Assessment of nutritional quality indices of lipids in whole organism, flesh, and shell of *Pandalus borealis* consumed in Nigeria

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Classic fatty acid indices, nutritional quality indices and crude fats were determined, calculated and reported in this work as obtained from the body parts (whole organism, flesh and shell) of *Pandalus borealis* shrimp. The range of the crude fat (CF) was 0.80 to 1.31 g/100 g with corresponding edible portion (EP/100 g) 0.53 to 1.02 g/100 g. The energy density was low at 29.6 to 48.5 kJ/100 g (19.5 to 37.6 kJ/00 g) in CF/EP/100g or 7.20 to 11.8kcal/100g (4.75 to 9.14 kcal/100 g) in CF/EP/100 g. The classic fatty acid indices were (% of total fatty acids); reporting range values: ∑SFA (18.3 to 19.6%), ∑MUFA (29.2 to 40.6%), trans fatty acids, ∑TFA (9.00E-5 to 1.50E-4%), ∑n-6 PUFA (23.1 to 24.0%), ∑n-3 PUFA (16.7 to 18.5%), ∑n-6+ ∑n3 - PUFA (39.8 to 42.0%), ∑UFA (71.2 to 81.8%), EPA (5.80 to 8.87%) and DHA (8.88 to 11.4%). Nutritional quality indices reported were: PUFA/SFA; atherogenicity index (AI), thrombogenicity index (TI), hypocholesterolemic/hypercholesterolemic ratio (HH), unsaturation index (UI), health-promoting index (HPI), EPA+DHA, fish lipid quality/flesh lipid quality (FLQ) and peroxidizability index (PI). Most of the nutritional quality indices values were of health-promoting results, e.g. AI (0.13 to 0.14) were better than Eskimo diet (0.39); TI (0.21 to 0.24) were better than Eskimo diet (0.28), n-6/n-3 (1.27:1 to 1.38:1) were better than (4:1 to 10:1) and close to PUFA/SFA of ≥ 0.40 (1.0-1.5) with values ranging from 2.03 to 2.28. Pandalus borealis shrimp body parts produced low ∑SFA, low energy, insignificant ∑TFA, high ∑UFA, and favorable nutritional health quality indices.

Keywords: *Pandalus borealis*, Low energy density, nutritionally favorable health quality indices.

1. INTRODUCTION

According to Wikipedia [1], a shrimp (PL: shrimp or shrimps) is a crustacean (a form of shellfish) with an elongated body and a primarily swimming mode of locomotion – typically belonging to the Caridea or Dendrobranchiata of the decapod order, however, some crustaceans outside of this order are also referred to as "shrimp". In a broader definition, shrimp may be synonymous with prawn, referring to stalk-eyed swimming crustaceans with long whiskers (antennae) and slender legs [2]. Any small crustacean that resembles a shrimp tends to be called one [3]. They swim forward by paddling with swimmerets (pleopods) on the underside of their abdomens. Shrimps have thin, fragile legs which they use primarily for perching [3].

Bauler [4], in his book titled "Remarkable Shrimps: Adaptations and Natural History of Carideans", characteristically explained both shrimp and prawn as follows. Sh*rimp is* characteristically used to refer to those crustaceans with long antenna, smaller legs and a laterally compressed, muscular abdomen that is highly adapted for both a forward and backward (retrograde) escape response. Pr*awn is* often used as a synonym of sh*rimp for* penaeoidean and caridean shrimp,

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especially those of large size. The English Oxford Dictionaries provide the following definitions [5].
Shrimp: a small free-swimming crustacean with an elongated body, typically marine and frequently of commercial importance as food.
Prawn: a marine crustacean which resembles a large shrimp [6].
Historically, it was the distinction between walking and swimming that formed the primary taxonomic division to the former suborders Natantia and Reptantia. Members of the Natantia (shrimp in the broader sense) were adapted for swimming, while the Reptantia (crabs, lobsters, etc.) were adapted for crawling or walking [4]. Many shrimp species are small as the term sh*rimp sug*gests, about 2 cm (0.79 in) long, but some shrimp exceed 25 cm (9.8in). Larger shrimps are often referred to as prawns.
Shrimp have a widespread habitat: they are found close to the seafloor of coasts and estuaries, rivers and lakes. Species are numerous and they may be adapted to a particular habitat [3]. Most shrimp species are marine, although about a quarter of the species described are found in fresh water [7]. Marine species are found at depths of up to 5000 meters (16000ft) [8], from the tropics to the polar regions. Two species of M*erguia are* known to be semi-terrestrial and spend a significant part of their life on land on mangrove [9,10].
Decapods were traditionally grouped into two suborders: Natantia (or swimmers) and Reptantia (or walkers). Natantia included the shrimp. Natantia was thought to be paraphyletic, that is, it was thought that originally all decapods were like shrimp [11].
Classifications are now based on clades, and the paraphyletic suborder Natantia has been discontinued. On this basis, taxonomic classifications now divide the order Decapoda into two suborders: Dendrobranchiata for the largest shrimp clade, and Ploecyemata for all other decapods. The Ploecyemata are in turn divided into half a dozen infra-orders [11].

