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The Lipid Composition Profiles as Contributed by the Whole Organism, Flesh and Shell of *Pandalus borealis* Shrimp and their Nutritional Values

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Abstract

The lipid compositions were determined in the body parts (whole organism, flesh and shell) of *Pandalus borealis* shrimp on a dry weight basis. Crude fat varied from 0.80 - 1.31 g/100 g, SFA was 18.3 - 19.6% of total fatty acids, MUFA was 39.2 - 40.6%, PUFA varied from 39.8 - 42.0%, total unsaturated fatty acids varied from 80.4 - 81.7% and PUFA/SFA ranged from 2.04 - 2.29. Among the sterols, cholesterol was the only significant sterol with a value range of 44.7 - 57.3 mg/100 g or 99.9942 - 99.9965%. In the phospholipids lecithin (phosphatidylcholine) was the highest in all the shrimp samples with values of 47.6 - 70.7 mg/100 g (48.6 - 55.8%). The results of these quality parameters were close in values: MUFA/SFA (2.08 - 2.19), PUFA/SFA (2.04 - 2.29), Σn-6/Σn-3 (1.27 - 1.38), EPA + DHA (16.7 - 18.5), EPSI (0.9321 - 1.02), C16: 0: C18:1 cis-9 (0.6080 - 0.6882), % C16:0 in Σ SFA (52.9 - 61.3), % C18:0 in ΣSFA (38.4 - 47.0) and ΣUFA (80.4 - 81.7). The quality parameters make *Pandalus borealis* a source of nutritionally health friendly lipids.

Keywords: *Lipids Composition; Pandalus borealis Body Parts*

Abbreviations

FAs: Fatty Acids; LDL: Low Density Lipoprotein; SFA: Saturated Fatty Acid; MUFA: Monounsaturated Fatty Acid; CV: Coefficient of Variation; LA: Linoleic Acid; ALA (α-LA): Alpha-Linolenic Acid; AA: Arachidonic Acid; EPA: Eicosapentaenoic Acid; DHA: Docosahexaenoic Acid; PUFA: Polyunsaturated Fatty Acid; GLA: Gamma-Linolenic Acid; DGLA: Dihomo-Gamma-Linolenic Acid; EPSI : Essential PUFA Status Index; HDL: High Density Lipoprotein; TC: Total Cholesterol; LC: Long – Chain; VLC: Very –Long- Chain; rxy; Correlation Coefficient; Rxy: Regression Coefficient; SD: Standard Deviation; CA: Coefficient of Alienation; IFE: Index of Forecasting Efficiency; r_{xy}^2: Coefficient of Determination (variance), TAG: Triacylglycerol; GC: Gas Chromatography; FID: Flame Ionisation Detector; PFPD: Pulse Flame Photometric detector.

Introduction

Shrimp is used to refer to some decapod crustaceans, although the exact animals covered can vary. In a broader perspective, the word shrimp may be used to cover any of the groups with elongated bodies and a primarily swimming mode of locomotion-chiefly Caridea and Dendrobranchiata. However, the term may be restricted to Caridea or to smaller species of either group, or to only the marine species. In a broader definition, shrimp may be used synonymously with prawn, covering stalk-eyed swimming crustaceans with long narrow muscular tails (abdomens), long whiskers (antennae) and slender legs [1]. They swim by paddling with swimmerets on the underside of their abdomens. Crabs and lobsters have strong walking legs, whilst shrimps have thin fragile legs used primarily for perching [2].

Specifically, shrimps are swimming crustanceans with long narrow muscular abdomens and long antennae with well-developed pleopods (swimmerets and slender walking legs; which are adapted for swimming than walking). It was the distinction between walking and swimming that formed the primary taxonomic division into the former suborders of Natantia and Reptantia. Members of the Natantia (shrimp) were adapted for swimming while the Reptantia (crabs, lobsters, etc.) were adapted for crawling or walking [3]. Other groups also have common names which include the word "shrimp" [4]; any small swimming crustacean resembling a shrimp is also called a shrimp [2].

Shrimps are widespread, being found near the seafloor of most coasts, estuaries, rivers and lakes. There are numerous species, each being adapted to particular habitat [2]. Most shrimp species are marine, although about a quarter of them are found in fresh water [5]. Marine species live at depths of up to 5,000 metres (16,000 ft) [6], and can be found from the tropics to the polar regions. Their lifespan ranges between one to seven years.

Most shrimps are omnivorous, although some are specialized for particular modes of feeding: like some being filter feeders [using their setose (bristly) legs as a sieve]; some scrape algae from rocks; and some cleaner shrimps feed on the parasites and necrotic tissue of the reef fish they groom [6]. On the other hand, shrimps are eaten by various animals, particularly fish and seabirds, and frequently host bopyrid parasites [6]. Shrimps play important roles in the food chain being important food sources for larger animals from fish to whales. The muscular tails of shrimp can be delicious to eat, hence, they are widely caught and farmed for human consumption.

Shrimps of commercial interest belong to the suborder Natantia. The FAO had earlier determined the categories and terminology used in the reporting of global fisheries defining a shrimp as a "decapod crustacean of the suborder Natantia" [7]. According to the Codex Alimentarius Commission of the FAO and WHO: The term shrimp (which includes the frequently used term prawn) refers to the species covered by the most recent edition of FAO listing of shrimp, FAO Species Catalogue, Volume 1, Shrimps and prawns of the world, an annotated catalogue of species of interest to fisheries FAO Fisheries Synopsis No. 125 [8]. On the other hand, the Species Catalogue says the highest category it deals with is the suborder Natantia of the order Crustacea Decapoda to which all shrimps and prawns belong [9].

The species for this study is the Northern prawn, *Pandalus borealis* Krøyer, 1838. PANDL, Pandal 1. *Pandalus borealis* Kroyer, 1838, Naturhist. Tidsskr, 2:254 [10]. Synonymous names are: *Dymas typus* Krøyer, 1861; *Pandalus borealis typica* Retovsky, 1946. Other FAO names are: Northern shrimp (En), Crevette nordique (Fr), Camarón norteпo (Sp). *Pandalus borealis* has been widely fished since the early 1900s in Norway, and later in other countries following Johan Hjort's practical discoveries of how to locate them. They have a short lifespan which leads to a variable stock on a yearly basis. They are not considered overfished. Habitat: Depth 20 to 1380 m [11]. Bottom clay and mud and it is marine [12]. Size: Maximum total length 120 mm (♂), 165 mm (♀) [9].

Most literature information on the lipid profiles in *Pandalus borealis* had been based on *P. borealis* larvae. They included the followings. Ouellet., *et al*. [13] studied lipid condition on the survival in shrimp (*Pandalus borealis*) larvae. Groups of shrimp (*P. borealis*) larvae were reared under different food concentrations and types to assess changes in condition and survival during development. The triacyglycerol (TAG) content of larvae accumulated rapidly during the initial phase of intermoult followed by a decline to a minimum coincident with ecdysis. Differences among experiments in the magnitude of the mortality (from 0.86 to 4.66% d^{-1}) at the first moult were related to the proportion of larvae in poor TAG condition. The results are consistent with the concept that the TAG condition index can be used to forecast, on a relative basis, different survival among larval groups.

Pederson and Storm [14] determined lipid class and fatty acid compositions in shrimp larvae (*Pandalus borealis* and *P. montagui*) collected along transects across banks on the West Greenland shelf in June 1999, May and July 2000. The lipid class contents were investigated as indices of larval shrimp lipid condition and food type. Fatty acid compositions were investigated for lipid biomarkers to establish tropic relationships between larval shrimp and potential prey. This study supports the hypothesis forwarded by Anderson [15] that year-class strength variability of Pandalus mainly is determined during the pelagic larval phase by bottom-up processes and variability in the

timing of zooplankton production. The determination of the distribution and lipid composition of *Pandalus* shrimp larvae in relation to hydrography in West Greenland waters was carried out by Pedersen [16]. The abundance and distribution of shrimp larvae were studied along four transects off West Greenland in June – July 1996. The study was a first attempt to investigate shrimp larvae distribution and lipid composition in relation to hydrography in West Greenland waters. Such studies could be important to achieve better recruitment predictions for both species of *Pandalus* (*P. borealis* and *P. montagui*).

