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Regional Difference in Fatty Acid Content of Korean Shellfish

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Abstract Regional variation in the fatty acid content of shellfish was investigated on 5 species of Korean shellfish including murex shell, ark shell, jack-knife clam, orient hard clam, and little neck clam that were originated from 2 geographically different regions in Korea (Region 1: South coast, 34-35°N, 127-129°E; Region 2: West coast, 36-38°N, 126-127°E). Significant regional difference in total fatty acids content was observed in murex shell and little neck clam ($p<0.01$), but not in the other species of shellfish. The contents of saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids including *n*-3 and *n*-6 fatty acids were appreciably higher in murex shell from Region 2 and in little neck clam from Region 1 than the shellfish originated from their counterpart areas ($p<0.05$). Nevertheless, relative percentages of the fatty acids remained constant within same species regardless of geographic regions or species. Considering the facts of that the fish/shellfish are unique sources of *n*-3 fatty acids and a little neck clam is the most-consumed shellfish in Korea, *n*-3 fatty acids intake might vary with the habitat of the shellfish that Koreans consume.

Keywords: shellfish, little neck clam, murex shell, fatty acid, *n*-3 fatty acid

Introduction

Shellfish has been known as an important source of *n*-3 polyunsaturated fatty acids (PUFA) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (1,2). Epidemiological and clinical researches have revealed the beneficial effects of PUFA, particularly *n*-3 PUFA, for the prevention of cardiovascular diseases, and which effects were independent of total fat and cholesterol intakes (3-5). The curative or preventive effects of *n*-3 PUFA are presumably due to the anti-inflammatory potency of *n*-3 PUFA that results from either competitive inhibition of the synthesis of eicosanoids generated from *n*-6 PUFA or from increased production of anti-aggregatory prostacyclins from *n*-3 PUFA (6,7). For this reason, it has been also suggested that the consumption of fish/shellfish would have favorable effects on ischemic heart disease and thrombosis (3,4,8,9). Indeed, intake of *n*-3 PUFA was inversely proportional to the cardiovascular mortality or death from coronary heart disease (9-11). Therefore, PUFA composition as well as fat content must be considered when fish/shellfish is recommended as a means of improving health (3,12).

Fat content and PUFA composition of fish/shellfish are influenced by species (1,13-18), season (2,13,14,19-23), availability and composition of food (13,14), water temperature (13), stage of sexual development (13), and self-regulation of fatty acid synthesis (13). Previously, we reported that fatty acid contents and compositions of 12 species of commonly consumed Korean shellfish varied significantly with species (1) and season (2), nevertheless, the shellfish were still excellent sources of *n*-3 PUFA such as EPA and DHA and presented favorable ratio of *n*-3 PUFA to *n*-6 PUFA (*n*-3/*n*-6).

Fatty acid compositions of marine animals might differ greatly by collection region that associated with a number of factors such as differences in food availability and composition or water temperature (13,24,25). Mahaffey (26) also pointed out that the consumption of recommended amounts of fish/shellfish might result in very different intakes of *n*-3 PUFA because of substantial difference in the amount of *n*-3 PUFA present in various marine animals depending on collection season or regions (26). Currently, there has been a growing interest in seafood as a unique source of *n*-3 PUFA. Therefore, as the same stream to the previous shellfish research, here we investigated the influence of geographic regions where shellfish were caught on the fatty acid content and composition of shellfish, particularly on PUFA contents and fatty acids-related nutritional indices including the ratio of PUFA to saturated fatty acids (SFA) (P/S) and *n*-3/*n*-6. Based on our previous studies, 5 species of shellfish were selected among 12 species of commonly consumed Korean shellfish for the regional difference in fatty acids because they were grown or caught at 2 geographically different regions (Table 1, Fig. 1).

