22:2n-6	0.40 ± 0.01	0.42 ± 0.19	tr	0.21 ± 0.03	0.23 ± 0.04	0.38 ± 0.08	0.23 ± 0.04	tr
21:5n-3	0.60 ± 0.01	0.63 ± 0.04	0.70 ± 0.01	0.74 ± 0.02	0.81 ± 0.02	1.02 ± 0.03	1.24 ± 0.03	1.08 ± 0.06
22:4n-6	0.24 ± 0.01	0.12 ± 0.03	0.34 ± 0.02	0.41 ± 0.03	0.49 ± 0.04	0.42 ± 0.02	0.34 ± 0.02	0.33 ± 0.02
22:5n-6	0.18 ± 0.00	0.30 ± 0.01	0.36 ± 0.03	0.54 ± 0.01	0.53 ± 0.02	0.38 ± 0.01	0.29 ± 0.01	0.41 ± 0.03
22:5n-3	0.62 ± 0.00	0.85 ± 0.02	1.32 ± 0.05	1.36 ± 0.04	1.51 ± 0.07	1.40 ± 0.07	1.30 ± 0.03	1.09 ± 0.03
22:6n-3	8.46 ± 0.34	21.6 ± 0.17	10.3 ± 0.45	15.3 ± 0.78	17.9 ± 0.91	12.8 ± 0.50	10.8 ± 0.27	12.2 ± 0.12
ΣPolyenes	38.1	56.1	46.6	55.5	59.3	57.8	56.7	52.4
Σn-3	28.8	45.2	33.7	42.0	46.0	45.4	45.4	40.8
Σn-6	3.93	4.44	5.94	6.82	6.99	6.55	5.73	5.60
n-3/n-6	7.33	10.19	5.67	6.15	6.58	6.94	7.92	7.29

[1]Data are presented as mean ± standard deviation of 6 (2 groups x 3) determinations.
[2]tr, trace.
[3]The data were presented as the sum of (20:1n-11)+(20:1n-9).
[4]NMID, non-methylene interrupted diene.

large amount in oyster in the spawning period. Fig. 2 showed coefficient of variation (CV, %) of the prominent fatty acids during growth. In both oysters, CV of 16:4n-3 was the highest of the fatty acids, accounting for 41.8% in the Korean oyster and 32.3% in the Japanese oyster, respectively. Most of the fatty acids in the Korean oyster showed CV more than 30%, while in the Japanese oyster showed CV less than 30%. These results suggest that the Korean spat was unstableness in their diet incorporation and lipid metabolism during growth compared to the Japanese spat, and that difference from their species specificity, though both oysters have a same scientific name. Changes in EPA and DHA content (mg/100 g sample) during growth of both oysters are shown in Fig. 3. EPA and DHA contents in the Korean and Japanese spats were only 33~45 mg just after hanging in the sea. This is explained that their body lipids were used as main energy sources during about 10 months of the hardening period. TL content in both oysters ranged from 0.45 g (Japanese spat) to 0.52 g/100 g sample (Korean spat) in June. At that time, small amount of EPA and DHA are associated with small amount of TL content. However, EPA and DHA contents in July were vigorously increased to 150~170 mg/100 g sample and 240~250 mg/100 g sample, respectively, with TL content (1.8~1.9 g/100 g sample) during only one month after hanging in the sea. This indicates that the spats are able to take enough diets and to accumulate a lot of body lipid. EPA and DHA contents, however, were decreased in August, known as a spawning period and particularly DHA content was decreased greatly compared to EPA content in the both oysters. This suggests that DHA might play an important role for development of eggs and sperms in the oysters and then they were released (Kim et. al., 1998). Both oysters showed an increasing tendency in n-3 fatty acid content with TL content and meat weight from after August to their harvest period, but those of the Korean spat decreased one more time in October during growth. This is thought due to that quit of individual in the Korean oyster participated in their spawning one more time. In the previous paper (Jeong et al., 1999a), it was demonstrated that the Japanese oyster showed over than two times in meat weight per oyster individual compared to the Korean oyster. Moreover, n-3 fatty acid content increased exponentially with meat weight and in a linear with TL content (Fig. 4). EPA and DHA contents in the oysters were the richest in

