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RESEARCH ARTICLE

Lipid Class and Fatty Acid Compositions of Dried Sea Cucumber *Apostichopus japonicus*

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Abstract:

Introduction:

Sea cucumber, *Apostichopus japonicus,* is becoming popular around the world due to its nutritional and medicinal properties. There are still no detailed chemical studies of the lipid class, glycolipids compositions of sea cucumber.

Methods:

This study was conducted to determine the lipid class and glycolipid compositions of dried sea cucumber, *A. japonicus,* and analyze fatty acid compositions of Monogalactosyl Diglycerides (MGDG), Steryl Glycosides (SG) and Sulfoquinovosyl Diglycerides (SQDG). Total lipids of sea cucumber were extracted by Bligh and Dyer method and Sep-Pak Silica plus long cartridge, and Thin Layer Chromatography (TLC) silica gel G-60 F254 was used for the separation of different lipid classes and glycolipid compositions. The composition of fatty acids was analyzed by GC.

Results & Conclusion:

The level of total lipids in the dried sea cucumber, *Apostichopus japonicus,* was 4 ± 1% of dry weight (w/w) and the amount of neutral lipids, glycolipids and phospholipids was 31 ± 1%, 29 ± 1% and 40 ± 1% of the total lipids (w/w), respectively. MGDG, SG and SQDG were the major glycolipids, and the contents were 37.5 ± 0.3%, 33.8 ± 0.5% and 23.6 ± 0.7% of the total glycolipids (w/w), respectively and significantly higher than other glycolipids ($p < 0.05$). SQDG contained much higher Arachidonic Acid (AA), Eicosapentaenoic Acid (EPA) and MGDG contained higher Docosahexaenoic Acid (DHA) compared with SG ($p < 0.05$). Further investigation is required to understand the positional distribution of fatty acids and molecular species in MGDG, SG and SQDG in detail.

Keywords: Sea cucumber, Lipid class, Total lipids, Glycolipids, Fatty acids, Echinoderms, Aquaculture.

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1. INTRODUCTION

Sea cucumbers belong to the phylum Echinodermata, class Holothuroidea. There are about 1,200 holothurian species in the world and commonly known as trepang, bêche-de-mer, or gamat [1]. Among echinoderms, sea cucumber *Apostichopus japonicus* is becoming popular around the world and the market demand of this species is increasing rapidly because of its dietary, aphrodisiac and curative properties [2]. Natural production of sea cucumbers has decreased due to overexploitation and pollution [3]. Depletion of natural production together with high commercial value has encouraged the people to develop aquaculture methods for sea cucumber culture [3 - 5]. However, worldwide production of sea cucumber has increased rapidly through aquaculture. China is the world leading country in sea cucumber production. Under controlled conditions, sea cucumbers are intensively mass-produced in Recirculating Aquaculture Systems (RAS) [6]. Moreover, sea cucumbers are very suitable species for co-culture or integrated multi-trophic aquaculture because they feed on organically rich substrates [6].

Sea cucumbers preferentially inhabit on muddy and sandy grounds, especially on the ocean and seashores and consume the sea bottom sediment containing organic matter, including protozoa, bacteria, diatoms , and detritus of plants or animals [7 - 12].

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Since sea cucumbers can autolyze after they have been caught, they must be stored using various processing methods. They are usually processed into boiled, dried or salted products [13, 14]. Sea cucumbers are usually marketed as fresh, frozen, dried, cooked-dried, cooked-salted and cooked-salted-dried products [15, 16]. Ferdouse [17] reported that sea cucumbers are mainly exported in dried form, but a small quantity of fresh and frozen sea cucumbers has also entered the international business. Approximately, 90% of this business takes place in the Asian Far East such as China, Hong Kong, Malaysia and Singapore [17].