Materials and Methods

Sample preparation Five species of shellfish including murex shell, ark shell, jack-knife clam, orient hard clam, and little neck clam were selected for the regional difference in fatty acids content of Korean shellfish because they were commonly consumed and available at 2 geographically different regions: Region 1 where is south coast of Korean peninsula corresponding to 34-35°N, 127-129°E and average water temperature of 16.1±6.6°C; Region 2 where is west coast corresponding to 36-38°N, 126-127°E and water temperature of 14.3±9.0°C (Fig. 1, Table 1, 2). The shellfish were purchased from local markets over several

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Fig. 1. Original habitats of the shellfish used in this study. Small circles and large circles belong to Region 1 (south coast) and Region 2 (west coast), respectively.

months encompassing in and out of spawning seasons. Detailed collection months are as follows; murex shell was collected at March, May, June, July, August, and October in 2003-2004. Ark shell, jack-knife clam, orient hard clam, and little neck clam were collected at March, May, June, July, August, October, and December in 2003-2004. The shellfish was alive when purchased. As soon as delivered, edible portions of 20-100 shellfish depending on their size were homogenized using a homogenizer (Hanil, Seoul, Korea) at high speed for 1 min without added solvent and stored at –20°C.

Fatty acid analysis Fatty acids in shellfish homogenates were converted to their corresponding fatty acid methyl esters (FAME) according to the method of Lepage and Roy (27). Two mL of methanol/benzene 4:1(v/v) solution was added to 0.1 g of homogenated sample. One-hundred μg of tridecanoic acid (C13:0) was included in the solution as an internal standard. While stirring, 200 μL of acetyl chloride was slowly added. Glass sample tubes were tightly closed with Teflon-lined caps and subjected to methanolysis at 100°C for 1 hr. Tubes were weighed before and after heating to check leakage of volatile contents. After tubes had been cooled in water, 5 mL of 6% aqueous K_2CO_3 was slowly added to stop the reaction and neutralize the mixture. The reaction mixture was centrifuged, and an aliquot of benzene upper phase was subjected to gas chromatography. All of these reactions were performed in triplicate for each shellfish sample.

Efficiency of methylation: Efficiency of methylation was tested as follows. Firstly, each homogenate prepared from

Table 1. Commonly consumed Korean shellfishes and their geographical availability

Common name	Local name	Spawning	Consumption (g/day)[1)]	Availability[2)]
Murex shell	Pibbulgodoong	May-Aug	0.3	Region 1 & 2
Ark shell	Pijogae	July-Oct	0.0	Region 1 & 2
Granulated ark shell	Komak	July-Sept	0.2	Region 1
Hard-shelled mussel	Honghap	March-June	0.4	Region 1
Pen shell	Kijogae	-[3)]	0.0	Region 1
Oyster	Gool	July-Sept	1.0	Region 1
Surf clam	Dongjook	March-Oct	-[3)]	Region 2
Pink butterfly shell	Bidanjogae	-[3)]	0.0	Region 3
Jack-knife clam	Garimatjogae	Aug-Sept	0.0	Region 1 & 2
Venus clam	Gamoorak	June-Aug	-[3)]	Region 2
Orient hard clam	Baekhap	June-Oct	0.2	Region 1 & 2
Little neck clam	Bagirak	July-Aug	1.7	Region 1 & 2

[1)]Values were referred to 'In-Depth Analysis on the 3rd (2005) Korean Health and Nutrition Examination Survey: Nutrition Survey' (Korea Health Industry Development Institute, 2007).
[2)]Habitat of each shellfish. Region 1, 2, and 3 represent south coast, west coast, and east coast of Korean peninsula, respectively.
[3)]Information was not available.

Table 2. Taxonomical classification of shellfish investigated in this study

Class	Order	Family	Genus species	Common name	Local name
Gastropoda	Neogastropoda	Muricidae	*Rapana venosa*	Murex shell	*Pibbulgodoong*
Bivalvia	Arcoida	Arcidae	*Scapharca broughtonii*	Ark shell	*Pijogae*
	Veneroida	Pharellidae	*Sinonovacula constricta*	Jack-knife clam	*Garimatjogae*
		Veneridae	*Meretrix lusoria*	Orient hard clam	*Baekhap*
			Ruditapes philippinarum	Little neck clam	*Bajirak*

5 species of shellfish was subjected to the fatty acid methylation procedure, where tridecanoic acid was not added into the homogenate samples: Experiment A. Secondly, shellfish homogenates were methylated using the methylation procedure, where tridecanoic acid was added into the each sample as described above: Experiment B. Lastly, a shellfish homogenate was methylated without tridecanoic acid (Mw=214.3), and then the same moles of tridecanoic acid methylester (Mw=228.3) as the tridecanoic acid added in Experiment B were added after methylation step, i.e., right before centrifugation step: Experiment C. These experiments were run in triplicate except Experiment A. Experiment A and B were conducted to validate the tridecanoic acid as an internal standard. Experiment B and C were performed to monitor the completeness of the methylation and extraction of FAME into benzene phase. Efficiency of methylation was determined by comparing the quantified amount of tridecanoic acid methylester between Experiment B and C.

