Lipid Class and Phospholipid Compositions of Sea Cucumber *Apostichopus japonicus* with Heat Pump-Decompression Hybrid Dryer and Hot Air Dryer

Anisuzzaman Md[1], Kamrunnahar Kabery[1], U-Cheol Jeong[1], Hyun-Chol Jung[2], Byeong-Dae Choi[1], Seok-Joong Kang[1*]

[1] Department of Marine Biology and Aquaculture, Gyeongsang National University, Tongyeong 53064, Republic of Korea.
[2] A1 Engineering Co., Ltd, Suncheon, 540856, Korea.

* Corresponding author. Tel.: +82. 55. 772. 9154; email: sjkang@gnu.ac.kr
Manuscript submitted April 16, 2019; accepted June 6, 2019.
doi: 10.17706/ijbbb.2019.9.4.210-221

Abstract: This study was carried out to determine the effect of heat pump-decompression hybrid dryer (HD, 55 ± 1°C) and commercial hot air dryer (CD, 80 ± 2°C) on the lipid class, phospholipid and fatty acid compositions of sea cucumber, *Apostichopus japonicus*. The results showed that the highest total lipids (4.38%), phospholipids (44.31%) and glycolipids (28.05%) were obtained in the hybrid dryer (HD) group sea cucumber. Phosphatidylcholine (PC) and phosphatidylethanolamine (PE) were the major phospholipids in both dried sea cucumber and the contents were 59.02%, 28.41% (HD) and 56.45%, 26.53% (CD) of total phospholipids (w/w), respectively. In both treatments, the major fatty acids of PE were 16:0, DMA 18:0, 18:0, 20:4n-6 and 20:5n-3. Total polyunsaturated fatty acids (PUFAs) of PE was 35.12% (HD dried sea cucumber), 26.60% (CD dried sea cucumber) higher than monounsaturated fatty acids 20.81% (HD dried sea cucumber), 19.86% (CD dried sea cucumber). In HD dried sea cucumber, PC contained much higher 20:4n-6 and EPA, but lower 18:1n-9 and 22:1n-9, compared with those of PI. The highest amount of branched chain fatty acids (BCFA) and polyunsaturated fatty acids (PUFA) were found in HD dried sea cucumbers compared to CD dried sea cucumbers. Comparing the two methods, hybrid dryer is better in terms of total lipid content, phospholipid and fatty acid compositions of sea cucumber.

Key words: Sea cucumber (*Apostichopus japonicus*), dryer, lipid class, phospholipids, fatty acid.

1. Introduction

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 aphrodisiac and curative properties [1]. Sea cucumbers are usually marketed as fresh, frozen, dried, cooked-dried, cooked-salted and cooked-salted-dried products [2], [3]. Sea cucumbers preferentially inhabit on muddy and sandy grounds, especially on the ocean and sea shores and consume the sea bottom sediment containing organic matter, including prozotoa, bacteria, diatoms, and detritus of plants or animals [4]-[9].

Sea cucumbers have many therapeutic effects with high protein and low lipid content and containing minerals and vitamins such as magnesium, iron, calcium, zinc, vitamin A, riboflavin, niacin and thiamine [10]-[17]. Sea cucumber extracts have many bioactive compounds and have antiviral, anti-cancer, antibacterial, anti-oxidant, anti-inflammation effects [18]-[22]. Lipids of sea cucumber play essential roles

in the metabolic activities of organisms [23], [24]. In particular, 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 [25], [26] and arachidonic acid is responsible for wound healing and blood clotting [27].

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 [28], [29]. The traditional sun drying method is mostly used for the preservation of 80% of the sea cucumbers harvested all over the world [10], [30]. In this method, sea cucumbers are cleaned, removed internal organs, gutted, cooled and sun dried [10]. This process is carried out at 18°C–25°C for 72–96 hr [30]. This traditional technique leads to many problems such as long processing time, pest invasions, loss of many active ingredients, oxidation of lipid, inadequate removal of water, and contamination during the process [29]-[32]. In order to get better quality dried sea cucumbers, heat pump-decompression hybrid dryer and hot air dryer are alternatives to sun drying methods. However, there are still no detailed chemical studies of the lipid class, phospholipid components and fatty acid compositions of PE, PC and PI. Therefore, this study was carried out to determine the effect of heat pump-decompression hybrid dryer and hot air dryer on the lipid class, phospholipid compositions of *A. japonicus* and analyze fatty acid compositions of PE, PC and PI.

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, 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 [10], [30]. After that, samples were divided into two groups for drying processing.

In the first of the two different drying processes used, *A. japonicus* samples were placed on 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. In the second method, the samples were placed on a hot air dryer (DY-1412, Dongyang Science Co., Ltd., Korea) at 80 ± 2°C. 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 phosphatidylethanolamine (PE), phosphatidylcholine (PC), phosphatidylinositol (PI) were purchased from Sigma (Gillingham, UK).

2.4. Total Lipid Extraction and Lipid Class Separation

Total lipids of sea cucumber were extracted according to the Bligh and Dyer method (1959) [33] by using 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 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, glycolipid (GL) and phospholipid (PL) in total lipid of sea cucumber.