However, total lipid content, and lipid and fatty acid composition of *Pandalus borealis* from Balsfjord, northern Norway were estimated by Hopkins., *et al*. [17] to study growth and feeding relationships. Variations in total lipid content (g of lipid, and as % of wet and dry body weights) of *Pandalus borealis*, ranging from eggs to 52 mo old adults, indicate that lipid growth exhibits marked seasonal oscillations while growth in carapace length shows only comparatively weak seasonality. Their findings thus emphasise that *Pandalus borealis* in Balsfjord preys primarily on pelagic organisms. The seasonal pelagic production cycle, both in terms of quantity and quality, strongly influences the deposition and mobilization of the prawns' lipid reserves. The lipid percentage of *P. borealis* is, however, less than that of herbivorous zooplankton but substantially greater than that of the lipid-deficient benthos. This establishes the fact that these lipids reach the fish via the food web. From the above, more work needs to be done to establish the lipid profiles of *Pandalus borealis* as a food source.

Shrimps, caught from fresh, marine and brackish waters and ponds of various types, are becoming delicacies in Nigeria. They are eaten either whole (shell + flesh) after drying or as flesh alone (when fresh). Not much information is available on the chemical composition of shrimps found in Nigeria. The purpose of this paper is to document and give available background information on *Pandalus borealis* Krøyer, 1838 and to provide data on the lipid profiles of the whole shrimp, its flesh (endoskeleton) and its shell (exoskeleton) which could be included in food composition and nutrition tables.

Materials and Methods

Collection and Treatment of Samples Before Analyses

Wet samples were collected from trawler catches from Idumota (along the Lagos Atlantic Ocean). The shrimps were washed briefly with distilled de-ionised water to remove any adhering contamination, drained under folds of filter paper and identified. Samples were collected in crushed ice in insulated containers and brought to the laboratory for preservation prior to analyses. The washed shrimps were wrapped in aluminium foil and frozen at -4°C for 1 - 3 days before analyses were carried out.

Samples Preparation for Analyses

On removal from the freezer, samples were identified (from the University Zoology Department), defrosting occurred for about one hour, whole shrimps were beheaded and outer shells removed. The various parts were dried at 105°C and blended in a blender. The three distinct samples were whole organism (head + flesh + shell), flesh (endoskeleton only) and shell (head + body shell). Two shrimp samples were used to constitute one group sample.

Crude Fat Determination

About 0.25g of each aliquot was weighed into the extraction thimble and the fat extracted with petroleum ether (40 - 60°C boiling range) using a Soxhlet apparatus [18]. The extraction lasted 5 - 6h.

Preparation of Fatty Acid Methyl Esters (FAMEs) and Analyses

The crude fat extracted was converted to the methyl ester using the boron trifluoride method [19]. The gas chromatographic conditions for the analysis of fatty acid methyl easters were as follows:

GC: HP 5890 powered with HP ChemStation rev. A09.01[1206] software;

- injection temperature: split injection; split ratio: 20:1;
- carrier gas: nitrogen; inlet temperature: 250°C;
- column type: HP INNOWAX; column dimensions: 30 m × 0.25 mm × 0.25 µm; oven program: initial temperature at 60°C: first ramping at 10°C/min for 20 min (260°C), maintained for 4 min; second ramping at 15°C/min for 4 min (320°C), maintained for 10 min.
- detector; flame ionization detector (FID); detector temperature: 320°C; hydrogen pressure: 22 psi; compressed air: 35 psi.

The peaks were identified by comparison with standard fatty acid methyl esters.

Analyses of Sterols

The sterol analysis was as described by AOAC [20]. The aliquots of the extracted fat were added to the screw-capped test tubes. The samples were saponified at 95°C for 30 min using 3 ml of 10% KOH in ethanol to which 0.20 ml of benzene had been added to ensure miscibility. Deionised water (3 ml) was added and 2 ml of hexane was used in extracting the non- saponifiable materials. Three extractions, each with 2 ml of hexane were carried out for 1h, 30 min and 30 min respectively to achieve complete extraction of the sterols. The hexane was concentrated to 1 ml in the vial for gas chromatography analysis and 1 µl was injected into the injection pot of GC. The gas chromatography conditions of analysis were similar to the GC conditions for methyl ester analyses. The peaks were identified by comparison with standard sterols.

Analyses of Phospholipids

Modified method of Raheja., *et al*. [21] was employed in the analysis of the extracted oil phospholipids content determination. The gas chromatography conditions for the analysis of phospholipids were as follows:

GC: HP 5890 powered with HP ChemStation rev. A09.01[1206] software;

- injection temperature: split injection; split ratio: 20:1;
- carrier gas: nitrogen; inlet temperature: 250°C;
- column type: HP5; column dimensions: 30 m × 0.25 mm × 0.25 µm; oven program: initial temperature at 50°C: first ramping at 10°C/min for 20 min (250°C), maintained for 4 min; second ramping at 15°C/min for 4 min (310°C), maintained for 5 min.
- detector: pulse flame photometric detector (PFPD); detector temperature: 320°C; hydrogen pressure: 20 psi; compressed air: 30 psi.

Quality Assurance

For the purpose of ensuring the accuracy of the results obtained, the following actions were carried out: standard chromatograms were prepared for sterols, phospholipids and fatty acids methyl esters which were then compared with respective analytical results; calibration curves were prepared for all the standard mixtures and correlation coefficient determination for each fatty acid parameter (36), same for sterols (7) and phospholipids (5). Correlation coefficient should ≥ 0.95 for the result to be acceptable. It is a statistical index that shows the quality assurance of the calibration curve performed. It was performed with the Hewlett Packard Chemistry (HPCHEM) software. Fatty acids were listed with the chain length and double bond numbers. At the data source and reference database levels, values for individual fatty acids are usually expressed as percentages of total fatty acids since this is the most common form of analytical presentation. (It was used here.) At the user data base level, values per 100g of food are required. At all levels of data management both modes of

expression are useful for comparative evaluation. A conversion factor derived from the proportion of the total lipids present as fatty acids is required [22] for converting percentages of total fatty acids to fatty acids per 100 g of food. (This was not done in this report because no conversion factor to convert crude fat to fatty acids was available for shell fish).

Statistical Analysis

Statistical analysis [23,24] was carried out to determine mean, standard deviation (SD), coefficient of variation in percent (CV %). Also calculated were linear correlation coefficient (r_{xy}), coefficient of determination (r_{xy}^2), linear regression coefficient (R_{xy}), coefficient of alienation (CA) and index of forecasting efficiency (IFE). The r_{xy} was subjected to the table (critical) value at $r_{=0.05}$ to see if significant differences existed in the values of the fatty acids, sterols and phospholipids in the body parts of *P. borealis*.

Results and Discussion

Results

Table 1 shows the crude fat and total energy levels of the shrimp samples on dry weight basis. The values between the three samples were relatively close with the coefficient of variation of 25.7.

Parameter	Whole organism	Flesh	Shell	Mean	SD	CV%
Crude fat (g/100 g)	1.30	1.31	0.80	1.14	0.292	25.7
Energy (kJ/100 g)	48.1	48.5	29.6	42.1	10.8	25.7

Table 1: *Crude fat and total energy levels of whole organism, flesh and shell parts (dry weight) of Pandalus borealis.*

SD: Standard Deviation; CV%: Coefficient of Variation

Both the saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid of the samples are shown in Table 2. The following members were in traces in the three samples: C12:0, C14:0, C20:0, C22:0, C24:0, C14:1n-9, cis, C24:1n-15, cis, C18:1n-6, trans and C18:1n-9, trans whereas the following had values of 0.00% each: C6:0, C8:0, C10:0 and C18:1n-11, trans. The coefficient of variation percent (CV%) ranged from low to high values (1.82 - 84.3). The bulk of the SFA came from C16:0 and C18:0 with values of 10.2-11.2% (CV% = 5.21) in C16:0 and 7.01-9.19% (CV% = 13.7) in C18:0. The other minor contributors to the SFA were C12:0 (0.0181 - 0.0466%) and C14:0 (0.0101 - 0.0178%). Total SFA values ranged as 18.3 - 19.6% and CV% of 3.45 showing that SFA values were close. The SFA values showed that the results followed this trend: whole organism < flesh < shell.