***Gas chromatography-mass selective detector (GC-MSD) analysis*:** Analysis of methyl esters was performed by a GC-MSD (Hewlett Packard, GC-6890, MS-5973, Wilmington, DE, USA) on a fused silica DB-Wax column (60 m × 0.25 mm i.d., J&W, Folsom, CA, USA). Carrier gas was helium at a flow rate of 1.0 mL/min and a linear velocity of 26 cm/sec. One μL of the sample was injected with a split ratio of 30:1 and run in constant flow mode. Chromatographic conditions were as follows: injector and detector temperatures, 250°C; initial oven temperature, 90°C for 5 min, rising to 180°C at 10°C/min with a hold time of 3 min, to 230°C at 3°C/min with a hold time of 3 min, to 245°C at 2°C/min, and then to 250°C at 0.7°C/min with a final hold time of 10 min. Each peak was identified by comparison with the retention times of 32 known standards as well as by their mass fragment patterns. Fatty acid concentration was calculated from the standard curves of individual fatty acids.

Statistical analysis Data were analyzed using the generalized linear model (GLM) procedure of the statistical package SAS 9.1. All values were adjusted for the season.

Results and Discussion

Efficiency of methylation and GC/MSD response to FAME Prior to the quantification of fatty acids, efficiency of methylation and GC/MSD responses to FAME were tested. Tridecanoic acid (C13:0) was validated as an effective internal standard because it was totally absent in all of 5 shellfish. Methylation efficiency was determined by comparing Experiment B with C, as described in experimental section. The amount of tridecanoic acid methyl ester quantified from Experiment B was 91.61± 7.00% of that from Experiment C. GC/MS chromatogram for FAME was shown in Fig. 2. The pair 20:5/22:0 was clearly resolved at a retention time of 54.89 and 55.17 min under this chromatographic condition. GC/MSD response to the various fatty acids were tested and summarized in Table 3. Responses were not proportional to the actual concentration of fatty acids, therefore, standard curves presenting 'fatty acid concentration versus GC/MSD response' were constructed for individual fatty acids, from which fatty acids in the shellfish samples were quantified.

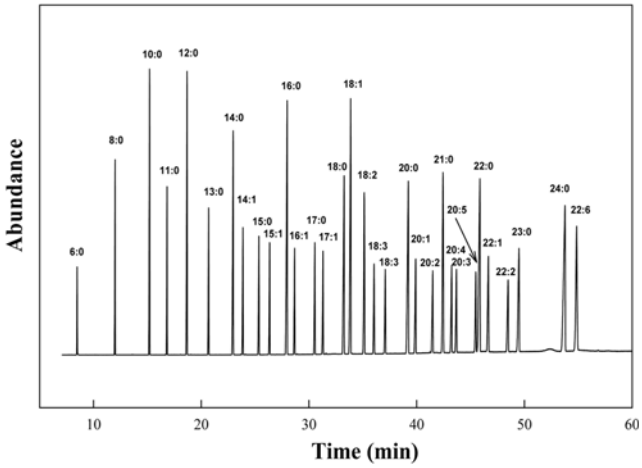

Fig. 2. GC-MS chromatogram of fatty acids determined in this study. Each peak represents methyl ester of individual fatty acid.

Regional difference in fatty acid contents and compositions of shellfish Fatty acid contents and compositions of shellfish were determined in 5 species of Korean shellfish depending on the geographical regions of their habitats. Table 1 listed commonly consumed 12 species of Korean shellfish among which 5 species of shellfish including murex shell, ark shell, jack-knife clam, orient hard clam, and little neck clam were selected for the regional difference in the fatty acids of Korean shellfish because they were available at 2 geographically different regions, i.e., both south coast (Region 1) and west coast (Region 2) of Korean peninsula (Fig. 1), and occupied about 60% of total shellfish intake of Korean (Table 1). The selected shellfish is biologically categorized into 1 species of Gastropoda and 4 species of Bivalvia (Table 2).