Table 4. Monthly variation in fatty acid composition of the oyster cultured with Japanese spat[1]

Fatty acid	Month (Jun 1995 - Jan 1996)							
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
14:0	2.51 ± 0.03	3.08 ± 0.50	4.40 ± 0.19	2.49 ± 0.09	2.27 ± 0.06	3.11 ± 0.09	3.67 ± 0.53	3.95 ± 0.01
15:0 iso	0.11 ± 0.00	0.06 ± 0.01	0.12 ± 0.03	0.06 ± 0.01	0.09 ± 0.02	0.10 ± 0.01	0.07 ± 0.01	0.15 ± 0.00
A15:0 anteiso	0.05 ± 0.02	tr[2]	tr	tr	tr	tr	tr	tr
15:0	0.45 ± 0.00	0.40 ± 0.03	0.63 ± 0.01	0.43 ± 0.04	0.54 ± 0.03	0.47 ± 0.02	0.06 ± 0.01	0.58 ± 0.05
16:0 iso	0.10 ± 0.01	0.04 ± 0.01	0.11 ± 0.01	0.04 ± 0.03	0.09 ± 0.00	0.09 ± 0.01	0.09 ± 0.00	0.16 ± 0.00
Pristanic	0.33 ± 0.00	0.17 ± 0.02	0.20 ± 0.01	0.21 ± 0.01	0.34 ± 0.01	0.27 ± 0.01	0.24 ± 0.01	0.24 ± 0.01
16:0	15.6 ± 0.01	19.5 ± 0.78	18.7 ± 0.69	17.4 ± 0.78	16.9 ± 0.45	15.8 ± 0.29	16.7 ± 0.22	16.1 ± 0.04
17:0 iso	0.41 ± 0.01	0.25 ± 0.06	0.48 ± 0.01	0.43 ± 0.03	0.44 ± 0.01	0.48 ± 0.04	0.48 ± 0.00	0.58 ± 0.01
17:0 anteiso	0.57 ± 0.07	0.31 ± 0.02	0.50 ± 0.01	0.44 ± 0.07	0.46 ± 0.03	0.50 ± 0.08	0.52 ± 0.03	0.54 ± 0.02
Phytanic	0.20 ± 0.06	0.05 ± 0.02	0.16 ± 0.02	tr	tr	tr	tr	0.05 ± 0.07
17:0	0.91 ± 0.12	0.74 ± 0.03	1.01 ± 0.09	0.82 ± 0.11	0.98 ± 0.09	1.08 ± 0.04	1.01 ± 0.08	1.08 ± 0.00
18:0	4.27 ± 0.04	3.85 ± 0.07	4.00 ± 0.23	4.03 ± 0.04	3.58 ± 0.05	3.13 ± 0.02	2.89 ± 0.06	3.36 ± 0.01
19:0	0.10 ± 0.06	0.06 ± 0.02	0.19 ± 0.01	0.12 ± 0.01	0.11 ± 0.01	0.12 ± 0.02	0.03 ± 0.01	0.16 ± 0.00
20:0	0.06 ± 0.00	0.13 ± 0.07	0.04 ± 0.03	0.05 ± 0.02	0.02 ± 0.00	0.05 ± 0.03	0.07 ± 0.02	0.07 ± 0.00