Fatty acid	Whole organism	Flesh	Shell	Mean	SD	CV%
C6:0	-	0.00	0.00	0.00	0.00	0.00
C8:0	0.00	0.00	0.00	0.00	0.00	0.00
C10:0	0.00	0.00	0.00	0.00	0.00	0.00
C12:0	0.0276	0.0466	0.0181	0.0308	0.0145	47.2
C14:0	0.0155	0.0178	0.0101	0.0145	0.0040	27.3
C16:0	11.2	10.2	10.3	10.6	0.5508	5.21
C18:0	7.01	8.62	9.19	8.27	1.13	13.7
C20:0	0.0002	0.0001	0.0001	0.0001	0.0001	43.3
C22:0	0.0002	0.0001	0.0001	0.0001	0.001	43.3
C24:0	0.00002	0.00002	0.00002	0.00002	0.00	0.00
SFA	18.3	18.8	19.6	18.9	0.6521	3.45
C14:1n-9, cis	0.00003	0.00002	0.00002	0.00002	0.00001	26.6
C16:1n-9, cis	4.63	4.17	3.69	4.16	0.4700	11.3
C18:1n-6, cis	6.77	6.45	5.12	6.11	0.8756	14.3
C18:1n-9, cis	18.4	14.8	15.9	16.4	1.87	11.5
C20:1n-11, cis	9.99	13.5	15.9	13.1	2.97	22.6
C22:1n-13, cis	0.1803	0.2621	0.0119	0.1514	0.1276	84.3
C24:1n-15, cis	0.00002	0.00002	0.00002	0.00002	0.00	0.00
MUFA (cis)	40.0	39.2	40.6	39.9	0.7251	1.82
C18:1n-6, trans	0.00008	0.00005	0.00005	0.00006	0.00002	27.1
C18:1n-9, trans	0.00007	0.00004	0.00005	0.00005	0.00001	27.1
C18:1n-11, trans	0.00	0.00	0.00	0.00	0.00	0.00
MUFA (trans)	0.00015	0.00009	0.0001	0.0001	0.00003	28.4
MUFA (total)	40.0	39.2	40.6	39.9	0.7251	1.82

Table 2: *Saturated and monounsaturated fatty acid composition of the body parts of Pandalus borealis (% total fatty acids)*

SFA: Saturated Fatty Acid; MUFA: Monounsaturated Fatty Acid

Table 3 contains the various concentrations of PUFA n - 6 and n - 3 fatty acids. The Table shows both long - chain (LC) and very long chain (VLC) fatty acids (LC, 18 and VLC, 20 - 24) carbon atoms. The major polyunsaturated fatty acids found in the samples were linoleic acid (LA) (C18:2 cis-9, 12), arachidonic acid (AA) (C20:4 cis-5, 8, 11, 14), γ-linolenic acid (GLA) (C18:3 cis-6, 9, 12), docosadienoic acid (C22:2 cis-13, 16), eicosapentaenoic acid (EPA) (C20:5 cis-5, 8, 11, 14, 17) and docosahexaenoic acid (DHA) (C22:6 cis-4, 7, 10, 13, 16, 19); very low values came from alpha-inolenic acid (ALA) (C18:3 cis-9, 12, 15), eicosatrienoic acid (C20:3 cis-11, 14, 17), dihomo-γ- linolenic acid (DGLA) (C20:3 cis-8, 11, 14) and eicosadienoic acid (C20:2 cis-11, 14). For the major PUFA:LA had values of 18.0 - 19.0% (CV% = 2.94); GLA had levels of 0.1584 - 0.2422% (CV% = 22.1); AA had values of 4.45 - 5.02% (CV% = 6.02): docosadienoic acid had values of 0.0959 - 0.3355% (CV% = 55.2); DHA had values of 8.88 - 11.4% (CV% = 12.8); EPA had values of 5.80 – 8.87% (CV% = 21.1). The ALA was very low at 0.00008 - 0.0002% and CV% of 40.2. The pattern of concentration of n - 6 PUFA in the samples followed the reverse trend observed in SFA as whole organism > flesh > shell; in the n - 3 PUFA, the trend was whole organism < flesh > shell which is also the reverse as observed in the MUFA profiles. This last trend was observed in the total n-6 + n-3 PUFA (whole organism < flesh > shell).

Fatty acid	Whole organism	Flesh	Shell	Mean	SD	CV%
C18:2n-6, cis	19.0	18.2	18.0	18.4	0.5398	2.94
C18:3n-6, cis	0.2422	0.1833	0.1584	0.1946	0.0431	22.1
C20:2n-6, cis	0.00003	0.00002	0.00002	0.00002	0.00001	26.4
C20:3n-6, cis	0.0004	0.0006	0.0003	0.0004	0.0002	43.8
C20:4n-6, cis	4.45	5.02	4.80	4.75	0.2863	6.02
C22:2n-6, cis	0.3355	0.0959	0.2194	0.2169	0.1198	55.2
n-6 PUFA (cis)	24.0	23.5	23.1	23.5	0.4424	1.88
C18:2n-6 cis, trans	0.00009	0.00006	0.00006	0.00007	0.00002	26.9
n-6 PUFA (total)	24.0	23.5	23.1	23.5	0.4424	1.88
C18:3 n-3	0.0002	0.00008	0.0001	0.0001	0.00005	40.2
C20:3n-3	0.0001	0.00008	0.00009	0.0001	0.00003	26.9
C20:5n-3	8.87	7.16	5.80	7.28	1.54	21.1
C22:6n-3	8.88	11.4	10.9	10.4	1.33	12.8
n-3 PUFA (total)	17.8	18.5	16.7	17.7	0.9104	5.15
n-6 +n-3 PUFA	41.8	42.0	39.8	41.2	1.18	2.86

Table 3: *PUFA n-6 and n-3 fatty acid composition of the body parts of Pandalus borealis (% total fatty acids).*

PUFA: Polyunsaturated Fatty Acid (Essential Fatty Acid).

Some quality parameters of the fatty acids of the samples as compiled from Tables 2 and 3 are shown in Table 4. Parameters that were highly comparable in the shrimp samples were: MUFA/SFA [2.08-2.19; CV % of 3.11]; PUFA/SFA [2.04-2.29; CV % of 5.98]; EPA/DHA [0.5315-0.9994; CV % of 34.3]; Σ n-6/Σn-3 [1.27-1.38; CV % of 4.55]; EPA + DHA [16.7-18.5 %; CV % of 5.15]; EPSI [0.9321-1.02; CV % of 4.59] and Σ UFA (MUFA + PUFA) [80.4-81.7%; CV % of 0.8041].

Parameter	Whole organism	Flesh	Shell	Mean	SD	CV%
MUFA/SFA	2.19	2.08	2.08	2.11	0.0658	3.11
PUFA/SFA	2.29	2.23	2.04	2.18	0.1307	5.98
EPA/DHA	0.9994	0.6297	0.5315	0.7202	0.2467	34.3
n-6/n-3 (LA/α-LA)	107814	232929	156092	165612	63098	38.1
Σn-6/Σn-3	1.35	1.27	1.38	1.33	0.0606	4.55
AA/DGLA	11376	8051	18731	12719	5465	43.0
EPA +DHA	17.8	18.5	16.7	17.7	0.9105	5.15
ESPI(MUFA/PUFA)	0.9577	0.9321	1.02	0.9695	0.0445	4.59
C16:0:C18:1cis-9	0.6080	0.6882	0.6515	0.6492	0.0401	6.18
C18:0:C18:1 cis-9	0.3696	0.5763	0.5788	0.5082	0.1201	23.6
% C16:0 in ΣSFA	61.3	53.9	52.9	56.0	4.59	8.19
% C18:0 in ΣSFA	38.4	45.8	47.0	43.7	4.66	10.7
ΣUFA=(MUFA+PUFA)	81.7	81.2	80.4	81.1	0.6521	0.8041
EFA	100	100	100	100	0.00	0.00

Table 4: *Some quality parameters of the fatty acids of Pandalus borealis body parts extracted from Tables 2 and 3.*

ΣUFA: Total Unsaturated Fatty Acid; EPSI: Essential PUFA Status Index; ΣFA: Total Fatty Acid

Table 5 shows the levels of the various phospholipids. The concentration level of the phospholipids was close at 97.8-131 mg/100 g with CV% of 15.1 and ratio concentration of whole organism: flesh (1.00:0.96), whole organism: shell (1.00:1.28) and flesh: shell (1.00:1.34). Phosphatidylcholine (PC or lecithin) was the most concentrated phospholipid in the three samples forming levels of (mg/100 g): 70.1 (or 55.8%) in whole organism, 70.7 (53.8%) in flesh and 47.6 (48.6%) in shell.