80 mg of extracted total lipid were 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 [34]. Then, 30 mL of methanol was eluted through the cartridge, 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 Phospholipids

100 mg of phospholipid was dissolved in 1 mL of chloroform to adjust the sample concentration. The TLC plates (20 ×20 mm) were coated with silica gel G-60 were activated in a dry oven at 105 ° C for 60 min and then cooled in a desiccators. The prepared samples were applied to the TLC plates. An elution system consisting of chloroform: methanol: water 65:35:6 (v/v/v), was utilized for the separation of phospholipids [35]. 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).

2.6. Analysis of Fatty Acid Compositions

Methyl esters of the fatty acids contained in the PE, PC and PI were prepared as follows: 100 mg of lipid were put into a capped tube and added 1.5 ml 0.5 N NaOH-methanol solution. The sample was mixed by vortex and heated 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 into 2 ml iso-octane and fatty acids were analyzed via GC technique using gas chromatography (Clarus 600, Perkin Elmer, USA) equipped with 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 [36].

2.7. Statistical Analysis

All statistical analyzes were performed using the SPSS 16.0 program and one-way ANOVA test followed by Duncan's multiple rang test.

3. Results and Discussion

3.1. Lipid Content and Compositions

The total lipid content of sea cucumber, *A. japonicus* dried by hybrid dryer (HD) and commercial hot air dryer (CD) were 4.38 ± 0.51% and 3.81 ± 1.01% (% of dry weight) respectively. These values were 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 *Stichopus chloronotus* (4.56%), *Holothuria leucospilota* (7.16%) and *Abyssocucumis abyssorum* (9.00%) in both dried sea cucumber [37], [38]. Lipid composition of dried sea cucumber, *Apostichopus japonicus* are shown in Table 1. In HD dried sea cucumber, total lipids consisted of 27.64% neutral lipids and 72.36% polar lipids which comprised 28.05% of glycolipids and 44.31% of phospholipids. The total lipids comprised 37.34% of neutral lipids, 25.37% of glycolipids and 37.29% of phospholipids in CD dried sea cucumber. In both sample, 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%) [37].

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%) [39], [40].

The phospholipid compositions of dried sea cucumber, *A. japonicus* are shown in Table 2. In our study, the phospholipid contents of HD dried sea cucumber was much higher than that of CD dried sea cucumber. PC and PE were found as the major phospholipid class and the contents were 59.02%, 24.77% (HD dried), and 56.45%, 26.53% (CD dried) of total phospholipids (w/w), respectively. CL, PI, SM were minor components, which accounted for 2.73, 7.75, 2.09% (HD dried) and 4.85, 6.96, 5.21% (CD dried) of total phospholipids, respectively. Latyshev *et al*. (2009) [41] reported that phospholipid compositions of sea cucumber were similar to those of *Paralithodes camtschaticus* and *Chinoecetes japonicus*.

Table 1. Lipid Composition of Dried Sea Cucumber, *Apostichopus japonicus*

Lipid composition	HD	CD
	Content (%)	
Total lipid	4.38 ± 1.051[1]	3.81 ± 1.01[1]
Neutral lipids	27.64 ± 1.052[2]	37.34 ± 1.252[2]
Glycolipids	28.05 ± 1.422[2]	25.37 ± 1.312[2]
Phospholipids	44.31 ± 3.422[2]	37.29 ± 3.235[2]

HD: Sea cucumbers dried in hybrid dryer

CD: Sea cucumbers dried in commercial hot air dryer

[1]% of dry weight

[2]% of total lipids

Table 2. Phospholipid Composition of Dried Sea Cucumber, *Apostichopus japonicus*

Lipid class	HD	CD
	Content (%)	
Cardiolipin (CL)	2.73 ± 0.11	4.85 ± 0.15
Phosphatidylethanolamine (PE)	28.41 ± 0.76	26.53 ± 0.65
Phosphatidylinositol (PI)	7.75 ± 0.19	6.96 ± 0.35
Phosphatidylcholine (PC)	59.02 ± 0.85	56.45 ± 0.75
Spingomylin (SM)	2.09 ± 0.18	5.21 ± 0.24

HD: Sea cucumbers dried in hybrid dryer

CD: Sea cucumbers dried in commercial hot air dryer

3.2. Fatty Acid Compositions

The fatty acid compositions of PE, PC and PI in the dried sea cucmber, *A. japonicus* are shown in Table 3 (HD dried sea cucumber) and Table 4 (CD dried sea cucumber). In both dried sea cucumber, the principal fatty acids of PE were as below: 16:0, DMA 18:0, 18:0, 20:4n-6 (arachidonic acid [AA]) and 20:5n-3 (eicosapentaenoic acid [EPA]). Total polyunsaturated fatty acids (PUFAs) of total lipids was 35.12% (HD dried sea cucumber), 26.60% (CD dried sea cucumber) higher than monounsaturated fatty acids 20.81% (HD dried sea cucumber), 19.86% (CD dried sea cucumber). Moreover, among the PUFAs of sea cucumber,

the level of AA was much higher than EPA which was similar to the tropical *H. leucospilota*, but the temperate *Euapta fraudatrix* was just the opposite in both dried sea cucumber [37]. High content of EPA and AA of sea cucumber may be associated with their self-repair ability [12], [42].