- The taxonomists De Grave and Fransen [12] recognize four major groups of shrimps: the suborder Dendrobranchiata and the infra-orders Procarididea, Stenopodidea and Caridea. This contains decapods only and is identical to the traditional Natantia group.
- All shrimp of commercial interest belong to the Natantia. The FAO determines the categories and terminology used in the reporting of global fisheries. They define a shrimp as a "decapod crustacean of the suborder Natantia" [13].
- According to the Codex Alimentarius Commission of the FAO and WHO: "The term sh*rimp (wh*ich includes the frequently used term prawn) refers to the species covered by the most recent edition of the FAO listing of shrimp, FAO Species Catalogue, Volume 1[14]. The Species Catalogue states that the highest category it deals with is "the suborder Natantia of the order Crustacean Decapoda to which all shrimps and prawn belong" [15].

The following Table IA contains the principal commercial shrimp, the seven most harvested species; all of them are Decapods [1]. Group: Dendrobranchiata
The main use of shrimp in SE Asia is in the production of shrimp paste, a fermented product that goes under names such as bl*achan (Ma*laysia and Indonesia) [37]. Bl*acang (al*so spelled as bl*achan), i*s the Malay and most common name for SE Asian fermented shrimp paste, which is called te*rasi or trasi in I*ndonesia, k*api in T*hailand, and ba*goong in t*he Philippines. The paste referred to as ba*lichko in M*acao is similar. A form of bl*acang is* also found in Burma and Sri Lanka [38]. The Indo-Pacific species described as having 'commercial importance', i.e. sought by fishermen and regularly sold in markets, include a few genera such as Ac*etes and Caridina [37*]. Potted shrimp is a delicacy in England, as described by Dorothy Hartley [39]. Shrimp paste is also an English favorite; however, it is quite different from the fermented shrimp paste of SE Asia [37].
Most shrimp are sold frozen and marketed based on their categorization of presentation, grading, color and uniformity [40]. Shrimp is generally sold whole, though sometimes only shrimp meat is marketed. Shrimp has high levels of omega-3 fatty acids and low levels of mercury [41]. Shrimp is high in calcium, iodine and protein, but low in energy. Shrimp meal is also a significant source of cholesterol, from 122 mg to 151 mg/100 g of shrimp, depending on the method of preparation [42]. Even with these cholesterol levels, shrimp consumption is considered healthy for the circulatory system

Table IA – Principal commercial shrimp species

Common name	Scientific name	FAO	WoRMS
Whiteleg shrimp	*Litopenanus vannamei* (Boone 1931)	16, 17	18
Giant tiger prawn	*Penaeus monodon (*Fabricius 1798)	19, 20	21
Akiami paste shrimp	*Acetes japonicus* (Kishinouye 1905)	22, 23	24
Southern rough shrimp	*Trachysalambria curvirostris* (Stimpson 1860)	25, 26	27
Flesh prawn	*Fenneropenaeus chinensis* (Osbeck 1765)	28, 29	30
Bana prawn	*Fenneropenaeus merguiensis* (De Man 1888)	31, 32	33
Northern prawn	*Pandalus borealis* (Krøyer 1838)	34, 35	36

because the lack of significant levels of SFA in shrimp means that its high cholesterol content actually improves the ratio of LDL to HDL cholesterol and lowers triglycerides [43].
This study concerns one major commercial shrimp named P*andalus borealis. The* fact sheet on P*andalus borealis is* as follows.
Classification:
Biota
- Animalia (Kingdom)
- Athropoda (Phylum)
- Crustacea (Subphylum)