Sea cucumbers have many therapeutic effects with high protein and low lipid content and contain minerals and vitamins such as magnesium, iron, calcium, zinc, vitamin A, riboflavin, niacin and thiamine [18 - 25]. Sea cucumber extra-cts have many bioactive compounds and have antiviral, anti-cancer, antibacterial, antioxidant, anti-inflammation effe-cts [26 - 30]. Lipids of sea cucumber play essential roles in the metabolic activities of organisms' effects [31, 32]. Long-chain polyunsaturated fatty acids Especially Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) may reduce the risk of coronary heart disease, cancer, inflammation and arthritis [33, 34] and arachidonic acid is responsible for wound healing and blood clotting [35]. Moreover, interest in the research on sea cucumber, *A. japonicus* is now more intense and many researchers in this field have studied the collagen, saponin and various other aspects [36 - 38]. However, there are still no detailed chemical studies of the lipid class, glycolipid components and fatty acid compositions of MGDG, SG and SQDG. Therefore, this study was carried out to determine the the lipid class, glycolipid compositions of dried sea cucumber, *A. japonicus* and analyze fatty acid compositions of MGDG, SG and SQDG.

2. MATERIALS AND METHODS

2.1. Experimental Sample

Live specimens of sea cucumbers, *Apostichopus japonicus* were hand-picked by scuba diving. They were collected from the coast of Tongyeong, the Republic of Korea. All samples were kept in plastic bags.

2.2. Pretreatment

Sea cucumbers were transported to laboratory in seawater. The body of each sea cucumber was cut from the anus nearly to the oral organ and then their visceral organs were removed. The body walls were washed carefully with distilled water. The sea cucumbers were boiled at 100°C for 45 min in 3.5% salt-containing water [18, 39]. After that, for drying, *A. japonicus* samples were placed on a dry plate of a heat pump-hybrid dryer (DHPD250, A1 Engineering Co., Ltd., Korea) at 55 ± 1°C where the internal vacuum was -2,000 mmAqG. The samples were dehydrated to a moisture content of 12% or less.

2.3. Reagents and Instrumentation

All reagents and solvents were of analytical grade and supplied by Sigma (Gillingham, UK) and Merck (Darmstadt, Germany). Chromatographic material used for thin layer chromatography (TLC) was silica gel G-60 F254 (Merck). The reference phospholipid standards such as acyl monogalactosyl diglycerides (Acyl MGDG), 6-0-acyl steryl glycosides (6-0-acyl SG), monogalactosyl diglycerides (MGDG), steryl glycosides (SG), digalactosyl diglycerides (DGDG) and sulfoquinovosyl diglycerides (SQDG) were used.

2.4. Total Lipid Extraction and Lipid Class Separation

Total lipids of sea cucumber were extracted according to the Bligh and Dyer method (1959) [40] by using a solvent mixture consisting of chloroform and methanol (2:1, v/v). After phase equilibration, the lower chloroform layer was removed and total lipids were extracted by removing the solvent using a rotary evaporator (R-114, BUCHI, Swiss) at 38 °C.

Sep-Pak Silica plus long cartridge (Waters, USA) was used for the separation of different lipid classes such as Neutral lipid (NL), Glycolipid (GL) and Phospholipid (PL) from the total lipids of sea cucumber.

Eighty milligrams of extracted total lipid was put into the cartridge and 15 mL of chloroform was passed through the cartridge. Then chloroform was collected and placed in a round flask, dried with a rotary evaporator, and quantified to obtain neutral lipids. After obtaining neutral lipids, 15 mL of acetone was eluted by passing through the cartridge, and dried in the same manner as before, and quantified to obtain glycolipids [41]. Then, 30 mL of methanol was eluted through the car-tridge, dried with a rotary evaporator, and quantified to get phospholipids. The above procedure was repeated several times to obtain samples necessary for analysis.

2.5. Analysis of Glycolipids

One hundred milligrams of glycolipids was dissolved in 1 mL of chloroform to adjust the sample concentration. The TLC plates (20 x 20 mm) coated with silica gel G-60 were activated in a dry oven at 105 ° C for 60 min and then cooled in a desic-cator. The prepared samples were applied to the TLC plates. An elution system consisting of chloroform: acetone: water 30:60:2 *(v/v/v)*, was utilized for the separation of glycolipids. The developed TLC plates were passed through N_2 to dry the TLC plates and then subjected to qualitative and quantitative analysis using a TLC scanner (CAMAG, TLC Scanner 4) [42].