Phospholipid	Whole organism (%)	Flesh (%)	Shell (%)	Mean	SD	CV%
Cephalin (PE)	26.9 (21.4)	25.7 (19.6)	22.7 (23.2)	25.1	2.15	8.58
Lecithin (PC)	70.1 (55.8)	70.7 (53.8)	47.6 (48.6)	62.8	13.2	21.0
Ptd-L-Ser (PS)	27.2 (21.6)	33.3 (25.3)	26.2 (26.7)	28.9	3.84	13.3
Lysophosphatidyl-choline (LPC)	2.99e-2 (0.0238)	5.82e-2 (0.04436)	8.01e-3 (0.0082)	3.21e-2	0.0252	78.5
PtdIns (PI)	1.50 (1.19)	1.64 (1.25)	1.39 (1.42)	11.5	0.1229	8.15
Total	126	131	97.8	118	17.9	15.1
Ratio	Whole org : flesh 1.00 : 0.96	Whole org : shell 1.00: 1.28	Flesh : shell 1.00: 1.34	-	-	-

Table 5: *Phospholipid levels (mg/100g) of the body parts of Pandalus borealis.*

PE: Phosphatidylethanolamine; Lecithin: Phosphatidylcholine; PS: Phosphatidylserine; PI: Phosphatidylinositol

We have the sterol levels of the samples in Table 6. The level of cholesterol ranged from 40.5 - 57.3 mg/100g or ratio of 1.00:1.28, 1.00:1.41 and 1.00:1.10. Of these total level of the sterols, cholesterol occupied a level of 99.9936-99.9965 % meaning that cholesterol was the main sterol of the samples.

Sterol	Whole organism	Flesh	Shell
Cholesterol	57.3 (99.9965%)	44.7 (99.9942%)	40.5 (99.9936%)
Cholestanol	2.65e-4	3.95e-4	3.95e-4
Ergosterol	2.94e-4	7.45e-4	7.45e-4
Campesterol	9.16e-4	9.30e-4	9.30e-4
Stig-masterol	0.00	0.00	0.00
5-Avenasterol	4.34e-4	4.36e-4	4.36e-4
Sitosterol	6.96e-5	7.42e-5	7.42e-5
Total	57.3	44.7	40.5
Ratio	Whole org : flesh 1.00 : 1.28	Whole org : shell 1.00: 1.41	Flesh : shell 1.00: 1.10

Table 6: *Sterol levels (mg/100g) of the body parts of Pandalus borealis.*

Discussion

The present crude fat values were close to the values in *Oreochromis niloticus* (0.23 - 2.25 g/100 g) [25] but better than in Tongue sole fish (0.03 - 0.36 g/100g) [26]. The low values of the crude fat in the samples shows that they exhibited the behaviour of white fish in terms of lipid content.

SFA with C12:0, C14:0 and C16:0 are known to be the primary contributors to elevated blood cholesterol, and so contribute to cardio-vascular diseases; C14:0 being the major culprit. SFA with 12, 14, or 16 carbons generally constitute about 25% of the total fat in animal foods. In the present report, all the samples C12:0, C14:0 and C16:0 constituted just about 11.24% (whole organism), 10.26% (flesh) and 10.33% (shell); each of them being lower than the minimum usual value of 25% in animals. C18:0 is also thought to increase the risk of cardiovascular diseases; this negative effect is probably due in part to an increase in blood clotting [27]. However, C18:0 may not be as hypercholesterolemic as the other SFA (apparently because it is converted to oleic acid) [28]. The pathways of fatty acid metabolism have been reviewed by Mead and Kayama [29]. Fish are able to synthesise *de novo* from acetate, and the even-chain SFA. Radio tracer studies have shown that fish can convert C16:0 to the omega -7 monoene and C18:0 to omega-9 monoene.

The C16:0 is by far the most prevalent (usually) SFA in our diet and is present to some degree in essentially all fats. C16:0 range in the present report was 46.9-61.2% showing its pre-eminence in total SFA. Considering the influence on the lipoprotein profile, 16:0 is intermediate, that is, it can be neutral when placed on a triglycerides molecule with PUFA, MUFA or 18:0, or cholesterol-raising when attached along with 12:0 + 14:0. In high amounts, 16:0 can even raise TC and LDL when substituted for 18:0, MUFA or PUFA in people who already have elevated TC or who eat large amounts of cholesterol. Accordingly, the general advice has been to remove as much SFA from the diet as possible [30]. However, Enig and Fallon [31] had enumerated many important roles in the body chemistry:

- Saturated fatty acids constitute at least 50% of the cell membranes, giving the cells necessary stiffness and integrity.
- They play a vital role in the health of our bones. For calcium to be effectively incorporated into the skeletal structure, at least 50% of the dietary fats should be saturated.
- They lower Lp (a), a substance in the blood that indicates proneness to heart disease. They protect the liver from alcohol and other toxins, such as Tylenol.
- They enhance the immune system.

- They are needed for the proper utilization of essential fatty acids. Elongated omega-3 fatty acids are better retained in the tissues when the diet is rich in SFA.
- Saturated 18-carbon stearic acid and 16-carbon palmitic acid are the preferred foods for the heart, which is why the fat around the heart muscle is highly saturated. The heart draws on this reserve of fat in times of stress.
- Short-and medium-chain saturated fatty acids have important antimicrobial properties. They protect us against harmful microorganisms in the digestive tract.

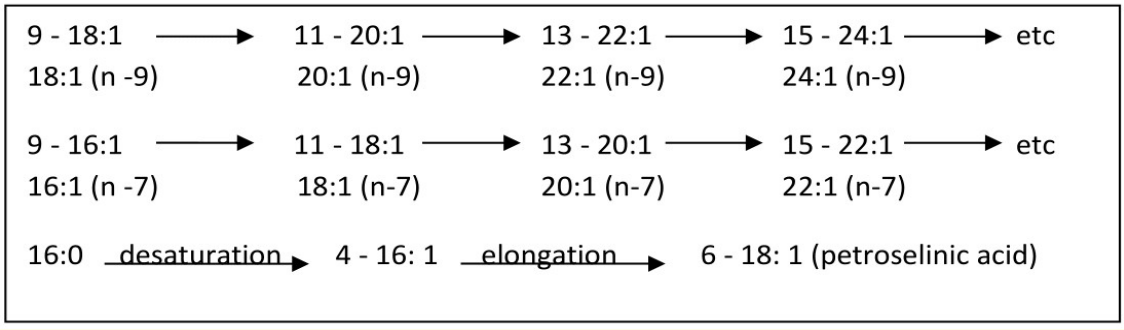
Among MUFA, the most concentrated monounsaturated fatty acid was C18:1 n-9, cis in all the three samples with values range of 14.8 - 18.4% with low CV% of 11.5. This was very closely followed by C20:1 n-11, cis with values range of 9.99 - 15.9% with higher CV% of 22.6. The usual second highest concentrated MUFA among fatty acids (FAs) is C18:1 n-6, cis, it is occupying the third position in this report having values range of 5.12 - 6.77% and CV% of 14.3. Another significant MUFA in the results was C16:1n-9, cis having values of 3.69 - 4.63% with CV% of 11.3. Both C24:1n-15, cis, C22:1n-13, cis and C14:1n-9, cis contributed very little to the overall MUFA values. All the MUFA (trans, total) were in traces with total range of 0.00009 - 0.00015% and CV% of 28.4. Trans fats are not useful in our diet. Like saturated fats, they are relatively stable. They do not go rancid easily and hence can be used in cooking. The MUFA most commonly found in our food is oleic acid, the main component of olive oil as well as the oils from almonds, pecans, cashews, peanuts and avocados. 16-carbon palmitoleic acid has strong antimicrobial properties; it is found almost exclusively in animal fats; it spanned a range of 9.09 - 11.6% in the total MUFA values. The pattern of MUFA concentration in the samples was: whole organism > flesh < shell, a reverse case in flesh as seen in SFA.