Multicrustacea (Superclass)
- Malacostraca (Class)

Eumalacostraca (Subclass)
- Eucarida (Superorder)
- Decapoda (Order) [Latreille 1802]
- Pleocyemata (Suborder)
- Caridea (Inftraorder)

Pandaloidea (Superfamily)
- Pandalidae (Family)
- P*andalus (Gen*us)
- P*andalus borealis (Spe*cies)

Environment: marine
Original description Krøyer, H. (1838) [44].
Descriptive notes: Distribution: Greenland to Martha's Vineyard, Massachusetts. Widely fished since 1900s in Norway, and later in other countries following Johan Hjort's practical discoveries of how to locate them. They have a short life, which contributes to a variable stock on a yearly basis. They are not considered overfished [1].
Maximum length (mm): 165
Depth (m): 20 – 1380 [34, 35, 36].
2010 production (thousand tonnes):
- wild = 361
- farmed = –
- total = 361

Taxonomic citation: DecaNet eds. [45]
Status: Accepted
Rank: Species
Parent: P*andalus (Lea*ch 1814)
Original name: P*andalus borealis (Krø*yer 1838)

Previous studies on the anatomical part of P*andalus borealis have* been reported. Adeyeye [46] reported the amino acid profile of the whole organism, flesh and shell of P*andalus borealis (Krø*yer 1838). The report showed the total amino acid values as 86.6 to 93.0 g/100 g; the total essential amino acid range was 37.9 to 40.9 g/100 g cp (42.9 to 44.0%); cysteine/total sulfur amino acid, the Cys/TSAA range was 1.98 to 17.5; predicted protein efficiency ratio (P-PER): P-PER1 (1.21 to 1.71), P-PER2 (1.65 to 2.12); essential amino acid index, EAAI (79.5% to 99.4%); biological value, BV (75.0% to 96.6%); Lys/Trp (3.05 to 62.5) and Met/Trp (2.54 to 37.8). Adeyeye [47] also reported the classic fatty acid indices, while providing an in-depth discussion of this subject. In this report, the major discussion is based on an assessment of the nutritional quality indices of lipids in whole organism, flesh and shell of P*andalus borealis cons*umed in Nigeria. This report assists in predicting the health status on the consumption of P*andalus borealis fat.*

2. MATERIALS AND METHODS

Shrimps caught from fresh marine water, brackish water, and ponds of various types have become delicacies in Nigeria. They are eaten either whole (shell + flesh) after drying or as flesh (when fresh) [47]. The body of the shrimp is divided into two main parts: the head and thorax, which are fused together to form the cephalothorax, and a long narrow abdomen. The shell that protects the cephalothorax is harder and thicker than the shell elsewhere on the shrimp and is called the carapace. The carapace typically surrounds the gills, through which water is pumped by the action of the mouth parts [8].

2.1. COLLECTION AND TREATMENT OF SAMPLES PRIOR TO ANALYSES

Wet samples were collected from trawler catches from Idumota (along the Lagos Atlantic Ocean). The shrimps were washed with distilled de-ionized water and drained under folds of filter paper. Samples were collected in crushed ice in insulated containers and brought to the laboratory for preservation. The washed shrimp were wrapped in aluminum foil and kept in the laboratory refrigerator (2.8°C) pending analyses. Sample identification occurred before preservation.

2.2. SAMPLE PREPARATION FOR ANALYSES

On removal from the laboratory refrigerator, defrosting was allowed to occur for about one hour. Whole shrimps were beheaded and the outer shells removed. The various parts were dried at 105°C and blended in a blender after reaching constant drying weight. The three distinct samples were whole organisms (head + flesh + shell), flesh (endoskeleton only), and shell (head + body shell).

2.3. CRUDE FAT DETERMINATION

About 0.25 g of each aliquot was weighed in the extraction thimble and the fat extracted with petroleum ether (40 to 60°C boiling range) using a Soxhlet apparatus [47]. The extraction process lasted 5-6 h. Determinations were in duplicate.

2.4. PREPARATION OF FATTY ACID METHYL ESTERS (FAMES) AND ANALYSES

The crude fat extracted was converted to methyl ester using the boron trifluoride method [47]. The gas

chromatographic conditions for the analysis of fatty acids methyl esters were as follows:
GC: HP5890 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 x 0.25 mm x 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 obtained were identified by comparison with standard fatty acid methyl esters. Determinations were in duplicate.