2.6. Analysis of Fatty Acid Compositions

Methyl esters of the fatty acids contained in the MGDG, SG and SQDG were prepared as follows: 100 mg of lipid was put into a capped tube and 1.5 ml 0.5 N NaOH-methanol solution was added. The sample was mixed by vortex and heated at 100°C for 8 minutes for saponification. After cooling, methylation was done by using a fatty acid methyl ester (FAME) with BF_3-methanol. Then the sample was dissolved to 2 ml iso-octane and fatty acids were analyzed via GC technique using gas chromatography (Clarus 600, Perkin Elmer, USA) equipped with a capillary column (Omegawax-320, 30 m × 0.25 mm I.D., Supelco Co., Bellefonte, PA, USA). The operating parameters were as follows: carrier gas =helium; detector (FID) temperature =270°C; injection temperature = 250°C; column temperature =180°C for 8 min, programmed to increase at 3°C/min up to 230°C with a final holding time of 10 min; split injection at 1:50 ratio. Menhaden oil was used as standard. Each of the specific fatty acid methyl ester peaks was identified by determining its equivalent chain length with reference to the known standard [43].

2.7. Statistical Analysis

All statistical analyses were performed using the SPSS 18.0 program and one-way ANOVA test followed by Duncan's multiple range test.

3. RESULTS AND DISCUSSION

3.1. Lipid Content and Compositions

The total lipid content of dried sea cucumber, *A. japonicus,* was 4 ± 1% (% of dry weight). This value was higher than those of *Euapta godeffroyi* (1.58%), *Holothuria pardalis* (1.66%), *Holothuria moebii* (2.42%) and *Holothuria impatiens* (3.14%), but lower than those of *A. japonicus* (3.93%), *Stichopus chloronotus* (4.56%), *Holothuria leucospilota* (7.16%) and *Abyssocucumis abyssorum* (9.00%) [44, 45]. Lipid composition of dried sea cucumber, *A. japonicus,* is shown in Table **1**. The total lipids consisted of 31% neutral lipids and 69% polar lipids which comprised 29% of glycolipids and 40% of phospholipids.

It is remarkable that dried sea cucumber, *A. japonicus,* was found to contain significantly higher content of glycolipids compared to *C. fraudatrix* (8.5%), *C. japonica* (1.6%), *Haliclona aqueducta* (4.3%), *H. panicea* (2.8%) and *Myxilla incrustans* (3.2%) [46, 47].

The phospholipids content of dried sea cucumber was much higher than those of *H. moebii* (12.5% of total lipids), *H. impatiens* (19.2%), *S. chloronotus* (21.8%), *E. godeffroyi* (22.1%) and *H. pardalis* (26.6%) [44].

The results of TLC separation of different glycolipids are shown in Fig. (**1**). The glycolipid compositions of dried sea cucumber, *A. japonicus* are shown in Table **2**. In this study, MGDG and SG were found as the major glycolipids class. MGDG (37.5%) was found to be higher than other glycolipids but not significantly different from SG (33.8%)(p < 0.05). The content of SQDG was 23.6%, which was significantly higher than that of DGDG (2.3%), 6-O-acyl SG (1.6%) and of acyl MGDG (1.2%) and no significant difference was observed in DGDG, 6-O-acyl SG and acyl MGDG (p < 0.05). Glycolipids can be found in lower invertebrates such as spongia, echinoderm and zebrafish. Among them, larger amounts of glycolipids have been found in echinoderms like sea cucumbers as they feed on glycolipid-rich algae whereas arthropoda have the lowest glycolipid contents [48].

3.2. Fatty Acid Compositions

Although many studies have been conducted about the fatty acid profile in different species of sea cucumbers [20, 49 - 51], there are a very few studies on lipid class of *A. japonicus* and there are no studies on the glycolipid fatty acids compositions of sea cucumber, *A. japonicus*.

Gas chromatography-flame ionization detector chromatograms of SQDG MGDG and SG are shown in Fig. (**2**). The fatty acid compositions of MGDG, SG and SQDG in the dried sea cucumber, *A. japonicus,* are shown in Table **3**. The principal fatty acids of MGDG are as follows: 16:0,18:0, 18:1n-9, 22:1n-9 and 22:6n-3. Total monounsaturated fatty acids (MUFAs) of total lipids were 23.15%, significantly higher (p < 0.05) than Polyunsaturated Fatty Acids (PUFAs) (18.5%).The main saturated (SFA) and Polyunsaturated Fatty Acids (PUFA) found in MGDG were palmitic acid (16:0) and docosahexaenoic acid (DHA, 22:6n-3), while the main monounsaturated fatty acids were cis-oleic acid (18:1n-9). There was a low concentrate of arachidonic acid (20:4n-6) and eicosapentaenoic acid (20:5n-3).