Total fatty acid contents of the shellfish ranged 1,024-3,397 mg/100 g with the lowest being murex shell from Region 1 (south coast) and the highest being orient hard clam from Region 2 (west coast) (Table 4, Fig. 1). Significant regional difference in the total fatty acids content was observed in murex shell and little neck clam ($p<0.01$), but not in the other species of shellfish. Total fatty acids content was 3-fold higher in murex shell from Region 2 and 2-fold higher in little neck clam from Region 1 than the shellfish originated from their counterpart areas ($p<0.01$) (Fig. 1). Table 4 also listed 23 fatty acids detected in the shellfish and their detailed contents and compositions. The most prominent fatty acid was palmitic acid (C16:0) in all shellfish with constituting 21-33% of the total fatty acids, regardless of the appreciable difference in the total fatty acid content depending on either geographic region or species. The compositional dominance of palmitic acid in marine animals has been typically observed, which was independent of species, season, temperature, diet, or geographical region (1,2,16). It could be attributed to the fact of that the palmitic acid is a key metabolite and utilized as an energy source, for which *de novo* synthesis of the fatty acid occurs in shellfish or fish (28). The major fatty acids, beside palmitic acid, in the shellfish were, stearic acid (8-13%), EPA (8-18%), and DHA (10-19%).

Table 3. GC/MSD responses to various fatty acid methyl esters

Fatty acids		Concentration (%)	Response (%)
Caproic acid	C6:0	4	0.8
Caprylic acid	C8:0	4	1.4
Capric acid	C10:0	4	2.3
Undecanoic acid	C11:0	2	1.6
Lauric acid	C12:0	4	3.7
Tridecanoic acid	C13:0	2	2.5
Myristic acid	C14:0	4	5.3
Myristoleic acid	C14:1, *cis*-9	4	2.8
Pentadecanoic acid	C15:0	2	3.0
cis-10-Pentadecenoic acid	C15:1	2	2.9
Palmitic acid	C16:0	6	8.0
Palmitoleic acid	C16:1, *cis*-9	2	2.9
Heptadecanoic acid	C17:0	2	2.6
cis-10-Heptadecenoic acid	C17:1	2	2.5
Stearic acid	C18:0	4	4.6
Oleic acid	C18:1, *cis*-9	6	6.6
Linoleic acid	C18:2, *cis*-9,12	4	4.3
Linolenic acid	C18:3, *cis*-9,12,15	2	2.2
γ-Linolenic acid	C18:3, *cis*-6,9,12	2	2.3
Arachidic acid	C20:0	4	4.3
cis-11-Eicosenoic acid	C20:1	2	2.2
cis-11,14-Eicosadienoic acid	C20:2	2	2.0
cis-11,14,17-Eicosatrienoic acid	C20:3	2	1.9
cis-8,11,14-Eicosatrienoic acid	C20:3	2	
Arachidonic acid	C20:4, *cis*-5,8,11,14	2	2.0
cis-5,8,11,14,17-Eicosapentaenoic acid	C20:5	2	2.0
Heneicosanoic acid	C21:0	2	4.1
Behenic acid	C22:0	4	4.4
Erucic acid	C22:1, *cis*-13	2	2.3
cis-13,16-Docosadienoic acid	C22:2	2	2.0
cis-4,7,10,13,16,19-Docosahexaenoic acid	C22:6	2	1.6
Tricosanoic acid	C23:0	2	2.3
Lignoceric acid	C24:0	4	4.5
Nervonic acid	C24:1, *cis*-15	2	2.4

Contents of the 4 major fatty acids were significantly higher in murex shell from Region 2 and little neck clam from Region 1, which was exactly comparable tendency to that of total fatty acids (Table 4, Fig. 1). On the other hand, there was no statistically noticeable difference observed in ark shell, jack-knife clam, and orient hard clam between 2 regions. Interestingly, relative percentage of the fatty acids tended to be constant within same species regardless of collection regions, which suggests that the factors associated with the geographical regions such as availability and composition of food or water temperature had an impact on fatty acid content but not on fatty acid composition (i.e., % contribution to total fatty acids) of murex shell and little neck clam inhabiting south coast or west coast of Korean peninsula.