22:0	tr	tr	0.09 ± 0.02	tr	tr	0.10 ± 0.04	0.09 ± 0.02	0.15 ± 0.00
24:0	tr	tr	0.01 ± 0.00	tr	tr	0.07 ± 0.01	0.05 ± 0.01	0.11 ± 0.04
ΣSaturates	25.6	28.7	30.5#	26.5	25.8	25.2	25.9	27.0
16:1n-9	0.24 ± 0.07	0.30 ± 0.07	0.35 ± 0.23	0.37 ± 0.05	0.41 ± 0.05	0.44 ± 0.06	0.38 ± 0.03	0.47 ± 0.01
16:1n-7	2.15 ± 0.03	2.28 ± 0.11	3.67 ± 0.83	2.05 ± 0.10	2.11 ± 0.05	2.77 ± 0.06	3.05 ± 0.07	3.02 ± 0.04
16:1n-5	0.23 ± 0.01	0.16 ± 0.04	1.38 ± 0.09	0.93 ± 0.12	0.84 ± 0.04	0.60 ± 0.08	0.84 ± 0.04	0.83 ± 0.06
17:1n-10	0.08 ± 0.03	tr	0.35 ± 0.03	0.06 ± 0.05	0.02 ± 0.00	0.32 ± 0.03	0.29 ± 0.04	0.29 ± 0.01
17:1n-8	0.10 ± 0.06	0.23 ± 0.06	0.41 ± 0.08	0.25 ± 0.10	0.29 ± 0.05	0.17 ± 0.04	0.17 ± 0.00	0.29 ± 0.02
18:1n-11	0.24 ± 0.01	0.40 ± 0.01	0.25 ± 0.02	0.20 ± 0.03	0.41 ± 0.01	0.63 ± 0.01	0.51 ± 0.02	0.65 ± 0.03
18:1n-9	2.08 ± 0.01	2.49 ± 0.05	3.17 ± 0.98	1.75 ± 0.07	2.05 ± 0.03	2.02 ± 0.04	2.37 ± 0.01	3.63 ± 0.04
18:1n-7	4.36 ± 0.01	3.31 ± 0.05	4.90 ± 0.10	4.19 ± 0.12	4.15 ± 0.10	4.84 ± 0.04	4.65 ± 0.03	5.15 ± 0.08
18:1n-5	0.34 ± 0.01	0.20 ± 0.00	0.22 ± 0.09	0.20 ± 0.12	0.14 ± 0.14	0.12 ± 0.00	0.12 ± 0.01	0.21 ± 0.01
20:1n-11	1.69 ± 0.01	2.08 ± 0.09	3.37 ± 0.123	2.75 ± 0.15	2.38 ± 0.20	2.02 ± 0.033	1.11 ± 0.04	1.80 ± 0.38
20:1n-9	0.45 ± 0.00	0.46 ± 0.00		0.25 ± 0.16	0.20 ± 0.21		0.45 ± 0.02	
20:1n-7	3.70 ± 0.03	2.71 ± 0.05	3.83 ± 0.10	3.67 ± 0.09	3.26 ± 0.03	2.84 ± 0.03	3.29 ± 0.10	3.31 ± 0.02
22:1n-11	tr	tr	0.01 ± 0.00	tr	tr	0.17 ± 0.04	0.15 ± 0.02	0.16 ± 0.14
22:1n-9	tr	0.13 ± 0.01	0.19 ± 0.06	0.14 ± 0.06	0.18 ± 0.09	0.18 ± 0.12	0.29 ± 0.02	0.43 ± 0.18
22:1n-7	tr	tr	0.16 ± 0.03	tr	tr	0.08 ± 0.04	0.06 ± 0.01	0.01 ± 0.00