Major fatty acids of SG were 14:0, 16:0, 18:0, 18:1n-9, 22:0, 22:6n-3 and 24:1n-9. SG was found to contain significantly higher values of and SFA followed by MUFA, n-9 HUFA PUFA(p < 0.05). In this study, the highest amount of n-9 highly monounsaturated fatty acids (HUFA) were found in SG (29%) compared to MGDG, SQDG. Garg (1998) [52] reported that high-monounsaturated fatty acids could reduce plasma triglycerides by 19% and "bad" Very-Low-Density-Lipoprotein (VLDL) cholesterol by 22% in patients with diabetes.n-9 highly monounsaturated fatty acids have improved insulin sensitivity and decreased inflammation [53].

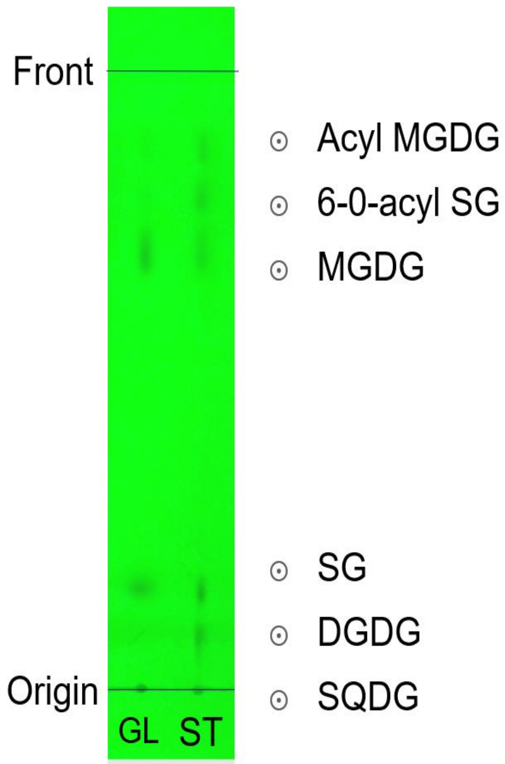

Fig. (1). Schematic TLC separations of glycolipids from dried sea cucumber. Chloroform-acetone-water (30:60:2, v/v/v). acyl monogalactosyl diglycerides (Acyl MGDG), 6-0-acyl steryl glycosides (6-0-acyl SG), monogalactosyl diglycerides (MGDG), steryl glycosides (SG), digalactosyl diglycerides (DGDG), and sulfoquinovosyl diglycerides (SQDG).