The detailed fatty acids were categorized into saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), or polyunsaturated fatty acids (PUFA) according to the typical fatty acid classification (Table 5). Marine fish has been known to present higher content of PUFA than SFA due to their diets composed of mainly zooplankton (17,25,29,30). However, in most of analyzed shellfish, the contents of SFA (37-49%) tended to be a little higher than those of PUFA (30-43%), and MUFA was lowest (19-26%) in all shellfish, which consequently led to the relatively low ratio of PUFA to SFA (P/S=0.6-1.7). This tendency could be partially explained by their diet or different feeding habits depending on species, e.g., plankton feeder, herbivorous feeder, carnivorous feeder, or mud swallower (25). In line with the above results, there was no significant difference in the relative percentage of each fatty acid class within same shellfish species inhabiting south or west coast of Korea. It suggests that the environments surrounding the shellfish might not be sufficiently different to influence on fatty acid compositions of the shellfish. Indeed, water temperature, a main factor influencing the unsaturation of fatty acids in marine animals, was not appreciably different between south coast (16.1°C) and west coast (14.3°C). It has been reported that the unsaturation of fatty acids in marine animals tends to increase under low environmental

Table 4. Geographical difference in fatty acid content of shellfish[1)]

Fatty acid	Murex shell			Ark shell			Jack-knife clam			Orient hard clam			Little neck clam		
	R 1	R 2	Pr	R 1	R 2	Pr	R 1	R 2	Pr	R 1	R 2	Pr	R 1	R 2	Pr
C14:0	22±3 (2)	70±7 (2)	***	42±7 (2)	32±7 (3)		41±5 (2)	69±18 (3)		21±3 (2)	123±49 (4)		41±9 (2)	20±4 (2)	**
C15:0	10±2 (1)	29±5 (1)	*	5±1 (0)	3±1 (0)		10±1 (1)	11±2 (1)		4±1 (0)	14±4 (0)		16±3 (1)	5±1 (0)	**
C16:0	258±43 (25)	883±116 (26)	***	400±71 (22)	246±34 (22)		407±73 (21)	565±95 (26)		319±25 (29)	999±359 (29)		757±150 (33)	319±63 (30)	**
C16:1	33±7 (3)	53±11 (2)	*	139±33 (8)	75±17 (7)	*	208±37 (11)	177±46 (8)		66±8 (6)	343±165 (10)		128±29 (6)	77±26 (7)	*
C17:0	40±9 (4)	121±28 (4)		47±7 (3)	25±5 (2)		26±5 (1)	30±5 (1)		23±1 (2)	47±15 (1)		47±9 (2)	22±5 (2)	
C18:0	124±21 (12)	423±61 (13)	**	179±27 (10)	108±21 (10)		197±42 (10)	209±36 (10)		94±6 (9)	271±92 (8)		223±38 (10)	122±30 (11)	*
C18:1 (9)	48±9 (5)	133±21 (4)	**	67±11 (4)	40±6 (4)	*	82±19 (4)	104±18 (5)		51±4 (5)	139±50 (4)		101±21 (4)	56±15 (5)	*
C18:1 (13)	26±6 (3)	77±12 (2)	**	67±13 (4)	43±6 (4)	*	126±25 (7)	117±23 (5)		45±5 (4)	186±79 (5)		104±22 (4)	52±13 (5)	*
C18:2 *n*-6	30±7 (3)	67±19 (2)		45±8 (2)	29±5 (3)		47±9 (2)	37±7 (2)		17±3 (2)	74±29 (2)		32±7 (1)	31±11 (3)	
C18:3 *n*-6	ND[2)] (0)	ND (0)		ND (0)	3±3 (0)		3±1 (0)	1±1 (0)	**	ND (0)	ND (0)		5±4 (0)	ND (0)	
C18:3 *n*-3	8±2 (1)	20±8 (1)		16±4 (1)	8±1 (1)		27±5 (1)	31±6 (1)		6±2 (1)	28±16 (1)	**	25±7 (1)	4±1 (0)	**
C20:0	4±1 (0)	12±2 (0)	*	16±7 (1)	2±1 (0)		6±2 (0)	7±1 (0)		5±1 (0)	6±3 (0)		10±4 (0)	5±2 (1)	
C20:1	111±27 (11)	458±74 (14)	**	80±16 (4)	52±12 (5)		81±17 (4)	96±19 (5)		50±11 (5)	169±55 (5)		136±38 (6)	33±10 (3)	***
C20:2 *n*-6	11±1 (1)	31±6 (1)	**	ND (0)	1±1 (0)		12±2 (1)	29±5 (1)		10±4 (1)	39±16 (1)		45±7 (2)	5±2 (1)	*
C20:3 *n*-3	ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)	
C20:3 *n*-6	ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)	
C22:0	2±1 (0)	5±2 (0)		ND (0)	ND (0)		9±2 (0)	4±1 (0)	*	ND (0)	ND (0)		ND (0)	ND (0)	
C22:1	3±3 (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)	
C20:4 *n*-6	82±13 (8)	263±40 (8)	**	56±10 (3)	27±4 (2)		41±9 (2)	50±9 (2)		45±4 (4)	71±22 (2)		59±12 (3)	36±8 (3)	
C20:5 *n*-3	83±19 (8)	291±52 (9)	**	303±78 (17)	199±18 (18)		266±60 (14)	242±45 (11)		112±11 (10)	330±136 (10)		208±44 (9)	103±30 (10)	**
C24:0	31±5 (3)	96±14 (3)	**	10±4 (1)	6±1 (1)		20±6 (1)	13±3 (1)		8±2 (1)	17±5 (0)		7±3 (0)	9±3 (1)	
C24:1	ND (0)	ND (0)		ND (0)	1±1 (0)		ND (0)	ND (0)		ND (0)	ND (0)		ND (0)	ND (0)	
C22:6 *n*-3	99±29 (10)	339±95 (10)		344±64 (19)	216±34 (19)		305±68 (16)	342±65 (16)		211±11 (19)	540±239 (16)		369±80 (16)	170±38 (16)	*
Total	1,024±188	3,368±502	**	1,815±326	1,116±110		1,913±381	2,134±365		1,087±63	3,397±1294		2,315±464	1,072±227	**