Oleic acid [9c-18:1 or 18:1(n-9)] is by far the most abundant monoenoic fatty acid in plant and animal tissues, both in structural lipids and in depot fats. Olive oil contains up to 78% oleic acid, and it is believed to have especially valuable nutritional properties as part of the Mediterranean diet. It has a number of important biological properties, both in the free and esterified form. Oleic acid is the biosynthetic precursor of a family of fatty acid with the (n-9) terminal structure and with chain-lengths of 20-24 or more. Petroselinic acid (6c-18:1) occurs up to a level of 50% or more in seed oils of Umbelliferae family, including carrot, parsley and coriander. *In vitro* studies by Weber., *et al*. [32] revealed that triacylglycerols containing petroselinoyl [18:1 (n-12)] moieties are hydrolysed by pancreatic lipase at much lower rates than other triacylglycerols. Consumption of coriander (*Coriandrum sativum*) oil, compared with other oils, led to significantly greater liver weights. However, no significant differences were observed among the groups fed with various levels of oleic acid in body weight, the weights of heart, liver, kidneys, spleen or testes, lipid content of heart or total-cholesterol, HDL-cholesterol and triacyglycerol concentrations of blood plasma. Ingestion of coriander oil on the other hand led to the incorporation of 18:1 (n-12) into heart, liver and blood lipids and to a significant reduction in the concentration of arachidonic acid in the lipids of hearts, liver and blood with a concomitant increase in the concentration of linoleic acid compared with results for the other groups. The Weber., *et al*. [32] data show that petroselinic acid from dietary triacylglycerols is absorbed by rats as readily as oleic acid, but the former reduces the concentration of arachidonic acid in tissue lipids which suggests [in view of earlier studies (Mohrhauer., *et al.* 33)] petrolenic acid mediated inhibition of arachidonic acid synthesis. C16:1 is also found in rich amounts in macadamia nut, olive, canola and peanut oils. C16:1 is beneficial in reducing bad cholesterol (LDL) and it behaves like a saturated and not as unsaturated fatty acid in its effect on HDL-cholesterol [34]. It also reduces the fat deposition in blood vessels and blood clot formation [35]. Gadoleic acid -trivial name for cis-icos-9-enoic acid, (20:1 n-11) is a common if minor constituent of animal tissues and fish oils [present in marine oils (from fish or sea mammals)], often accompanied by the 13-isomer. It is also found in rapeseed oil and seed oils of related species. Erucic acid (C22:1 cis-13) is a fatty acid that is apparently responsible for a favourable response of persons with nervous system disorders [36]. The administration of erucic acid in the diet reduces the serum levels and brain accumulation of a very-long-chain of saturated fatty acids (such as C26:0) responsible for demyelination [37,38].

Accumulation of certain long-chain fatty acids is associated with degenerative diseases of the central nervous system, such as behenic acid (C22:0, 0.001 - 0.0002%, very low insignificant value here) but about 1.0% in beef fat [39] and lignoceric acid (24:0, 0.0002%; in each sample; very low insignificant value here) but about 1.0% in beef fat as well as that of the unsaturated members of C22:1 (0.0119 -

0.2621% and C24:1(0.00002% in each sample) [39]. Accumulation occurs because enzymes needed to maintain turnover of those fatty acids are lacking [40]. Behenic acid has been found to be a cholesterol-raising SFA factor in humans [41]. When the MUFA values were compared to the literature values, the followings were observed where the literature values are from *Acanthurus montoviae* and *Lutjanus goreensis* fish (marine fish) [42]: C16 :1n - 9, cis (5.90 - 6.55%, literature; 3.69 - 4.63%,present); C18:1n-6, cis (5.82 - 6.51%, literature; 5.12 - 6.77%, present); C18:1n - 9, cis (10.9 - 18.2%, literature; 14.8 - 18.4, present) and C20 : 1n - 11, cis (1.29 - 11.7%, literature; 9.99 - 15.9%, present); these results were highly comparable.

The production of longer chain fatty acids of the n - 9 family and n - 7 family as well as the production of petroselinic acid are shown below (Scheme 1).



Scheme 1.

The essential fatty acids affect the fluidity, flexibility and permeability of the membranes, they are the precursor of the eicosanoids, are necessary for maintaining the impermeability barrier of the skin and are involved in cholesterol transport and metabolism. Knowledge of the significance of the long - chain PUFA of the n-3 type, particularly EPA and DHA, for human health has increased considerably since the 1970s [43,44]. As is well known they are abundant in fish oils [45]. This is demonstrated in the samples. The n-6 series are derived from LA and the n-3 series from ALA. Physiologically more important than these parent fatty acids are their elongated and desaturated derivatives of metabolites. While the desaturation steps (especially the first one) tend to be slow, the elongation steps proceed rapidly.

Many health disorders are linked with an undesired overproduction of eicosanoids [46]. These are hormone-like compounds which include prostaglandins, thromboxanes and leukotrienes. Several eicosanoids originate from AA which can be synthesised from LA. By virtue of their competitive inhibition in the enzyme systems, fatty acids of n-3 type especially EPA and DHA, can slow down the eicosanoid overproduction and thus prevent or cure health disorders (Figure 1) [46]. This can further be explained as shown in Figure 2 from FAO/WHO [47]. Saturated fatty acids and monounsaturated fatty acids can be biosynthesised from carbohydrates and proteins. Unsaturated fatty acids may be substrates for desaturases and elongases, as shown in the scheme for conversion in the n-9, n-6 and n-3 families of fatty acids [47,48]. The first members of each fatty acid family (oleic, linoleic and α-linoleic acid) compete for the same 6-desaturase, with rates of conversion increasing with the number of double bonds. This rate-limiting enzyme is under the control of many dietary and hormonal factors [49,50] and is believed to be important in the synthesis of 22:6n-3. Such an effect may explain why high intakes of linoleic acid reduce the level of 22:6n-3. Similarly, the 5-desaturase is modulated by dietary and hormonal factors. The C20 and C22 members of the n-6 and n-3 families can inhibit desaturation earlier in the sequence of fatty acid conversion [51]. It will appear that the 4-desaturation does not involve another specific desaturase, but an elongation, then 6-desaturase, both microsomal processes, followed by retroconversion

by the peroxisomal β-oxidation pathway [52]. The desaturation is thus a process based on intracellular cooperation. The activities of the elongases appear to be greater than those of desaturases [53].

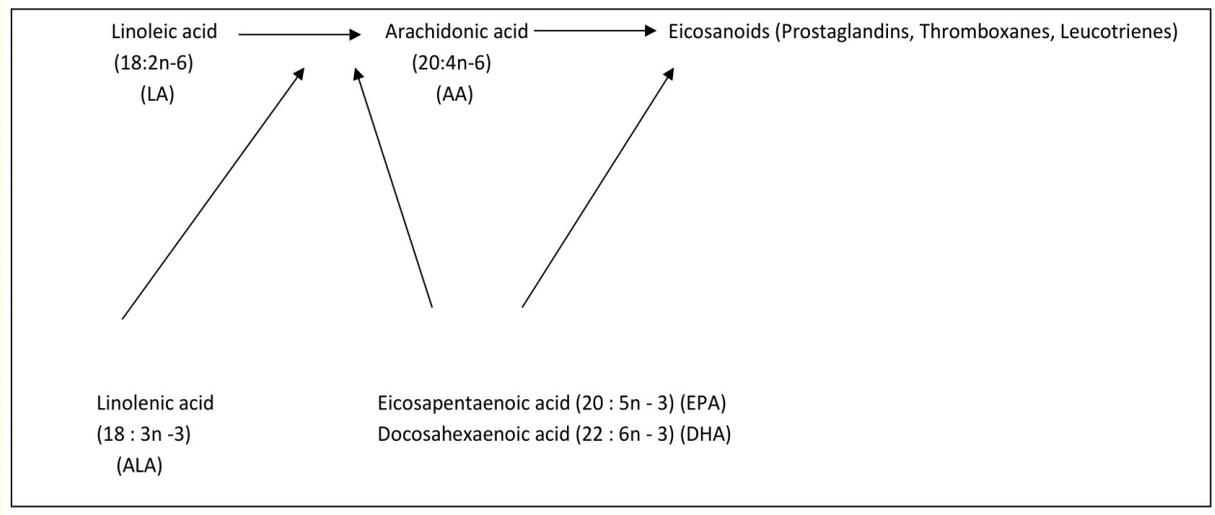


Figure 1: *Competition between n - 3 and n - 6 polyunsaturated fatty acids can slow down the eicosanoid formation [46].*