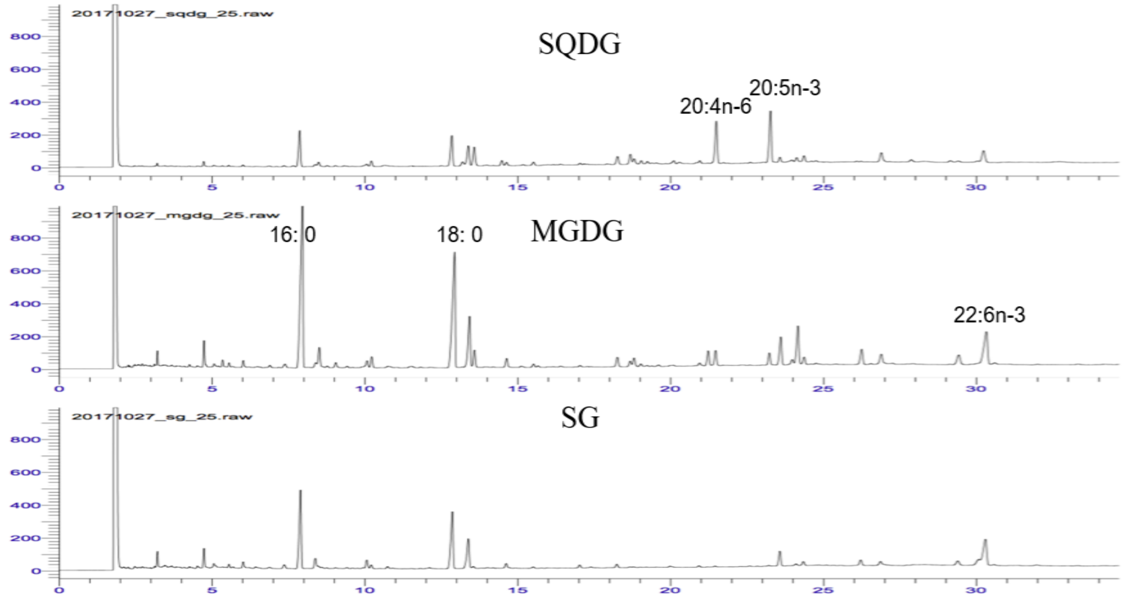

Fig. (2). Gas chromatography-flame ionization detector chromatograms of SQDG, MGDG and SG.

Table 1. Lipid composition of dried sea cucumber, *Apostichopus japonicus.*

Lipid Composition	Content (%)
Total lipid	4 ± 1[1]
Neutral lipids	31 ± 1[2]
Glycolipids	29 ± 1[2]
Phospholipids	40 ± 1[2]

[1]% of dry weight
[2]% of total lipids.

Table 2. Glycolipids composition of dried sea cucumber, *Apostichopus japonicus.*

Lipid Class	Content (%)
Acly monogalactosyl diglycerides (Acyl MGDG),	1.2 ± 0.1[a]
6-0-acyl steryl glycosides (6-0-acyl SG)	1.6 ± 0.2[a]
Monogalactosyl diglycerides (MGDG)	37.5 ± 0.3[d]
Steryl glycosides (SG)	33.8 ± 0.5[d]
Digalactosyl diglycerides (DGDG)	2.3 ± 0.08[b]
Sulfoquinovosyl diglycerides (SQDG)	23.6 ± 0.7[c]

Different superscript letters indicate statistically significant difference (P<0.05).

Table 3. Fatty acid composition of MGDG, SG and SQDG of dried sea cucumber *Apostichopus japonicus.*

Fatty acids	MGDG	SG	SQDG
iso 14:0	0.16 ± 0.02[b]	0.56 ± 0.03 [c]	0.05 ± 0.01 [a]
14:0	1.99 ± 0.06[b]	4.5 ± 0.6[c]	0.8 ± 0.2[a]
14:1n-9	0.35 ± 0.04[b]	0.46 ± 0.02[c]	0.24 ± 0.02[a]
14:1n-7	0.08 ± 0.01[a]	0.12 ± 0.01[b]	0.11 ± 0.02[b]
iso 15:0	0.53 ± 0.04[c]	0.05 ± 0.01[a]	0.18 ± 0.03[b]
anteiso-15:0	0.34 ± 0.03[a]	0.60 ± 0.02[a]	0.29 ± 0.02[a]
15:0	0.60 ± 0.05[b]	1.3 ± 0.5[c]	0.18 ± 0.02[a]
15:1n-8	0.09 ± 0.02[a]	0.07 ± 0.01[a]	0.05 ± 0.01[a]
15:1n-5	0.03 ± 0.01[a]	0.05 ± 0.01[a]	0.12 ± 0.02[b]
iso 16:0	0.29 ± 0.03[b]	0.41 ± 0.05[c]	0.23 ± 0.03 [a]
DMA 16:0	ND	ND	ND
pristanate	0.09 ± 0.01[a]	0.10 ± 0.02[a]	0.07 ± 0.01[a]
16:0	23.9 ± 0.5[c]	20.7 ±0.8[b]	7.8 ± 0.7[a]
16:1n-9	0.53 ± 0.05[a]	2.68 ± 0.09[b]	ND
16:1n-7	2.12 ± 0.09[c]	0.61 ± 0.03[b]	0.46 ± 0.02[a]
TME16:0	0.17 ± 0.02[a]	0.72 ± 0.04[c]	0.26 ± 0.03[b]
16:1n-5	ND	ND	0.95 ± 0.07[a]
anteiso 17:0	ND	0.23 ± 0.02	0.18 ± 0.02[a]

(Table 3) contd.....