[1)]Unit is mg/100 g. Value in parenthesis is a relative % to the amount of total fatty acids. *, **, and *** represent significant difference in fatty acid content (not a relative percentage) between 2 regions at $p<0.05$, $p<0.01$, and $p<0.001$, respectively.
[2)]Not detected.

temperatures in order to maintain their cell membrane fluidity, thus EPA and DHA comes to be generally predominant (13,20,31). However, in this study, no difference was observed in the relative percentage of the PUFAs between 2 regions. Only inter-class difference was observed (Table 5). The contents of *n*-6 and *n*-3 PUFA were 5-7% and 26-38% of the total fatty acids, respectively, thus resulted in relatively high ratio of *n*-3 to *n*-6 (*n*-3/*n*-6=4.1-8.0) for 4 species of Bivalvia. The favorable *n*-3/*n*-6 of these Bivalvia is expected to enhance their nutritional values, given the fact of that the *n*-3/*n*-6 in diet is more important value than the absolute amount of each class of

Table 5. Geographical difference in fatty acid related index of shellfish[1)]

Fatty acid[2)]	Murex shell			Ark shell			Jack-knife clam			Orient hard clam			Little neck clam		
	R1	R2	Pr	R1	R2	Pr	R1	R2	Pr	R1	R2	Pr	R1	R2	Pr
SFA	492±82 (48)	1638±218 (49)	**	698±116 (38)	422±58 (38)		716±134 (37)	908±151 (43)		474±32 (44)	1,478±509 (43)		1,102±211 (48)	504±105 (47)	**
MUFA	220±47 (21)	720±109 (21)	**	353±68 (19)	211±17 (19)	*	497±95 (26)	494±96 (23)		213±24 (20)	838±343 (25)		468±108 (20)	219±58 (20)	**
PUFA	313±65 (31)	1010±194 (30)	*	764±147 (42)	483±41 (43)		701±152 (37)	732±131 (34)		400±20 (37)	1082±447 (32)		743±149 (32)	349±80 (33)	*
P/S	0.7±0.1	0.6±0.1		1.0±0.1	1.7±0.3	*	1.0±0.0	0.8±0.1		0.9±0.1	0.7±0.1	**	0.7±0.0	0.7±0.1	
n-6	123±20 (12)	361±55 (11)	**	102±16 (6)	60±11 (5)		102±19 (5)	118±20 (6)		71±7 (7)	184±62 (5)		142±24 (6)	72±17 (7)	*
n-3	190±48 (19)	650±148 (19)	*	663±134 (37)	423±32 (38)		598±133 (31)	615±111 (29)		329±19 (30)	898±390 (26)		601±127 (26)	277±67 (26)	**
n-3/*n*-6	1.5±0.2	1.7±0.3		6.1±0.8	8.0±0.8		5.8±0.2	5.1±0.2		5.1±0.6	5.2±0.7		4.1±0.4	4.6±0.6	*
DHA+ EPA	182±48 (18)	630±141 (19)	*	647±130 (36)	414±32 (37)		572±128 (30)	584±106 (27)		323±20 (30)	870±374 (26)		577±121 (25)	274±66 (26)	**