2.5. QUALITY ASSURANCE

For the purpose of ensuring the accuracy of the obtained results, the following actions were performed: standard chromatograms were prepared for the fatty acids methyl esters, which were then compared with the respective analytical result; calibration curves were prepared for all the standard mixtures and the correlation coefficient was determined for each fatty acid parameter (31 in number). The correlation coefficient value should be ≥ 0.95 for the result to be acceptable. This is a statistical index that shows the quality assurance of the preformed calibration curve. It was performed using Hewlett Packard Chemistry (HPCHEM) software [47].

2.6. FATTY ACIDS CALCULATED AS EDIBLE PORTION

Fatty acids were listed with the chain length and double bond numbers. At the data source and reference data base levels, values for individual fatty acids are usually expressed as a percentage of total fatty acids since this is the most common forms of analytical presentation. At the user base level, values per 100 g 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 [47] for converting percentages of total fatty acids to fatty acids per 100g of food.

2.7. FATTY ACID AND QUALITY PARAMETERS

Lipids possess characteristic fatty acid composition and consequently influence health outcome. Fatty acids play critical roles in human metabolism, health, and diseases. Fatty acids are associated with cardiovascular diseases [48, 49, 50], neurological diseases [51, 52], fatty liver diseases (non-alcoholic) [52], allergic diseases [54], etc.

2.8. NUTRITIONAL INDICES

2.8.1 Polyunsaturated fatty acid/saturated fatty acid ratio (PUFA/SFA)

The PUFA/SFA ratio represents an index usually used to assess the impact of diet on cardiovascular health (CVH). It estimates how all PUFAs in the diet can depress low-density lipoprotein cholesterol (LDL-C) and lower levels of serum cholesterol and how all SFAs contribute to high levels of serum cholesterol. Hence, a higher PUFA/SFA ratio denotes a more positive effect [55].
SFAs responsible for raising serum cholesterol are C12:0,C14:0 and C16:O, thereby inhibiting the activity of low-density lipoprotein receptors (LDLRs); C18:O appeared to be biologically neutral because it can easily be metabolized to oleic acid and has no effects on circulating LDL-C levels [56].
The PUFA/SFA circulating formula is:

$$\sum \text{PUFA} / \sum \text{SFA} \quad (1)$$

2.8.2 Atherogenicity index (AI)

Ulbritcht and Southgate [57] developed this index, which characterizes the antherogenic potential of fatty acid. The AI indicates the relationship between the sum of SFAs [C12:0, C14: 0 and C16: 0] that are considered pro-atherogenic (i.e. they favor the adhesion of lipids to cells of the circulatory and immunological systems) [58] and UFAs that are considered to be anti-atherogenic, as they inhibit the accumulation of plaque and reduce levels of phospholipids, cholesterol and esterified fatty acids [58]. Hence, consumption of diets of products with low AI can reduce the levels of total cholesterol and LDL-C in human blood plasma [59].
The formula for calculating AI is:

$$AI = [C12;0 + (4 \times C14:0) + C16: 0] / \sum \text{UFA} \quad (2)$$

2.8.3 Thrombogenicity index (TI)

Both the index of thrombogenicity (IT) and index of atherogenicity (IA) were developed by Ulbritcht and Southgate [57]. This index characterizes the thrombogenic potential of fatty acids, predicting the tendency to form clots in blood vessels, and provides the contribution of different fatty acids, which denotes the relationship between the pro-thrombogenic fatty acids [C12:0,C14:0, C16:0] and the anti-thrombogenic fatty acids (MUFAs, the n-3 and n-6 PUFA families) [57]. Foods or products with low TI are beneficial for CVH.
The TI formula is:

$$TI = [C14:0 + C16:0 + C18:0] \; [(0.5 \times \sum \text{MUFA}) + (0.5 \times \sum \text{n-6 PUFA}) + (3 \times \sum \text{n-3 PUFA}) + (\text{n-3/n-6})] \quad (3)$$