Fatty acids	MGDG	SG	SQDG
DMA 17:0	ND	ND	ND
16:2n-4	0.96 ± 0.04[c]	0.37 ± 0.03[a]	0.80 ± 0.02[b]
17:0	1.25 ± 0.05[b]	0.23 ± 0.02[a]	1.24 ± 0.06[b]
16:3n-4	ND	0.27 ± 0.03[b]	0.08 ± 0.01[a]
16:3n-3	0.34 ± 0.03[a]	0.52 ± 0.04[b]	0.55 ± 0.02[b]
16:4n-3	0.44 ± 0.0[b]	0.16 ± 0.03[a]	0.14 ± 0.03[a]
anteiso 18:0	ND	ND	0.21 ± 0.02[a]
DMA 18:0	ND	ND	ND
16:4n-1	ND	0.20 ± 0.04[a]	0.21 ± 0.3[a]
18:0	19.04 ± 0.9[b]	18.8 ± 0.8[b]	7.2 ± 0.1[a]
18:1n-9	6.8 ± 0.5[a]	9.1 ± 0.7[b]	6.1 ± 0.5[a]
18:1n-7	1.95 ± 0.06[b]	0.51 ± 0.04[a]	5.5 ± 0.7[c]
18:1n-5	ND	ND	0.26 ± 0.04[a]
18:2n-6	1.02 ± 0.02[a]	1.04 ± 0.07[a]	1.18 ± 0.06[a]
DMA 19:0	ND	ND	ND
18:2n-4	0.19 ± 0.02[b]	0.05 ± 0.01[a]	0.17 ± 0.02[b]
19:0	0.41 ± 0.03[a]	0.37 ± 0.03[a]	0.83 ± 0.04[b]
19:1n-9	ND	0.06 ± 0.02[a]	0.05 ± 0.01[a]
18:3n-3	0.04 ± 0.01[a]	0.07 ± 0.01[a]	0.18 ± 0.02[b]
DMA 20:0	ND	ND	ND
20:0	1.17 ± 0.04[b]	0.92 ± 0.03[a]	1.98 ± 0.03[c]
20:1n-11	0.96 ± 0.08[a]	ND	2.39 ± 0.06[b]
20:1n-9	1.09 ± 0.03[b]	0.18 ± 0.02[a]	1.36 ± 0.06[c]
20:1n-7	0.30 ± 0.05[b]	0.17 ± 0.02[a]	0.80 ± 0.05[c]
20:1n-5	0.11 ± 0.02[a]	0.09 ± 0.01[a]	0.58 ± 0.03[b]
20::1NMID	ND	0.08 ± 0.01[a]	0.24 ± 0.02[b]
20:2n-6	ND	0.37 ± 0.02[a]	0.87 ± 0.05[b]
20:3NMIT	ND	0.06 ± 0.01[a]	0.40 ± 0.03[b]
20:3n-6	0.37 ± 0.03[b]	0.44 ± 0.03[b]	0.23 ± 0.02[a]
21:0	1.84 ± 0.06[c]	0.37 ± 0.02[a]	0.67 ± 0.06[b]
20:4n-6	1.91 ± 0.07[b]	0.20 ± 0.02[a]	18.3 ± 1[c]
21:1n-9	ND	0.15 ± 0.02 [a]	0.23 ± 0.02[b]
21:1n-7	ND	1.15 ± 0.06[b]	0.11 ± 0.01[a]
20:4n-3	1.91 ± 0.07[b]	0.28 ± 0.03[a]	ND
20:5n-3	1.44 ± 0.08[b]	0.06 ± 0.01[a]	20.3 ± 1[c]
22:0	3.69 ± 0.09[b]	5.03 ±0.14[c]	1.11 ± 0.03[a]
22:1n-11	0.63 ± 0.03[a]	ND	0.73 ± 0.06[a]
22:1n-9	5.2 ± 0.2[c]	0.52 ± 0.06[a]	1.14 ± 0.05[b]
22:1n-7	0.94 ± 0.07[a]	1.2 ± 0.1[b]	1.50 ± 0.07[c]
22:1n-5	0.11 ± 0.02[a]	0.12 ± 0.03[a]	0.13 ± 0.03[a]
22:2n-6	0.23 ± 0.03[a]	ND	0.30 ± 0.03[a]
22:3n-6	ND	ND	0.19 ± 0.02[a]
23:0	2.19 ± 0.08[c]	1.73 ± 0.04[b]	0.18 ± 0.03[a]
23:1n-9	1.65 ± 0.07[a]	1.58 ± 0.03[a]	2.86 ± 0.07[b]
23:1n-7	ND	ND	0.10 ± 0.02[a]
22:5n-6	ND	ND	0.12 ± 0.01[a]
23:5n-3	ND	ND	ND
23:5n-3	1.83 ± 0.09[c]	0.35 ± 0.03[a]	0.51 ± 0.03[b]
24:0	ND	1.74 ± 0.07[b]	0.42 ± 0.05[a]
22:6n-3	7.8 ± 0.2[c]	3.54 ± 0.09[b]	2.21 ± 0.08[a]
24:1n-9	0.25 ± 0.02[a]	14.21 ± 0.4[c]	3.4 ± 0.11[b]

(Table 3) contd.....