Fatty acid compositions of PC and PI were also noticed in both dried sea cucumber *A. japonicus*. In both HD and CD dried sea cucumber, major fatty acids of PC were 16:0, 16:1n-9, 18:0, 18:1n-7, 20:4n-6 and 20:5n-3. The principal fatty acids of PI were as follows 16:0, 18:0, 18:1n-9, 20:4n-6, 20:5n-3, 22:1n-9 (HD dried sea cucumber) and 16:0, 18:0, 18:1n-9, 22: 1n-9 (CD dried sea cucumber). In HD dried sea cucumber, PC contained much higher 20:4n-6 (arachidonic acid) and EPA, but lower 18:1n-9 and 22:1n-9, compared with those of PI. n-9 highly unsaturated fatty acids (HUFA) of PI was 33.63% (HD sea cucumber), 29.47% (CD sea cucumber) completely outclassing that of PC. In this study, the highest amount of branched chain fatty acids (BCFA) and polyunsaturated fatty acids (PUFA) were found in HD dried sea cucumbers compared to CD dried sea cucumbers. 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 [43]. 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 the inflammation, cancer, and arthritis [44], [45]. According to Jingjing Li *et al*. (2013) [46] intakes of long chain n-3 PUFAs are inversely co-related with the incidence of inflammatory disease like asthma in American young adults. Our results showed that long-chain polyunsaturated fatty acids were significantly higher in HD dried sea cucumbers.

Table 3. Fatty Acid Compositions of PE, PI and PC of HD Dried Sea Cucumber, *Apostichopus japonicus*

Fatty acid	PE	PC	PI
iso 14:0	0.18 ± 0.02	0.21 ± 0.02	0.36 ± 0.03
14:00	0.64 ± 0.04	1.07 ± 0.05	2.01 ± 0.09
14:1n-9	0.19 ± 0.02	0.23 ± 0.03	0.58 ± 0.05
14:1n-7	0.19 ± 0.03	0.18 ± 0.02	0.37 ± 0.03
iso 15:0	0.16 ± 0.02	0.86 ± 0.09	0.16 ± 0.01
anteiso-15:0	0.09 ± 0.01	0.49 ± 0.06	0.19 ± 0.03
15:00	0.21 ± 0.02	0.06 ± 0.01	0.57 ± 0.03
15:1n-8	0.07 ± 0.01	0.28 ± 0.03	0.11 ± 0.02
15:1n-5	0.12 ± 0.02	0.06 ± 0.01	0.15 ± 0.02
iso 16:0	0.05 ± 0.01	0.21 ± 0.05	0.62 ± 0.04
DMA 16:0	0.19 ± 0.02	0.2 ± 0.03	ND
Pristanate	0.28 ± 0.02	0.08 ± 0.01	0.46 ± 0.04
16:00	7.92 ± 0.53	7.4 ± 0.66	17.88 ± 0.68
16:1n-9	0.27 ± 0.02	5.74 ± 0.57	0.73 ± 0.04
16:1n-7	0.99 ± 0.05	0.39 ± 0.02	1.77 ± 0.06
TME16:0	1.61 ± 0.02	0.43 ± 0.03	0.36 ± 0.02
16:1n-5	0.27 ± 0.02	0.27 ± 0.02	0.19 ± 0.02
anteiso 17:0	0.2 ± 0.03	0.08 ± 0.01	0.41 ± 0.02
DMA 17:0	0.12 ± 0.01	0.45 ± 0.06	ND
16:2n-4	0.44 ± 0.04	0.32 ± 0.03	0.16 ± 0.02
17:00	0.86 ± 0.07	1.06 ± 0.05	2.21 ± 0.09
16:3n-4	0.24 ± 0.03	0.09 ± 0.01	0.74 ± 0.08
16:3n-3	0.16 ± 0.02	0.11 ± 0.02	0.68 ± 0.06
16:4n-3	0.19 ± 0.03	0.16 ± 0.02	0.12 ± 0.02