2.8.4 Hypocholesterolemic/hypercholesterolemic (HH) ratio

The HH ratio is an index used in the fatty acid profile of lamb meat. It was first proposed by Santos-Silva

et al [60]. SFA is high in lamb leading to a low value of PUFA/SFA. The HH ratio characterizes the relationship between hypocholesterolemic fatty acid (cis-C18:1 and PUFA) and hypercholesterolemic fatty acid. Since no C12:0 was detected in the lamb meat, Santos-Silva et al. [60] concluded that the formula only includes C14:0 and C16:0 in hypercholesterolemic fatty acid. Mierliță [61] later optimized the formula by adding C12:0 in hypercholesterolemic fatty acid in studies of sheep milk. The formula is:

$$HH\ (cis\text{-}\ C18{:}1 + \sum PUFA)/(C12{:}0+C14{:}0 + C16{:}0) \quad (4)$$

2.8.5 Health-promoting index (HPI)

HPI is the inverse of AI. The index was proposed by Chen et al [62]. It is currently mainly used in research on dairy products such as milk [62] and cheese [62].

$$\sum UFA/[C12{:}O + (4xC14{:}O) + C16{:}O] \quad (5)$$

2.8.6 Unsaturation index (UI)

Different unsaturated fatty acids have different weights in the UI, which indicates the impact of highly unsaturated fatty acid. Therefore, UI indicates the degree of unsaturation in lipids and is calculated as the percentage of each unsaturated fatty acid multiplied by the number of double bonds within that fatty acid [63]. The calculation formula is:

$$UI = 1 \times (\%monoenoics) + 2\ (\%dienoics) + 3x\ (\%trienoics) + 4 \times (\%tetraenoics) + 5 \times (\%pentaenoics) + 6x\ (\%hexaenoics) \quad (6)$$

2.8.7 Sum of eicosapentaenoic acid and docosahexaenoic acid (EPA +DHA)

Both EPA and DHA are n-3 long-chain (LC) PUFAs that play important roles in the human body; these include a reduction in the risk of CVD, hypertension and inflammation. DHA is an important (essential) component of the retina, neuronal system, visual functioning and cognitive functioning in humans [64].

2.8.8 Fish lipid quality/flesh lipid quality (FLQ)

The main aim of FLQ calculation is similar to the EPA + DHA index, which calculates the sum of EPA and DHA as a percentage of total fatty acids. For accurate calculation of FLQ, it would be necessary to know the EPA% (of total FAs) and DHA% (of total FAs) conversion to edible portions per 100 g, i.e. EPA% (-EP/100 g) + DHA (-EP/100 g). FLQ was originally used for fish lipid quality [65] or flesh lipid quality [66]. The formula is:

$$FLQ = 100 \times (C22{:}6n\text{-}3 + C20{:}5n\text{-}3)/\sum FA \quad (7)$$

2.8.9 Linoleic acid/α-linolenic acid (LA/ALA) ratio

This ratio [LA, C18:2n-6/α – linolenic acid (ALA, C18:3n-3)] was developed for guiding infant formula. Tissues of adults have a lower rate of synthesis of n-3 long-chain PUFAs than those of infants, hence the LA/ALA ratio in the diet does not have much of an impact on adults.

2.8.10 *Trans* fatty acid (TFA)

*Trans fatt*y acid (TFA) is a component of fatty acid present in the human diet. The Food and Drug Administration (FDA) defined TFA as the sum of all unsaturated fatty acids that contain one or more isolated (i.e., non-conjugated) double bond(s) in t*rans con*figuration [67]. On the other hand, the European Food Safety Authority (EFSA) defined TFA as those fatty acids present as either t*rans – MU*FA or t*rans – PUFA*. T*rans PUFA*s h*ave* at least one t*rans doub*le bond and may therefore also have double bonds in the cis *con*figuration. Conjugated fatty acid (CLA) is separated from TFA as an independent section by EFSA. CLAs are thought to have health benefits that are different from those of TFAs, such as anti-cancer [68] and anti-atherosclerosis [69] activities, therefore it is appropriate to exclude CLA from the definition of TFA.

2.8.11 Omega - 6 /omega - 3 fatty acid ratio (n-6/n-6 FA ratio)

Omega – 6 and omega – 3 polyunsaturated fatty acids (PUFAs) are essential fatty acids that must be derived from diet since they cannot be produced by humans and other mammals because of the lack of endogenous enzymes for omega – 3 desaturation [70]. As a result of agri-business and modern agriculture, western diets contain excessive levels of omega – 6 PUFAs but very low levels of omega -3 PUFAs, leading to an unhealthy omega – 6/omega – 3 ratio of 20:1, instead of the 1:1 ratio during evolution in humans [71]. Thus, an unbalanced omega – 6/omega – 3 ratio in favor of omega - 6 PUFAs is highly prothrombotic and proinflammatory, which contributes to the prevalence of atherosclerosis, obesity and diabetes [70, 71, 72]. Regular consumption of diets rich in omega - 3 PUFAs have been associated with low incidence of these diseases, particularly in Icelandic populations, Inuit indigenous people, and Native Americans in Alaska [73, 74].