ΣMonoenes	15.7	14.8	22.1	16.8	16.5	17.1	17.7	20.2
16:2n-7	tr	tr	tr	0.05 ± 0.03	0.04 ± 0.03	tr	tr	tr
16:2n-4	0.08 ± 0.03	0.07 ± 0.02	0.26 ± 0.04	0.17 ± 0.11	0.14 ± 0.01	0.37 ± 0.07	0.48 ± 0.02	0.43 ± 0.07
17:2n-8	0.12 ± 0.09	0.29 ± 0.01	0.23 ± 0.05	0.10 ± 0.04	0.11 ± 0.06	0.16 ± 0.01	0.15 ± 0.02	0.28 ± 0.01
16:4n-3	6.17 ± 0.05	6.00 ± 0.10	3.91 ± 0.38	6.57 ± 0.49	5.52 ± 0.21	4.08 ± 0.30	3.19 ± 0.18	2.46 ± 0.18
18:2n-9	0.15 ± 0.00	0.10 ± 0.05	0.11 ± 0.02	0.08 ± 0.03	0.09 ± 0.00	tr	tr	0.08 ± 0.00
18:2n-6	1.32 ± 0.01	1.04 ± 0.01	1.19 ± 0.02	1.26 ± 0.05	1.16 ± 0.01	0.95 ± 0.02	0.96 ± 0.03	1.31 ± 0.01
18:2n-4	0.14 ± 0.02	0.13 ± 0.02	0.25 ± 0.04	0.25 ± 0.03	0.18 ± 0.00	0.29 ± 0.03	0.37 ± 0.03	0.39 ± 0.01
18:3n-4	tr	0.05 ± 0.01	0.29 ± 0.02	0.19 ± 0.04	0.15 ± 0.03	0.22 ± 0.01	0.22 ± 0.01	0.25 ± 0.01
18:3n-3	1.36 ± 0.03	0.76 ± 0.01	0.90 ± 0.03	0.93 ± 0.07	0.88 ± 0.07	0.86 ± 0.05	0.84 ± 0.04	0.83 ± 0.01
18:3n-1	tr	tr	tr	tr	tr	0.03 ± 0.01	0.04 ± 0.00	tr
18:4n-3	2.73 ± 0.03	2.03 ± 0.04	1.30 ± 0.06	1.36 ± 0.06	1.38 ± 0.02	1.58 ± 0.02	1.71 ± 0.02	1.76 ± 0.03
18:4n-1	tr	tr	tr	tr	tr	0.09 ± 0.01	0.11 ± 0.01	tr
19:3n-6	0.81 ± 0.00	0.58 ± 0.02	0.46 ± 0.08	0.49 ± 0.04	0.46 ± 0.01	0.50 ± 0.07	0.45 ± 0.04	0.40 ± 0.05
20:2NMID (5,11)[4]	0.06 ± 0.01	0.12 ± 0.01	0.01 ± 0.00	0.07 ± 0.05	0.09 ± 0.05	0.02 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
20:2NMID (5,13)	0.34 ± 0.02	0.44 ± 0.01	0.49 ± 0.09	0.37 ± 0.08	0.43 ± 0.06	0.69 ± 0.09	1.01 ± 0.01	0.84 ± 0.04
20:2	tr	tr	0.11 ± 0.01	0.08 ± 0.02	0.07 ± 0.01	0.09 ± 0.03	0.01 ± 0.00	0.12 ± 0.01