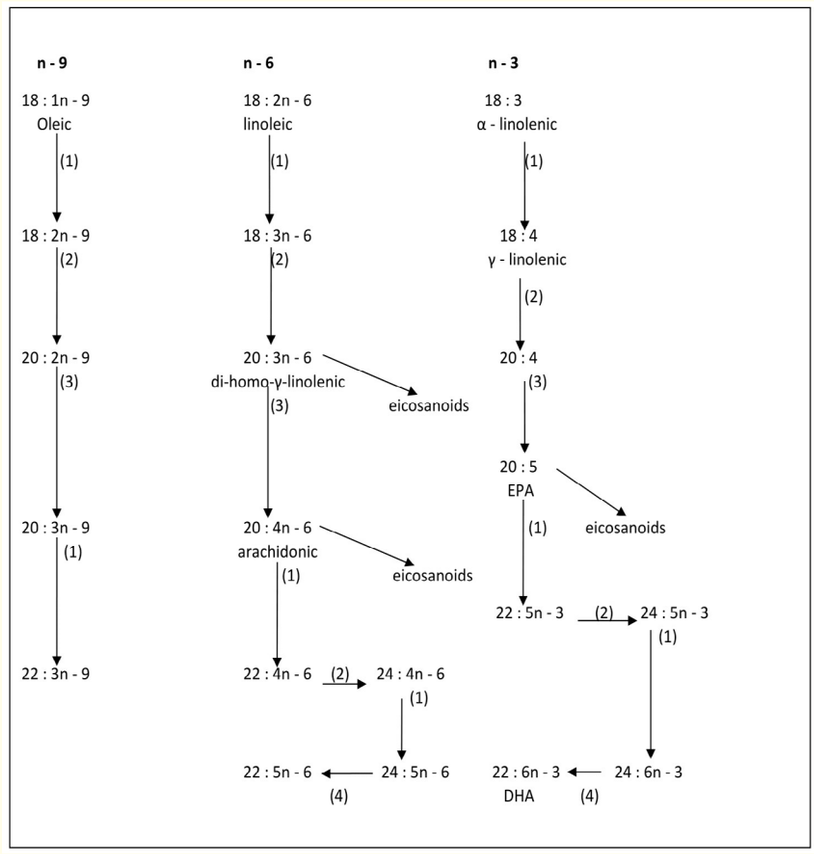


Figure 2: *Sequence of conversions of unsaturated fatty acids.*
(1) = Δ 6 desaturases; (2) = elongases; (3) = Δ 5 desaturases; (4) = β - oxidation (peroxisomes) [47,48].

The PUFA n-3 fatty acids (FAs) have antiatherosclerotic efficacy [54]. This is mainly on:

- inhibition of synthesis of vasoaggresive low density;
- lipoprotein (LDL):
- acceleration of LDL elimination;
- non-influence on the vasoprotective high density lipoproteins (HDL) or even enhanced HDL production;
- decrease in the total serum triglycerides;
- shifting the eicosanoid balance in favour of the antiaggregatory fraction;
- reduction of the platelet aggregation and prolongation of bleeding time;
- reduction of blood pressure.

In many highly-developed countries cardiovascular diseases pose a serious health risk and often rank first among causes of death. Thus, for many years, in Germany more than 500 per 100 000 inhabitants (1989: 586) have been dying annually of heart and circulatory disorders. Compared with this carcinoma ranks "only" second with about 260 deaths per 100 000 [55]. Death rates from ischemic heart disease (in percentage of all deaths) in the United States, Denmark and Greenland are 40.4, 34.7 and 5.3, respectively [56]. The low rate of deaths from cardiovascular diseases in Greenland has been linked with the consumption of marine oils. There is evidence suggesting that long-chain n-3 polyunsaturated fatty acids also have beneficial effects on diseases other than those of the heart and of the blood vessels. They include [49]: inflammatory diseases; nephritis; strokes; arthritis; lupus erythematosis, multiple sclerosis; cancer; skin diseases; asthma.

In general, lipids of marine species are characterised by low levels of linoleic acid (18:2 n-6) and linolenic acid (18:3 n-3) as well as high levels of long-chain n-3 polyunsaturated fatty acids [57]. However, the LA was high but ALA was very low and insignificant; see Table 3 [LA PUFA = 18.0-19.0%; ALA PUFA = 0.00008-0.0002%; EPA PUFA= 5.80-8.87%; DHA PUFA = 8.88-11.4%]. This trend was also observed in various fatty acid composition (%) of several marine fish lipids [57]. It is also observed that EPA and DHA were the predominant n-3 fatty acids in the samples as earlier observed in several marine fish lipids [58]. The typical fatty acid composition of marine fish oils results from the fatty acid composition of the marine phytoplankton. These fatty acids reach the fish via the food web [59].

Table 7 contains the statistical analysis of results from Tables 2 and 3 data. The correlation coefficient r_{xy} was high in all the sample comparisons (whole organism/flesh, whole organism/shell and flesh/shell) with values of 0.9896 - 0.9989 with this trend: whole organism/flesh (0.9989) > whole organism/shell (0.9951) > flesh/shell (0.9896); however, only whole organism/flesh was significantly different ($r_{=0.05}$ at critical value of 0.997) among the three compositions. The coefficient of regression (R_{xy}) showed that for everyone unit increase in the fatty acids of the three comparisons, the corresponding R_{xy} was 1.2069, 3.0811 and 2.1524 respectively. The mean values of the comparisons were similar at the value of 33.3% in each case but slightly different levels of standard deviation (SD) of 13.1, 12.6, 11.9; and finally, the coefficient of variation (CV%) followed similar trend of 39.3, 37.9 and 35.8 showing the closeness of the data values of the fatty acids in the three samples. The coefficient of alienation (C_A) was low in each comparison with values range of 0.0456 - 0.1440; this led to high levels of index of forecasting efficiency (IFE) of 0.8560 - 0.9544. These values would make the prediction of relationship easy between the compared groups. Since the IFE is high in each case (0.8560 - 0.9544 or 85.60 - 95.44%), it means the reduction in the error of prediction was high in each case with corresponding low error of prediction of 0.0456 - 0.1440 or 4.56 - 14.4%. The implication of the low error of prediction physiologically is that any of the samples could carry out the biochemical activities of any other member of the series and vice versa.

Statistics	Whole organism		Flesh	Whole organism		Shell	Flesh		Shell
r_{xy}		0.9989			0.9951			0.9896	
r_{xy}^2		0.9979			0.9903			0.9793	
R_{xy}		1.2069			3.0811			2.1524	
Mean	33.3		33.3	33.3		33.3	33.3		33.3
SD	13.1		12.6	13.1		11.9	12.6		11.9
CV %	39.3		37.9	39.9		35.8	37.9		35.8
C_A		0.0456			0.0987			0.1440	
IFE		0.9544			0.9013			0.8560	
Remark		*			NS			NS	

*r_{xy} = correlation coefficient; R_{xy} = regression coefficient; C_A = coefficient of alienation; IFE = index of forecasting efficiency; * = results significantly different at n-2 and $r_{=0.05}$ (critical value = 0.997); NS = not significant different.*

Table 7: *Statistical analysis of the results from Tables 2 and 3 pertaining to totals of SFA, MUFA and PUFA*

The relative proportion of MUFA/SFA is an important aspect of phospholipid compositions and changes to this ratio have been claimed to have effects on such disease states as cardiovascular disease, obesity, diabetes, neuropathological conditions and cancer. For example, they have been shown to have cyto-protective actions in pancreatic β-cells. cis-Monoenoic acids have desirable physical properties for membrane lipids in that they are liquid at body temperature, yet are relatively resistant to oxidation. They are now recognised by nutritionists as being beneficial in the human diet. The MUFA/SFA values of 2.08-2.19 are good enough.