[1)]Unit is mg/100 g, except P/S and *n*-3/*n*-6. Value in parenthesis is a relative percentage to the amount of total fatty acids. *, **, and *** represent significant difference of fatty acid content (not a relative percentage) between 2 regions at $p<0.05$, $p<0.01$, and $p<0.001$, respectively.
[2)]SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; P/S, PUFA/SFA; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid.

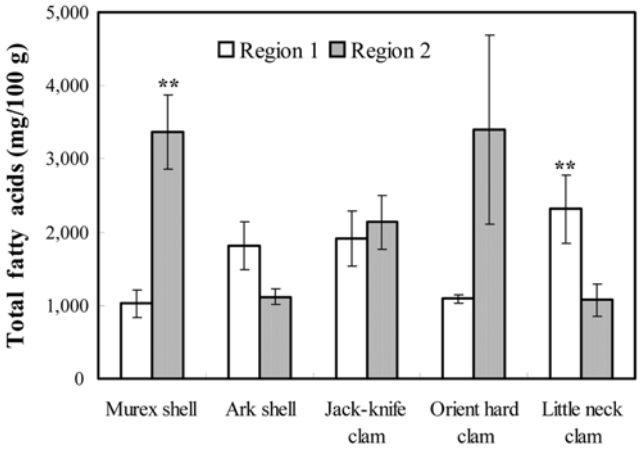

Fig. 3. Regional difference in total fatty acid content of Korean shellfish. **Significant difference in fatty acid content between 2 regions at $p<0.01$.

fatty acids for disease prevention, because *n*-3 PUFA competitively inhibits the biosynthesis of *n*-6 PUFA-derived eicosanoids and vice versa (6,7). Murex shell, the only shellfish sample that belongs to Gastropoda class, presented 2-fold higher *n*-6 PUFA (11-12%) mainly due to the prominent increase in the content of arachidonic acid (8% of total fatty acid), thus led to the relatively low *n*-3/*n*-6 (1.5-1.7), when it compared to Bivalvia. It has been previously observed that the Gastropoda was relatively abundant in arachidonic acid and poor in DHA than Bivalvia, and which has been attributed to the difference in their feeding habits: carnivorous feeder versus plankton feeder (1,2,32). Nevertheless, the content of *n*-3 PUFA was found to be still higher than that of *n*-6 PUFA in both classes of shellfish, particularly high amounts of EPA+ DHA (182-870 mg/100 g) were observed (Table 5), which confirmed the fact of that the shellfish was a significant dietary source of *n*-3 PUFA. As expected from the above results, the absolute amounts of SFA, MUFA, and PUFA including *n*-6 and *n*-3 PUFA were also substantially different between 2 regions in both murex shell and little neck clam, although there was no difference in the relative contribution of the fatty acids to their total fatty acids (Table 5).

The major finding of this study was that the amounts of fatty acids in the murex shell and little neck clam were significantly different between 2 regions, but their fatty acid compositions remained constant. Thus we assumed that water temperature was not an influencing factor on the significant difference. Rather, food availability in the respective habitats might be a factor that could explain the regional discrepancies in the absolute contents of fatty acids in the shellfish. The observations are noticeable because both murex shell and little neck clam occupy more than 50% of shellfish intake of Korean and fish/shellfish are unique sources of *n*-3 fatty acids, thus might affect, albeit small, on the intake of *n*-3 fatty acids.

This study was conducted in a local way by limiting samples to Korean shellfish, but we surely believe that it could give world-widely applicable information, in that this study clearly established that the fatty acid contents of shellfish might vary with collection regions even within same species, which eventually might result in different intake of unique nutrients to shellfish.

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