anteiso 18:0	0.1 ± 0.03	0.15 ± 0.02	0.32 ± 0.03
DMA 18:0	21.96 ± 0.89	1.66 ± 0.05	ND
16:4n-1	0.23 ± 0.02	0.02 ± 0.01	ND
18:00	5.24 ± 0.35	8.2 ± 0.75	8.53 ± 0.66
18:1n-9	1.35 ± 0.06	3.63 ± 0.35	9.14 ± 0.85
18:1n-7	3.05 ± 0.07	7.24 ± 0.63	3.38 ± 0.25
18:1n-5	2.16 ± 0.05	0.07 ± 0.01	0.1 ± 0.02
18:2n-6	1.69 ± 0.06	0.26 ± 0.03	0.06 ± 0.01
DMA 19:0	0.42 ± 0.05	0.79 ± 0.05	ND
18:2n-4	0.24 ± 0.03	0.08 ± 0.01	0.46 ± 0.03
19:00	0.63 ± 0.04	0.99 ± 0.08	0.65 ± 0.04
19:1n-9	0.12 ± 0.02	0.04 ± 0.01	0.12 ± 0.01
18:3n-3	0.09 ± 0.01	0.17 ± 0.02	0.08 ± 0.01
DMA 20:0	0.13 ± 0.02	0.15 ± 0.01	ND
20:00	1.42 ± 0.06	1.72 ± 0.05	0.96 ± 0.07
20:1n-11	2.65 ± 0.05	1.22 ± 0.02	1.52 ± 0.08
20;1n-9	0.73 ± 0.03	1.82 ± 0.07	1.64 ± 0.06
20:1n-7	0.43 ± 0.04	1.31 ± 0.06	0.42 ± 0.08
20:1n-5	0.6 ± 0.05	0.39 ± 0.04	0.24 ± 0.03
20::1NMID	0.2 ± 0.02	0.26 ± 0.02	0.14 ± 0.02
20:2n-6	0.17 ± 0.02	0.42 ± 0.04	2.09 ± 0.12
20:3NMIT	0.45 ± 0.03	0.37 ± 0.03	0.22 ± 0.02
20:3n-6	0.08 ± 0.02	0.14 ± 0.01	ND
21:00	0.51 ± 0.04	0.53 ± 0.02	0.25 ± 0.03
20:4n-6	15.66 ± 0.53	9.61 ± 0.48	6.56 ± 0.78
21:1n-9	0.12 ± 0.02	0.06 ± 0.01	0.18 ± 0.02
21:1n-7	0.06 ± 0.01	0.04 ± 0.01	0.11 ± 0.02
20:4n-3	0.06 ± 0.01	0.28 ± 0.02	ND
20:5n-3	12.64 ± 0.67	22.53 ± 0.95	6.11 ± 0.87
22:00	0.81 ± 0.04	0.89 ± 0.05	0.79 ± 0.02
22:1n-11	0.62 ± 0.03	0.63 ± 0.02	0.24 ± 0.02
22:1n-9	0.45 ± 0.48	1.25 ± 0.08	19.21 ± 1.31
22:1n-7	1.13 ± 0.07	1.6 ± 0.04	0.5 ± 0.05
22:1n-5	1.07 ± 0.05	0.15 ± 0.01	0.14 ± 0.02
22:2n-6	0.26 ± 0.03	0.18 ± 0.02	0.3 ± 0.03
22:3n-6	0.45 ± 0.04	0.04 ± 0.01	0.21 ± 0.02
23:00	0.11 ± 0.01	0.51 ± 0.03	0.14 ± 0.02
23:1n-9	1.8 ± 0.09	1.72 ± 0.08	1.11 ± 0.05
23:1n-7	0.05 ± 0.01	0.09 ± 0.01	0.32 ± 0.03
22:5n-6	0.99 ± 0.06	0.86 ± 0.08	0.11 ± 0.02
23:5n-3	0.23 ± 0.01	0.68 ± 0.02	0.36 ± 0.02
24:00	0.09 ± 0.01	0.23 ± 0.03	0.24 ± 0.04
22:6n-3	1.78 ± 0.07	4.48 ± 0.35	1.3 ± 0.06

24:1n-9	1.33 ± 0.06	2.11 ± 0.07	0.92 ± 0.03
∑ n-9HUFA	6.36	16.6	33.63
∑ BCFA	2.34	3.88	1.9
∑ SFA	17.93	22.13	33.98
∑ MUFA	20.81	31.38	43.3
∑ PUFA	35.12	40.09	17.92

HD, Sea cucumbers dried in hybrid dryer; ND, not detected; HUFA, Highly unsaturated fatty acids; BCFA, Branc hed chain fatty acid; SFA, Saturated fatty acid; MUFA, Mono unsaturated fatty acid; PUFA, Poly unsaturated fatty acid; PE, Phosphatidylethanolamine; PC, Phosphatidylcholine; PI, Phosphatidylinositol.

Table 4. Fatty Acid Compositions of PE, PI and PC of CD Dried Sea Cucumber, *Apostichopus japonicus*