Table 4. 〈Continued〉

Fatty acid	Month (Jun 1995 - Jan 1996)							
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
20:2n-6	0.16 ± 0.00	0.11 ± 0.00	0.12 ± 0.04	0.12 ± 0.01	0.13 ± 0.00	0.18 ± 0.05	0.16 ± 0.04	0.18 ± 0.00
20:3n-6	0.10 ± 0.02	0.10 ± 0.0	0.18 ± 0.01	0.13 ± 0.01	0.13 ± 0.01	0.14 ± 0.01	0.12 ± 0.00	0.18 ± 0.00
20:4n-6	2.55 ± 0.02	1.88 ± 0.04	3.47 ± 0.12	3.85 ± 0.06	3.55 ± 0.06	3.43 ± 0.04	3.00 ± 0.05	3.35 ± 0.04
20:3n-3	0.09 ± 0.04	0.04 ± 0.01	0.07 ± 0.05	tr	tr	0.08 ± 0.03	0.07 ± 0.02	0.08 ± 0.01
20:4n-3	0.47 ± 0.02	0.37 ± 0.00	0.32 ± 0.01	0.29 ± 0.01	0.30 ± 0.02	0.33 ± 0.01	0.34 ± 0.03	0.42 ± 0.03
20:5n-3	15.5 ± 0.43	14.4 ± 0.33	13.2 ± 0.38	15.9 ± 0.37	18.6 ± 0.25	24.0 ± 0.16	26.3 ± 0.33	21.0 ± 0.15
22:2NMID (7,13)	0.88 ± 0.00	0.87 ± 0.03	0.93 ± 0.04	0.72 ± 0.02	0.70 ± 0.03	0.54 ± 0.04	0.50 ± 0.02	0.70 ± 0.01
22:2NMID (7,15)	4.36 ± 0.03	3.69 ± 0.06	4.44 ± 0.10	4.64 ± 0.14	3.68 ± 0.05	3.02 ± 0.06	2.68 ± 0.08	3.11 ± 0.05
22:2n-6	0.18 ± 0.00	tr	tr	0.21 ± 0.03	0.22 ± 0.02	0.42 ± 0.08	0.15 ± 0.02	tr
21:5n-3	0.81 ± 0.01	0.68 ± 0.05	0.65 ± 0.02	0.77 ± 0.02	0.86 ± 0.02	1.14 ± 0.07	1.15 ± 0.03	1.07 ± 0.02
22:4n-6	0.15 ± 0.00	0.07 ± 0.03	0.33 ± 0.04	0.45 ± 0.05	0.41 ± 0.03	0.37 ± 0.02	0.31 ± 0.01	0.40 ± 0.03
22:5n-6	0.41 ± 0.00	0.35 ± 0.02	0.48 ± 0.03	0.57 ± 0.02	0.48 ± 0.00	0.35 ± 0.01	0.25 ± 0.01	0.39 ± 0.06
22:5n-3	1.07 ± 0.02	0.83 ± 0.03	1.03 ± 0.02	1.44 ± 0.05	1.47 ± 0.03	1.39 ± 0.05	1.27 ± 0.03	1.28 ± 0.05
22:6n-3	18.7 ± 0.15	21.6 ± 0.81	12.3 ± 0.21	15.6 ± 0.57	16.5 ± 0.30	12.1 ± 0.30	10.4 ± 0.12	11.2 ± 0.08
ΣPolyenes	58.7	56.6	47.1	56.7	57.7	57.5	56.2	52.5
Σn-3	46.9	46.7	33.8	42.9	45.5	45.6	45.2	40.1
Σn-6	5.68	4.13	6.23	7.08	6.53	6.34	5.40	6.21
n-3/n-6	8.26	11.3	5.42	6.05	6.97	7.19	8.38	6.45

[1]Data are presented as mean ± standard deviation of 6 (2 groups x 3) determinations.
[2]tr, trace.
[3]The data were presented as the sum of (20:1n-11)+(20:1n-9).
[4]NMID, non-methylene interrupted diene.

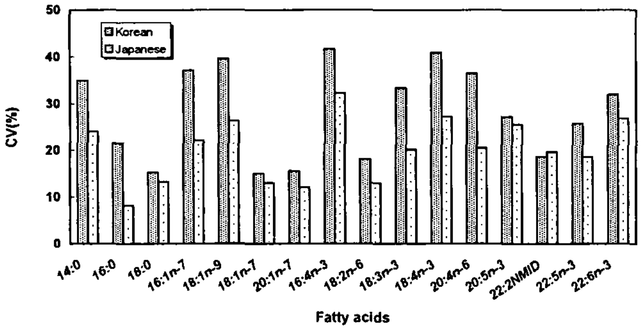

Fig. 2. Coefficient variation in the prominent fatty acid compositions of the cultured oysters with the Korean and Japanese spat during 8 months.

December (harvest period, 314 mg/100 g sample) and in July (pre-spawning period, 237~247 mg/100 g sample), respectively, during growth.

From these results, the cultured oyster with the Japanese spat contained about two times more n-3 fatty acid content per individual than the cultured oyster with the Korean one. The oyster in Korea therefore needs its breed improvement.