The ratio of PUFA/SFA (P/S ratio) is important in dietary oils in nutrition and health. The ratio of P/S is therefore important in determining the detrimental effects of dietary fats. The higher the P/S ratio the more nutritionally useful is the oil. This is because the severity of atherosclerosis is closely associated with the proportion of the total energy supplied by SFA and PUFA fats [60]. The values of P/S in this report are good. The n-6 and n-3 have critical roles in the membrane structure [61] and as precursors of eicosanoids [47,48], which are potent and highly reactive compounds. Since they compete for the same enzymes and have different biological roles, the balance between n-6 and n-3 FAs in the diet can be of considerable importance [62]. The ratio of n-6 to n-3 or specifically LA to ALA in the diet should be between 5:1 and 10:1 [62] or 4-10g of n-6 FAs to 1.0 g of n-3 FAs [63]. As LA is almost always present in foods, it tends to be relatively more abundant in animal tissues. This is supported in the present report as follows: C18:2 (n-6) ranged between 18.0-19.0% whereas C18:3 (n-3) ranged from 0.00008-0.00018%. In turn, these FAs are the biosynthetic precursors in animal systems of C20 and C22 PUFAs, with 3-6 double bonds, via sequential desaturation and chain- elongation steps (desaturases in animal tissues can only insert a double bond, via sequential desaturation and chain-elongation steps) [64]. Looking at Σ n-6/Σ n-3 in Table 5, the values of 1.27 - 1.38 fell within the range of 5:1 whereas LA/α-LA ratio range was 107814 - 232929. The LA/α-LA values were so high because the LA values were high but α-LA were low. This meant the desaturation and elongation leading to the production of EPA and DHA as well as AA might be unnecessary in these samples since they were already formed in situ in the samples. A high ratio between AA and DGLA as an indicator of Δ-5 desaturase activity in the skeletal muscle phospholipids has been related to good insulin activity [65]; the AA/DGLA in the samples ranged from 8051-18731 (Table 5) which were astronomically high. The AA levels were high (4.45 - 5.02%) whereas DGLA had values of 0.00026-0.00062; hence the high ratio of AA/DGLA.

For the assessment of the essential PUFA status of an individual, the total amount of the various EFA and PUFA in plasma or erythrocyte phospholipids is a useful indicator [66]. The following are further used as additional status markers to reliably assess the functional PUFA status [65]. The best known marker is mead acid [trivial name for all-cis-icosa-5, 8, 11- trienoic acid (20:3n-9)]. The synthesis of this

fatty acid is promoted if there are insufficient concentrations of LA and ALA to meet the need for the synthesis of long-chain PUFA. EPA and DHA inhibit mead acid synthesis; the presence of mead acid indicates a general shortage of all essential PUFA. Mead acid was not detected in any of the samples, EPA/DHA ratios being 0.5315-0.9994. Another suitable indicator of essential PUFA status is the essential PUFA status index (EPSI), which is the ratio between all essential PUFA (the sum of all n-3 and n-6 FAs) and all non-essential unsaturated FAs (the sum of all n-7 and n-9 FAs). The higher the EPSI status indexes the better the essential PUFA status. The present results had values of EPSI range of 0.9321-1.02 which were all above average. Finally, if there is a functional shortage of DHA, the body starts to synthesise the most comparable long-chain PUFA of the n-6 family, osbond acid (C22:5 n-6). Therefore, under steady state conditions, the ratio between DHA and osbond acid is a reliable indicator of the functional DHA status [67]. Therefore, the PUFA in the shrimp samples could not cause functional distress; it contained no osbond acid.

The differences in the fatty acids composition in whole organism-flesh, whole organism- shell and flesh-shell of the samples are shown in Table 8. These values were more concentrated in whole organism more than the flesh: all MUFA, n–6 PUFA and ΣUFA were more than in flesh; in whole organism – shell, MUFA (trans), n – 6 PUFA, n – 3 PUFA, n – 6 + n – 3 PUFA and ΣUFA were better concentrated in the whole organism; whereas flesh was better than shell in n-6 PUFA, n-3 PUFA, n-6 + n-3 PUFA and ΣUFA. This meant that everybody part of the shrimp would contribute positively to the fatty acids composition.

Parameter	Whole organism - flesh (%)	Whole organism-shell (%)	Flesh -shell
SFA	-0.5907 (-3.24)	-1.30 (-7.13)	-0.7115 (-3.78)
MUFA(cis)	+0.8373 (+2.09)	-0.6069 (-1.52)	-1.44 (-3.69)
MUFA(trans)	+0.0001 (+36.7)	+0.0001 (+34.7)	-0.000003 (-3.23)
ΣMUFA	+0.8374 (+2.09)	-0.6068 (-1.52)	-1.44 (-3.69)
n-6 PUFA	+0.5371 (+2.24)	+0.8775 (+3.66)	+0.3404 (+1.45)
n-3 PUFA	-0.7837 (-4.41)	+1.03 (+5.81)	+1.82 (+9.79)
n-6+n-3 PUFA	-0.2466 (-0.5907)	+1.91 (+4.57)	+2.16 (+5.13)
ΣUFA	+0.5907 (+0.7227)	+1.30 (+1.59)	+0.7115 (+0.8767)
ΣFA	0.00	0.00	0.00

Table 8: *Differences in the fatty acids composition in whole organism-flesh, whole organism-shell and flesh-shell of Pandalus borealis based on SFA, MUFA, PUFA and ΣFA.*

The PC is the building block of membrane bilayers, it is also the principal phospholipid circulating in plasma, where it is an integral component of the lipoproteins, especially the HDL [68]. Phosphatidylserine (PS) was in the second position in the concentration profiles with values of 26.2 - 33.3 mg/100g (21.6 - 26.7%). PS has been shown to enhance mood in a cohort of young people during mental stress and to improve accuracy during tee-off by increasing the stress resistance of golfers. The US Food and Drug Administration (USFDA) had stated that consumption of PS may reduce the risk of dementia in the elderly [25]. Phosphatidylethanolamine/cephalin (PE) was in the third position in concentration in the shrimp samples with values range of 22.7 - 26.9 mg/100g or 19.6 - 23.3%. PE is found in all living cells, although in human physiology it is found particularly in nervous tissue such as the white matter of brain, nerves, neural tissue and in spinal cord [25]. Phosphatidylinositol (PI or PtdIns) occupied the fourth position in concentration range of 1.39 - 1.64 mg/100 g or 1.19 - 1.42% and CV% of 8.15. PI is a negatively charged phospholipid. PI can be phosphorylated to form phosphatidylinositol phosphate (PIP), phosphatidylinositol bisphosphate (PIP2) and phophatidylinosiotol trisphosphate (PIP3). PIP, PIP2 and PIP3 are collectively called phosphoinositides. Phosphoinositides play important roles in lipid signaling, cell signaling and membrane tracking [20]. Lysophosphatidylcholine was the least concentrated in all the samples (8.01 e-3 to 5.82 e-2 mg/100g (0.0082 - 0.04436%) and highest CV% of 78.5

being the highest varied phospholipid in the three samples. Partial hydrolysis of PC with removal of only one fatty acid yields a lysophosphatidylcholine.

The report of Viswanathan Nair and Gopakumar [69] on lipid and fatty acid compositions of five species of lean fish, silver hew fish (*Johnius argantatus*), milk fish (*Chanos chanos*), pearl spot (*Etroplus suratensis*), cat fish (*Pseudarius jella* and *Trachysurus* sp) and three species of shell fish, mussed (*Perna viridis*), crab (*Neptunus pelagicus*) and fresh water prawn (*Macrobrachium rosenbergii*) showed that PC was the major phospholipid in all the samples studied. In lean fish its proportion varied from 55.9 - 63.8% and in shell fish, from 44.0 - 68.9% of total phospholipids. PE content was the second highest component (except in fresh water prawn). Its proportion in lean fish varied from 14.9 - 21.7% of total phospholipids. Fresh water prawn was notable for its very low content of phosphatidylethanolamine (8.6%). Phosphatidylserine, phosphatidylinositol and small quantities of lyso-derivatives of phosphatidylcholine and phosphatidylethanolamine were also present in the prawn samples. The present report showed that the *Pandalus borealis* phospholipids had the following total concentration trend (mg/100 g): shell < whole organism < flesh.

In Table 9, the differences in the phospholipids levels in the various body parts are shown. In the difference between the whole organism and flesh, only PE was higher in whole organism than the flesh, whereas PC, PS, lysophosphatidylcholine, PI and total were all more concentrated in flesh than the whole organism. In the whole organism-shell, all the differences were positive towards the whole organism; also, in the flesh-shell, all the differences were positive towards flesh.

Parameter	Whole organism -flesh (%)	Whole organism-shell (%)	Flesh -shell
PE	+ 1.20 (+4.45)	+4.18 (+15.5)	+ 2.98 (+11.6)
PC	- 0.6070 (-0.8663)	+22.5 (+32.1)	+ 23.1 (+32.7)
PS	- 6.09 (- 22.4)	+1.00 (+3.69)	+ 7.10 (21.3)
Lysophosphatidylcholine	- 0.0283 (- 94.6)	+ 0.0220 (+73.2)	+ 0.0502 (+86.2)
PI	- 0.1386 (- 9.25)	+0.1065 (+ 7.11)	+ 0.2451 (+15.0)
Total	- 5.67 (- 4.52)	+ 27.8 (+ 22.1)	+ 33.5 (+25.5)

Table 9: *Differences in the phospholipid levels in whole organism-flesh, whole organism-shell and flesh-shell of Pandalus borealis based on Table 7.*

PE: Phosphatidylethanolamine; Lecithin: Phosphatidylcholine; PS: Phosphatidylserine; PI: Phosphatidylinositol

The statistical analysis of the results from Table 7 is shown in Table 10. All the r_{xy} values were all significantly high with values of 0.9844-0.9951. The R_{xy} values were all moderate at values of 0.8696-2.3863. The mean values were all close with values of 19.6 - 26.2 mg/100g and CV% ranged from 101-113. The C_A values were generally low at 0.0165 - 0.1758 with corresponding high values of IFE at 0.8242 - 0.9835.