Fatty acid	PE	PC	PI
iso 14:0	0.11 ± 0.02	0.15 ± 0.03	0.3 ± 0.01
14:00	1.39 ± 0.06	2.11 ± 0.09	3.15 ± 0.52
14:1n-9	0.16 ± 0.02	0.17 ± 0.03	0.52 ± 0.05
14:1n-7	0.18 ± 0.01	0.17 ± 0.02	0.35 ± 0.03
iso 15:0	0.11 ± 0.02	0.75 ± 0.11	0.13 ± 0.02
anteiso-15:0	0.06 ± 0.01	0.42 ± 0.04	0.13 ± 0.02
15:00	1.21 ± 0.41	1.06 ± 0.05	1.57 ± 0.22
15:1n-8	0.07 ± 0.02	0.28 ± 0.03	0.11 ± 0.02
15:1n-5	0.11 ± 0.03	0.07 ± 0.01	0.14 ± 0.02
iso 16:0	0.04 ± 0.01	0.17 ± 0.03	0.55 ± 0.05
DMA 16:0	0.15 ± 0.03	0.17 ± 0.02	ND
pristanate	0.22 ± 0.02	0.08 ± 0.01	0.42 ± 0.12
16:00	9.92 ± 0.99	9.41 ± 0.89	19.81 ± 1.45
16:1n-9	0.24 ± 0.02	4.74 ± 0.62	0.65 ± 0.02
16:1n-7	0.92 ± 0.06	0.25 ± 0.01	1.51 ± 0.42
TME16:0	1.42 ± 0.09	0.35 ± 0.02	0.29 ± 0.04
16:1n-5	0.27 ± 0.02	0.25 ± 0.05	0.19 ± 0.01
anteiso 17:0	0.19 ± 0.02	0.08 ± 0.02	0.37 ± 0.02
DMA 17:0	0.11 ± 0.02	0.41 ± 0.03	ND
16:2n-4	0.41 ± 0.03	0.28 ± 0.02	0.13 ± 0.01
17:00	2.51 ± 0.18	2.17 ± 0.21	3.54 ± 0.64
16:3n-4	0.21 ± 0.03	0.07 ± 0.01	0.68 ± 0.15
16:3n-3	0.13 ± 0.02	0.08 ± 0.01	0.61 ± 0.05
16:4n-3	0.15 ± 0.02	0.14 ± 0.01	0.11 ± 0.02
anteiso 18:0	0.08 ± 0.02	0.13 ± 0.01	0.28 ± 0.02
DMA 18:0	20.76 ± 2.12	1.98 ± 0.05	ND
16:4n-1	0.23 ± 0.02	0.02 ± 0.01	ND
18:00	6.24 ± 0.86	9.22 ± 1.02	9.53 ± 1.52
18:1n-9	1.01 ± 0.06	2.63 ± 0.22	8.14 ± 1.14
18:1n-7	3.15 ± 0.41	7.21 ± 0.82	3.35 ± 0.45
18:1n-5	2.89 ± 0.08	1.07 ± 0.05	1.12 ± 0.07
18:2n-6	1.51 ± 0.08	0.23 ± 0.03	0.06 ± 0.02

DMA 19:0	0.38 ± 0.06	0.72 ± 0.02	ND
18:2n-4	0.21 ± 0.02	0.06 ± 0.01	0.41 ± 0.12
19:00	1.63 ± 0.06	1.99 ± 0.15	1.65 ± 0.22
19:1n-9	0.07 ± 0.02	0.01 ± 0.01	0.09 ± 0.02
18:3n-3	0.07 ± 0.02	0.15 ± 0.04	0.06 ± 0.02
DMA 20:0	0.13± 0.02	0.15 ± 0.02	ND
20:00	2.42 ± 0.15	2.72 ± 0.12	1.96 ± 0.42
20:1n-11	2.65 ± 0.42	1.22 ± 0.07	1.52 ± 0.09
20:1n-9	0.72 ± 0.03	1.74 ± 0.12	1.55 ± 0.08
20:1n-7	0.45 ± 0.04	1.35 ± 0.08	0.46 ± 0.07
20:1n-5	0.62 ± 0.03	0.42 ± 0.07	0.25 ± 0.02
20:1NMID	0.17 ± 0.01	0.18 ± 0.02	0.14 ± 0.02
20:2n-6	0.14 ± 0.02	0.38 ± 0.04	2.01 ± 0.05
20:3NMIT	0.43 ± 0.04	0.34 ± 0.03	0.19 ± 0.02
20:3n-6	0.04 ± 0.02	0.09 ± 0.01	ND
21:00	1.31 ± 0.05	1.34 ± 0.04	1.08 ± 0.06
20:4n-6	12.11 ± 2.02	6.25 ± 1.25	3.42 ± 0.18
21:1n-9	0.08 ± 0.02	0.04 ± 0.01	0.14 ± 0.02
21:1n-7	0.06 ± 0.02	0.04 ± 0.01	0.11 ± 0.02
20:4n-3	0.06 ± 0.01	0.24 ± 0.02	ND
20:5n-3	8.85 ± 1.02	18.53 ± 1.42	2.25 ± 0.05
22:00	1.82 ± 0.06	1.89 ± 0.09	1.78 ± 0.08
22:1n-11	0.62 ± 0.04	0.63 ± 0.05	0.24 ± 0.02
22:1n-9	0.41 ± 0.03	1.18 ± 0.09	17.11 ± 1.89
22:1n-7	1.25 ± 0.08	1.69 ± 0.12	0.59 ± 0.07
22:1n-5	1.07 ± 0.09	0.15 ± 0.02	0.14 ± 0.02
22:2n-6	0.24 ± 0.04	0.12 ± 0.02	0.24 ± 0.03
22:3n-6	0.39 ± 0.02	0.02 ± 0.01	0.16 ± 0.02
23:00	1.15 ± 0.08	1.49 ± 0.09	1.14 ± 0.05
23:1n-9	1.12 ± 0.07	1.63 ± 0.09	1.02 ± 0.06
23:1n-7	0.05 ± 0.02	0.09 ± 0.02	0.32 ± 0.05
22:5n-6	0.91 ± 0.04	0.78 ± 0.05	0.05 ± 0.02
23:5n-3	0.16 ± 0.03	0.59 ± 0.06	0.25 ± 0.02
24:00	0.11 ± 0.02	0.25 ± 0.02	0.28 ± 0.03
22:6n-3	1.16 ± 0.04	4.09 ± 0.25	1.4 ± 0.03
24:1n-9	0.78± 0.02	1.12± 0.05	0.25 ± 0.02
∑ n-9HUFA	4.59 ± 0.92	13.26 ± 0.62	29.47 ± 1.02
∑ BCFA	2.03 ± 0.22	3.43 ± 0.19	1.66 ± 0.09
∑ SFA	28.4 ± 1.11	32.31 ± 2.02	44.41 ± 2.12
∑ MUFA	19.86 ± 0.02	28.93 ± 0.15	39.92 ± 1.24
∑ PUFA	26.6 ± 0.85	31.88 ± 1.02	10.55 ± 0.09