Fatty acids	MGDG	SG	SQDG
∑ n-9 HUFA	16 ± 1[a]	29 ± 1[b]	15 ± 1[a]
∑ BCFA	1.58 ± 0.08[a]	2.81 ± 0.07[c]	2.11 ± 0.04[b]
∑ SFA	56± 2[b]	56 ± 2[b]	22 ± 1[a]
∑ MUFA	23.15 ± 1.35[a]	33 ± 1[c]	29 ± 1[b]
∑ PUFA	18.5 ± 2[b]	7.7 ± 0.9[a]	46.1 ± 2[c]

Different superscript letters indicate a statistically significant difference (P<0.05). ND, not detected; HUFA, Highly monounsaturated fatty acids; BCFA, Branched-chain fatty acid; SFA, Saturated fatty acid; MUFA, Monounsaturated fatty acid; PUFA, Polyunsaturated fatty acid; NMID, non-methylene interrupted dienoic fatty acid; NMIT, nonmethylene interrupted trienoic fatty acid.

Fatty acids present in the SQDG at 5% or more of the total fatty acids were 16:0, 18:0, 18:1n-7, 18:1n-9, 20:4n-6 and 20:5n-3. SQDG contained significantly higher 20:4n-6 (arachidonic acid) and eicosapentaenoic acid (EPA, 20:5n-3), but lower oleic acid (18:1n-9) and docosahexaenoic acid (DHA, 22:6n-3), compared with those of MGDG and SG ($p < 0.05$). Moreover, among the PUFAs of sea cucumber, the level of EPA was higher than AA which was similar to the temperate *Euapta fraudatrix*, but the tropical *H. leucospilota* was just the opposite [44]. Arachidonic acid promotes the tissue repair, growth of skeletal muscle tissue and early neurological development [54]. Jais *et al.* (1992) [55] also reported that arachidonic acid plays an important role in blood clotting, thus providing wound healing properties. The high content of EPA and AA of sea cucumber may be associated with their self-repair ability.

In this study, a considerable amount of branched chain fatty acids (BCFA) was found in MGDG, SG and SQDG. It is well-known that Sea-bed sediments contain a high level of branched-chain fatty acids which are derived from microorganisms [56, 57]. The detritus is the major diet of the holothurians like sea cucumbers and branched fatty acids, which were detected in this study, are derived from this diet. BCFA play a vital role to increase the expression of anti-inflammatory cytokine IL-10 and protect against necrotizing enterocolitis (NEC) in the rat pup model [58].

Polyunsaturated fatty acids (PUFAs) found in MGDG, SG and SQDG were 18.5, 7.7 and 46.1%, respectively. Long-chain polyunsaturated fatty acids especially arachidonic acid (AA, 20:4n-6), eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) can reduce inflammation, cancer, and arthritis [59]. According to Jingjing Li *et al.* [60], intakes of longchain n-3 PUFAs are inversely co-related with the incidence of an inflammatory disease like asthma in American young adults.

CONCLUSION

As a result of this study, total lipids were relatively rich in dried sea cucumber, *A. japonicus*, and contained considerable content of BCFA, MUFA, PUFAs and n-9 HUFA. Moreover, some differences were observed in the fatty acid compositions among MGDG, SG and SQDG. Further investigation is required to understand the positional distribution of fatty acids and molecular species in MGDG, SG and SQDG in detail.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All experimental protocols were approved by Institutional Animal Care and Use Committee (IACUC) of the Gyeongsang National University, Republic of Korea.

HUMAN AND ANIMAL RIGHTS

No humans were used in the study. All experiments on animals were followed according to guidelines of the Institutional Animal Care and Use Committee (IACUC) of the Gyeongsang National University, Republic of Korea.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

All datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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