Statistics	Whole organism		Flesh	Whole organism		Shell	Flesh		Shell
r_{xy}		0.9951			0.9844			0.9917	
r_{xy}^2		0.9903			0.9691			0.9834	
R_{xy}		0.8696			2.3863			1.7518	
Mean	25.1		26.2	25.1		19.6	26.2		19.6
SD	28.3		28.8	28.3		19.7	28.8		19.7
CV %	113		110	113		101	110		101
C_A		0.0985			0.1758			0.0165	
IFE		0.9015			0.8242			0.9835	
Remark		*			*			*	

*r_{xy}, R_{xy}, C_A, IFE= see Table IV; * = results significantly different at n - 2 and $r_{= 0.05}$ (critical value = 0.878).*

Table 10: *Statistical analysis of the results from Table 7.*

Cholesterol is a high molecular weight alcohol that is manufactured in the liver and most human cells. Like SFA, the cholesterol we make and consume plays many roles. Along with SFA, cholesterol in the membrane gives cells necessary stiffness and stability. When the diet contains an excess of PUFA, these replace SFA in the cell membrane, so that the cell wall actually becomes flabby. When this happens, cholesterol from the blood is "driven" into the tissues to give them structural integrity. This is why serum cholesterol levels may go down temporarily when we replace SFA with PUFA oils in the diet [70].

Cholesterol acts as a precursor to vital corticosteroids, hormones that help us deal with stress and protect the body against heart disease and cancer; and to the sex hormones like androgen, precursor to vitamin D, a very important fat-soluble vitamin needed for healthy bone and nervous system, proper growth, mineral metabolism, muscle tone, insulin production, reproduction and immune system function. The bile salts are made from cholesterol. Bile is vital for digestion and assimilation of fats in the diet. Recent research shows that cholesterol acts as an antioxidant [71]. This is the likely explanation for the fact that cholesterol levels go up with age. As an antioxidant, cholesterol protects us against free radical damage that leads to heart disease and cancer. Cholesterol is needed for proper function of serotonin receptors in the brain [72]. Low cholesterol levels have been linked to aggressive and violent behaviour, depression and suicidal tendencies.

Mother's milk is especially rich in cholesterol and contains a special enzyme that helps the baby utilize this nutrient. Babies and children need cholesterol-rich foods throughout their growing years to ensure proper development of the brain and nervous system. Dietary cholesterol plays an important role in maintaining the health of the intestinal wall [73]. This is why low- cholesterol vegetarian diets can lead to leaky gut syndrome and other intestinal disorders. However, like fats, cholesterol may be damaged by exposure to heat and oxygen. This damaged or oxidised cholesterol seems to promote both injury to the arterial cells as well as a pathological buildup of plaque in the arteries [74]. There was a degradation in the cholesterol level of the *Pandalus borealis* samples as follows: whole organism (57.3 mg/100g) > flesh (44.7 mg/100g) > shell (40.5 mg/100 g) whereas the relationships between whole organism/flesh, whole organism/shell and flesh/shell had these respective ratios: 1.00:1.28, 1.00:1.41, 1.00:1.10.

The differences in the sterol levels of the samples were calculated as shown in Table 11. The whole organism was better concentrated in cholesterol and total sterols when compared to flesh whereas the whole shrimp organism was also better than shell in both cholesterol and total sterols. In the comparison between flesh and shell, flesh was better concentrated in cholesterol and total sterols than in the shell; however, cholestanol, ergosterol, campesterol, stigmasterol, 5-avenasterol and sitosterol had equivalent values between flesh and shell resulting in 0.00 difference between flesh and shell in the six above-mentioned parameters.

Sterol	Whole organism- flesh(%)	Whole organism-shell (%)	Flesh-shell (%)
Cholesterol	+ 12.6 (22.0)	+16.8 (+29.3)	+4.19 (+9.36)
Cholestanol	-1.29e-4 (-48.7)	- 1.29e-4 (-48.7)	0.00 (0.00)
Ergosterol	-4.52e-4 (-154)	-4.52e-4(-154)	0.00 (0.00)
Campesterol	- 1.44e-4 (-1.57)	- 1.44e-4 (-1.57)	0.00 (0.00)
Stig-masterol	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
5-Avenasterol	- 2.11e-6 (-0.4869)	- 2.11e-6 (-0.4869)	0.00 (0.00)
Sitosterol	-4.58e-6(-6.57)	-4.58e-6(-6.57)	0.00 (0.00)
Total	+ 12.6 (+22.0)	+16.8 (+29.3)	+4.19 (+9.36)

Table 11: *Differences in the sterol levels in whole organism - flesh, whole organism - shell and flesh - shell of Pandalus borealis body parts.*

The statistical analysis of the variances from Table 10 was carried out as shown in Table 12. Both r_{xy} and r_{xy}^2 stood at 1.00 each. The R_{xy} values were negatively high at -4.2105 to-34.6154. The mean values ranged from 40.5 to 57.3 mg/100 g with corresponding very low values of SD (0.0014 - 0.0018) and CV% (0.0024 - 0.0045). C_A and IFE were not calculated since these will only result in error because r_{xy} > 1.00 (Table 12); also, no critical 'r' was available for n = 0 since the n-2 = 0 in the Table 12, hence results were not compared with Table critical value. (n = number of freedom).

Statistics	Whole organism		Flesh	Whole organism		Shell	Flesh		Shell
r_{xy}		1.0014			1.0042			1.0026	
r_{xy}^2		1.0029			1.0080			1.0045	
R_{xy}		- 30.2564			- 34.6154			-4.2105	
Mean	57.3		44.7	57.3		40.5	44.7		40.5
SD	0.0014		0.0018	0.0014		0.0018	0.0018		0.0018
CV %	0.0024		0.0041	0.0024		0.0045	0.0041		0.0045
C_A^+		-			-			-	
IFE+		-			-			-	

C_A and IFE were not calculated since these will only result in error because r_{xy} > 1.00; also no critical 'r' was available for n = 0 since the n - 2 = 0 in the present Table, hence results not compared with Table critical value.

Table 12: *Statistical analysis of the results from Table 10.*

Conclusions

The findings of this study showed that the samples contained slightly unequal distribution of all the parameters determined. The parameters concentration trend went thus: crude fat and total energy, flesh > whole organism > shell and CV% of 25.7; SFA: shell > flesh > whole organism with CV% of 3.45; MUFA: shell > whole organism > flesh with CV% of 1.82; total n-6 PUFA: whole organism > flesh > shell with CV% of 1.88; total n-3 PUFA: flesh > whole organism > shell with CV% of 5.15; n-6 + n-3 PUFA: flesh > whole organism > shell with CV% of 2.86; ΣUFA: whole organism > flesh > shell; phospholipids: flesh > whole organism > shell and sterols: whole organism > flesh > shell with CV% of 18.4. In the nine parameters above, flesh was first in four (44.4%) parameters, flesh was second in four (44.4%) parameters and third in only one (11.1%) parameters; whole organism was first in three (33.3%) parameters, second in five (55.6%) parameters and third in only one (11.1%) parameter; shell was first in two (22.2%) parameters and third in position in seven (77.8%) parameters. Finally, the overall analytical data results showed that flesh > whole organism > shell although every sample had good contribution at various levels to the concentration and nutrition qualities of the lipid of *Pandalus borealis*.

Quality Assurance

The correlation determined for all the standards: fatty acids, phospholipids and sterols, all had values ranging as follows: 0.99833 – 0.99997 (fatty acids), 0.99909 – 0.99999 (phospholipids) and 0.99920 - 0.99940 (sterols); all the correlation values were greater than 0.95 which is the critical correlation for acceptance of these types of analytical results, thus attesting to the quality assurance of the determinations.

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