CD, Sea cucumbers dried in commercial hot air oven dryer; ND, not detected; HUFA, Highly unsaturated fatty acids; BCFA, Branched chain fatty acid; SFA, Saturated fatty acid; MUFA, Mono unsaturated fatty acid; PUFA, Poly unsaturated fatty acid; PE, Phosphatidylethanolamine; PC, Phosphatidylcholine; PI, Phosphatidylinositol.

4. Conclusion

As a result of this study, it was determined that total lipid content, phospholipid and fatty acid compositions of sea cucumber change depending on the dryer. It was determined that total lipids, branched chain fatty acids (BCFA) and polyunsaturated fatty acids (PUFAs) were relatively abundant in the sea cucumber, *A. japonicus* dried by hybrid dryer (HD) compared to commercial hot air dryer (CD). Between two methods, hybrid dryer is better in terms of total lipid content, phospholipid and fatty acid compositions of sea cucumber.

Acknowledgement

This study was supported by "Development of 10 HP Hybrid (Decompression Type-Heat Pump System) Dryer for Drying of Marine Products (Sea Cucumber, Oyster)" from the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (Grant No. 10067058).

References

[1] Lovatelli, A., Conand, C., Purcell, S., Uthicke, S., Hamel, J., & Mercier, A. (2004). Advances in sea cucumber aquaculture and management. *FAO Fisheries Technical Paper,* 425-463. FAO Rome, Italy.

[2] Chang, L., Price, M. V., & Lampila, L. E. (1989). Effect of processing on proximate composition and mineral content of sea cucumbers (*Parastichopus* spp.). *Journal of Food Science, 54,* 567–572.

[3] FAO. (2009). A-1 fish, crustaceans, molluscs, etc. *Fisheries Statistics 2007*, 27. Rome.

[4] Yingst, J. Y. (1976). The utilization of organic matter in shallow marine sediments by an epibenthic deposit-feeding holothurian. *Journal of Experimental Marine Biology and Ecology, 23,* 55–69.

[5] Moriarty, D. J. W. (1982). Feeding of *Holothuria atra* and *Stichopus chloronotus* on bacteria, organic carbon and organic nitrogen in sediments of the great barrier reef. *Australian Journal of Marine and Freshwater Research, 33,* 255–263.

[6] Zhang, B. L., Sun, D. L., & Wu, Y. Q. (1995). Preliminary analysis on the feeding habit of *Apostichopus japonicus* in the rocky coast waters off Lingshan Island. *Marine Science, 3,* 11–13.

[7] Feng, J., Jong-Kuk, C., U-Cheol, Jeong., Anisuzzaman, M., Chung-Ho, R., Byeong-Dae, C., & Seok-Joong, K. (2016). Effects of fermented fecal solid diets on growth of the sea cucumber *Apostichopus japonicus*. *Korean Journal of Fisheries and Aquatic Science, 49,* 161-167.

[8] Anisuzzaman, M., U-Cheol, Jeong., Feng, J., Jong-Kuk, C., Kamrunnahar, K., Da-In, L., Hak-Sun, Y., & Seok-Joong, K. (2017). Effects of different algae in diet on growth and interleukin (IL)-10 production of juvenile sea cucumber *Apostichopus japonicus*. *Fisheries and Aquatic Science, 20,* 1-8.

[9] Anisuzzaman, M., Feng, J., U-Cheol, Jeong., Jong-Kuk, C., Hak-Sun, Y., Da-In, L., & Seok-Joong, K. (2018). Effects of *nannochloropsis* concentration in diet on growth, survival and anti-inflammatory cytokine (interleukin-10) production of the sea cucumber *Apostichopus japonicus*. *Turkish Journal of Fisheries and Aquatic Science, 18*, 567-575

[10] Cakli, Ş, Cadun, A., Kişla, D, & Dincer, T. (2004). Determination of quality characteristics of *Holothuria tubulosa*, (Gmelin, 1788) in Turkish sea (Aegean Region) depending on sun drying process step used in Turkey. *Journal of Aquatic Food Product Technology*, *13(3),* 69–78.

[11] Chen, J. (2005). Present status and prospects of sea cucumber industry in China. *FAO Fisheries Technical Paper, 1,* 25–38.

[12] Fredalina, B. D., Ridzwan, B. H., Abidin, A. Z., Kaswandi, M. A., Zaiton, H., Zali, I., & Jais, A. M. (1999). Fatty acid compositions in local sea cucumber. *General Pharmacology: The Vascular System, 33(4),* 337–340.

[13] Bordbar, S., Anwar, F., & Saari, N. (2011). High-value components and bioactive from sea cucumbers for functional foods: A review. *Marine Drugs, 9,* 1761–805.