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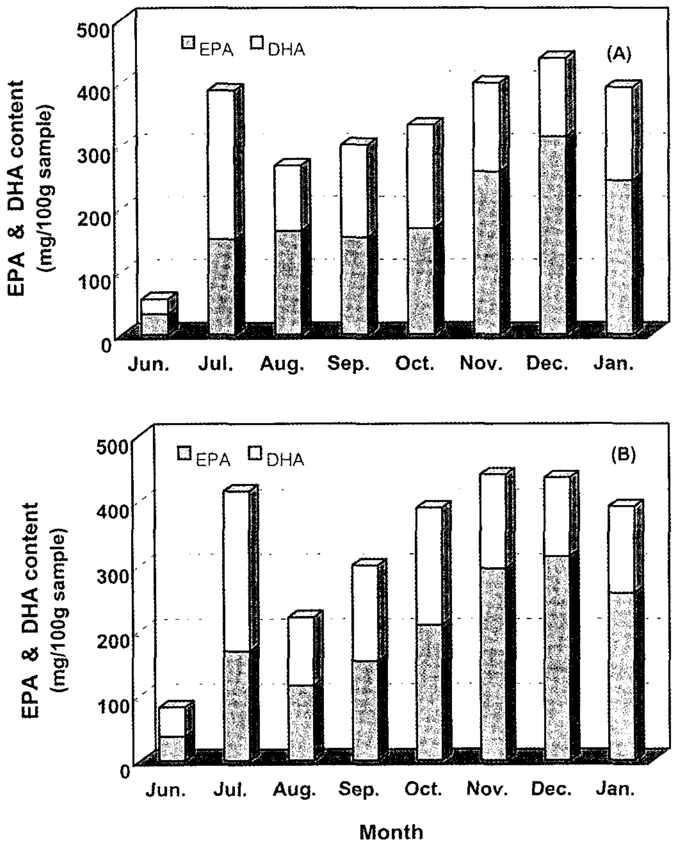

Fig. 3. Monthly variations in EPA and DHA contents of the cultured oysters with Korean (A) and Japanese (B) spats.

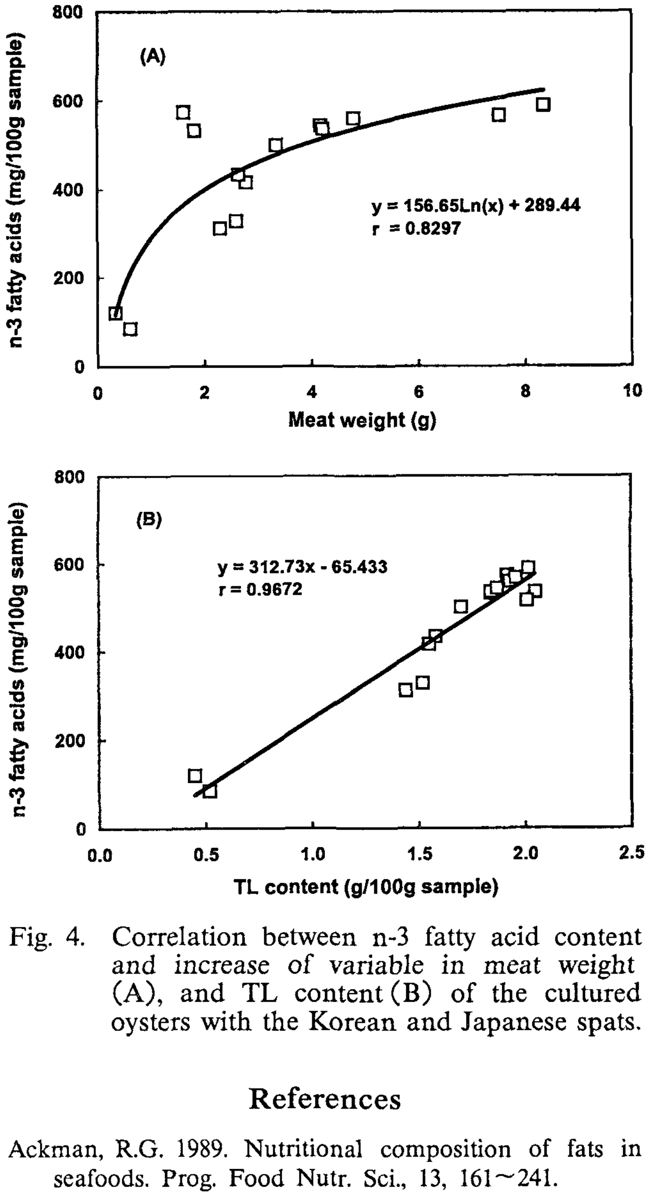

Fig. 4. Correlation between n-3 fatty acid content and increase of variable in meat weight (A), and TL content (B) of the cultured oysters with the Korean and Japanese spats.

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