[14] Guo, Y., Ding, Y., Xu, F., Liu, B., Kou, Z., Xiao, W., & Zhu, J. (2015). Systems pharmacology-based drug discovery for marine resources: An example using sea cucumber (Holothurians). *Journal of Ethnopharmacology, 165,* 61–72.

[15] Feng, J., Anisuzzaman, M., U-Cheol, J., Jong-Kuk, C., Hak-Sun, Y., Seung-Wan, K., & Seok-Joong, K. (2016). Comparison of fatty acid composition of wild and cultured sea cucumber *Apostichopus japonicus*. *Korean Journal of Fisheries and Aquatic Science, 49,* 474-485.

[16] Vergara, W., & Rodríguez, A. (2016) Nutritional composition of sea cucumber *Isostichopus* sp. *Natural Reserach, 7(03),* 130.

[17] Anisuzzaman, M., U-Cheol, J., Feng, J., Kamrunnahar, K., Jong-Kuk, C., Da-In, L., Hak-Sun, Y., & Seok-Joong, K. (2018). Effects of *Ulva lactuca* and *Laminaria japonica* algae in prepared feeds on growth, survival, fatty acid compositions and Interleukin (IL)-10 production of sea cucumber *Apostichopus japonicus*. *International Journal of Fisheries & Aquatic Studies, 6(2),* 387-395.

[18] Esmat, A. Y., Said, M. M., Soliman, A. A., El-Masry, K. S., & Badiea, E. A. (2013). Bioactive compounds, antioxidant potential, and hepatoprotective activity of sea cucumber (*Holothuria atra*) against thioacetamide intoxication in rats. *Nutrition, 29,* 258–267.

[19] Farshadpour, F., Gharibi, S., Taherzadeh, M., Amirinejad, R., Taherkhani, R., Habibian, A., & Zandi, K. (2014). Antiviral activity of *Holothuria* sp. a sea cucumber against herpes simplex virus type 1 (HSV-1). *European Review for Medical and Pharmacological Sciences, 18,* 333–337.

[20] Kiani, N., Heidari, B., Rassa, M., Kadkhodazadeh, M., & Heidari, B. (2014). Antibacterial activity of the body wall extracts of sea cucumber (Invertebrata; Echinodermata) on infectious oral streptococci. *Journal of Basic and Clinical Physiology and Pharmacology, 1,* 1–7.

[21] Wijesinghe, W. A., Jeon, Y. J., Ramasamy, P., Wahid, M. E., & Vairappan, C. S. (2013). Anticancer activity and mediation of apoptosis in human HL-60 leukaemia cells by edible sea cucumber (*Holothuria edulis*) extract. *Food Chemistry, 139,* 326–331.

[22] Lee, D. I., Park, M. K., Kang, S. A., Anisuzzaman, M., U-Cheol, J., Feng, J., Seok-Jeong, K., Lee, J. Y., & Yu, H. S. (2018). Sea cucumber lipid-soluble extra fraction prevents ovalbumin-induced allergic airway inflammation. *Journal of Medicinal Food*, *21(1)*, 21–29

[23] Sargent, J. R., Tocher, D. R., & Bell, J. G. (2002). The lipids. *Fish Nutrition, 181-257*. Elsevier (Academic Press), San Diego, California.

[24] Tocher, D. R. (2003). Metabolism and functions of lipids and fatty acids in teleost fish. *Reviews in Fisheries Science, 11,* 107–184.

[25] Harper, C. R., & Jacobson, T. A. (2005). Usefulness of omega-3 fatty acids and the prevention of coronary heart disease. *The American Journal of Cardiology*, *96*, 1521–1529.

[26] Roynette, C. E., Calder, P. C., Dupertuis, Y. M., & Pichard, C. (2004). n-3 polyunsaturated fatty acids and colon cancer prevention. *Clinical Nutrition, 23,* 139–151.

[27] Jais, A. M. M., Mcculloch, R., & Croft, K. (1994). Fatty acid and amino acid composition in haruan as a potential role in wound healing. *General Pharmacology, 25,* 947–950.

[28] Conand, C. (1990). The fishery resources of pacific island countries. Part 2: Holothurians, FAO. *Fisheries Technical Paper.*

[29] Duan, X., Zhang, M., Mujumdar, A.. S., & Wang, S. J. (2010). Microwave freeze drying of sea cucumber *Stichopus japonicus*. *Journal of Food Engineering, 96,* 491-7.

[30] Li, C., Li, H., Guo, S., Li, X., & Zhu, X. (2018). Evaluation of processing methods on the nutritional quality of sea cucumber (*Apostichopus japonicus* Selenka). *Journal of Aquatic Food Product Technology, 27(4),*

406–417.

[31] Moon, J. H., Kim, M. J., Chung, D. H., Pan, C. H., & Yoon, W. B. (2014). Drying characteristics of sea cucumber (*Stichopus japonicus* Selenka) using far infrared radiation drying and hot air drying. *Journal of Food Processing and Preservation, 38(4),* 1534–1546.

[32] Chong, N. V., Pindi, W., Chye, F. Y., Shaarani, S. M., & Lee, J. S. (2015). Effects of drying methods on the quality of dried sea cucumbers from Sabah — A review. *International Journal of Novel Research in Life Sciences, 2(4),* 49–64.

[33] Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology, 37,* 911-917.

[34] Stephane, N., Francine, E. A., Jacques, P., & Jacques, N. (2004). Separation and quantification by high performance liquid chromatography with light scattering detection of the main wheat flour phospholipids during dough mixing in the presence of phospholipase. *Journal of Chromatography A, 10471,* 77-83.

[35] Nasopoulou, C., Nomikos, T., Demopoulos, C. A., & Zabetakis, I. (2007). Comparison of antiatherogenic properties of lipids obtained from wild and cultured sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*). *Food Chemistry, 100,* 560-567.

[36] Ackman, R. G. (1969). Temperature effects in the calculation of equivalent chain length values for multiple-branched fatty acid esters and ketones on polar and non-polar open tubular columns. *Journal of Chromatography A, 42,* 170-175.

[37] Svetashev, V. I., Levin, V. S., & Lam, C. N. (1991). Lipid and fatty acid composition of Holothurians from tropical and temperate waters. *Comparative Biochemistry and Physiology B, 98,* 489–494.

[38] Drazen, J. C., Phleger, C. F., & Guest, M. A. (2008). Lipid, sterols and fatty acid composition of abyssal holothurians and ophiuroids from the north-east Pacific Ocean: Food web implication. *Comparative Biochemistry and Physiology B, 151,* 79–87.

[39] Jeanne, D. J. (1979). Lipid composition of marine and Estuarine invertebrates: Porifera and cnidaria. *Progress in Lipid Research, 18,* 1-30.

[40] Gilles, B., AurElie, C. M., & Gaetane, W. C. (2014). Glycolipids from Marine Invertebrates. *Wiley-vch verlag gmbh & co kgaa, 1,* 99-161.

[41] Latyshev, N. A., Kasyanov, S. P., & Kharlamenko, V. I. (2009). Lipids and fatty acids of edible crabs of the north-western Pacific. *Food Chemistry, 116,* 657–661.

[42] Zhong, Y., Khan, M. A., & Shahidi, F. (2007). Compositional characteristics and antioxidant properties of fresh and processed sea cucumber (*Cucumaria frondosa*). *Journal of Agricultural Food Chemistry, 55,* 1188–1192.

[43] Ran-Ressler, R. R., Glahn, R. P., Bae, S., & Brenn, J. T. (2013). Branched-chain fatty acids in the neonatal gut and estimated dietary intake in infancy and adulthood. *Nestle Nutrition Institute Workshop Series, 77,* 133–143.

[44] Harper, C. R., & Jacobson, T. A. (2005). Usefulness of omega-3 fatty acids and the prevention of coronary heart disease. *The American Journal of Cardiology*, *96*, 1521–1529.

[45] Roynette, C. E., Calder, P. C., Dupertuis, Y. M., & Pichard, C. (2004). n-3 polyunsaturated fatty acids and colon cancer prevention. *Clinical Nutrition, 23,* 139–151.

[46] Jingjing, L., Pengcheng, X., Daisy, Z., Akshay, S., Kiang, L., Martha, D., Carlos, I., David, J. J. James, M. S., & Ka, H. (2013). Intakes of long-chain omega-3 (n-3) PUFAs and fish in relation to incidence of asthma among American young adults: The CARDIA study. *The American Journal of Clinical Nutrition, 97,* 173–178.

Anisuzzaman Md received the B.Sc. and M.Sc. degrees from Bangladesh Agricultural University and the PhD degree in marine biology and aquaculture from Gyeongsang National University, Republic of Korea, in 2007, 2009 and 2018 respectively. He is currently working as an associate professor in Noakhali Science and Technology University, Bangladesh. His research focuses on the nutrition, lipid analysis, feed formulation, biology, sea cucumber culture, aquaculture.

Kamrunnahar Kabery was born in Bangladesh on September 21, 1992. She got the bachelor of agriculture from Bangladesh Agricultural University in 2015; the master degree in marine biology and aquaculture from Gyeongsang National University, Republic of Korea, in 2019. Her research focuses on the moina culture, fatty acid analysis, food waste treatment.

U-Cheol Jeong received the B.Sc. and M.Sc. leading PhD degree in marine biology and aquaculture from Gyeongsang National University, Republic of Korea, in 2005 and 2009 respectively. He is currently working as a research professor in Gyeongsang National University, Republic of Korea. His research on interest includes marine biology, aquaculture, n-3 PUFA, eel farming.

Hyun-Chol Jung received the B.Sc. and M.Sc in materials science & metallurgical engineering from Sunchon National University, Republic of Korea, in 2007 and 2009 respectively. He is studying forwards a doctoral degree in bio-nano system engineering, Chonbuk National University now. He is currently working as a senior researcher in A1 Engineering Co., Ltd, Suncheon, Korea. His research focuses on the nano technology, hybrid dryer.

Seok-Joong Kang received the BSc, MSc and Ph.D. from Pukyong National University, Republic of Korea, in 1980, 1982 and 1986. He worked at Gyeongsang National University (GNU), Rep. of Korea, as a professor. His research interests include fatty acid analysis, fish feed formulation, aquaculture & fish nutrition, sea cucumber and moina culture, recirculating aquaculture system (RAS).