2.8.12 Peroxidizability index (PI)

The PI was determined according to Du et al. [75]:

$$PI = (monoenoate \times 0.025) + (dienoate \times 1) + (trienoate \times 2) + (tetraenoate \times 4) + (pentaenoate \times 6) + (hexaenoate \times 8) \quad (8)$$

All health indices determinations were in duplicate.

2.8.13 Conversion of crude fat to true – total fatty acid (T –TFA) or edible portion in g/100 g (EP/100g)

Conversion from individual fatty acid (FA) as '% of total fatty acids (FACID)' (= FA as 'g per 100 g FACID') to individual FA as 'g per 100 g EP' (applicable if the FACID content per fat or food is not given).

When the content of total fatty acid in food or fat is not given, it is not necessary to calculate it by using fatty

acid conversion factors (XFA). The conversion factors reflect the ratio between the sum of fatty acid and total lipids (TL) in the food [47].

$$FACID\ (g/100\ g\ EP) = TL\ (g/100\ gEP) \times XFA \quad (9)$$

Fatty acid conversion factors had earlier been derived for various food products and summarized by Greenfield and Southgate [75]. As fatty acid conversion factors (XN) are given only for lean (0.7) and fatty fish (0.9) (without indication of corresponding fat content) and not for crustaceans and mollusks, FAO/INFOODs [76] made further investigations on these factors. The findings concluded that instead of using fixed factors it is more accurate to use the formula proposed by Weihrauch et al. [*47]*, who also proposed formulas for crustaceans and mollusks. [P*andalus borealis is* a crustacean.]
Two ways to estimate fatty acid conversion factors are proposed:
If fat is ≥ 0.55 g/100 g EP, the formula of Weihrauch et al. [47] (should be used for crustaceans).

$$Crustaceans: XFA = 0.956 - 0.237/TL \quad (10)$$

Note: Total lipids (TL) should be expressed as g/100 g EP.
The EP/100g (T-TFA) values were depicted in Table I.

2.8.14 Energy density values as concerned the T – TFA, CF and other lipids (OLS)

The energy equivalents (kJ/100g and kcal EP/100g) were calculated for CF, T-TFA and OLs in the samples

$$kJ/100\ g = 37.0 \times CF, \times T - T\text{-}FA, \times Ols \quad (11)$$
$$kcal/100\ g = 9.0 \times CF, \times T\text{-}TFA, \times Ols \quad (12)$$

Other lipids = phospholipids (PHOLIP), cholesterol (CHOLE), etc.

2.9. STATISTICAL ANALYSIS

In the statistical analysis, two models were used: descriptive statistics and inferential statistics [77]. In the descriptive model, values determined were grand mean, standard deviation (SD), and coefficient of variation per cent (CV%). In the inferential model, the following was determined: linear correlation coefficient (rxy), variance or coefficient of determination (rxy2), and linear regression coefficient (Rxy). The rxy was subjected to the standard Table (critical) value at rxy = 0.01 (rC(0.01)) at n-2 (df) to see if significant differences existed in the compared samples. Furthermore, the generated rxy values were used to calculate the coefficient of alienation (CA) and index of forecasting efficiency (IFE).

3. RESULTS AND DISCUSSION

Table I contained the following: contents of crude fat (CF), true-total fatty acid (T-TFA) and other lipids (OL) of the samples. The range of the CF was 0.80 to 1.31 g/100 g with mean of 1.14±0.291 g/100 g and CV% of 25.4; the slightly high CV% was due to the CF in the shell because the value in whole shrimp and flesh (1.31) > whole organism (1.30) > shell (0.80). The CF across the board was relatively low. The corresponding T-TFA (or EP/100g) range was 0.53 to 1.02 g/100 g; after multiplying CF by these conversion factors: whole organism (1.30 x 0.774), flesh (1.31 x 0.775) and shell (0.80 x 0.660). The energy density from the CF, T-TFA and OL levels were relatively low at these values in kJ/100 g and kcal/100g: CF (29.6 - 48.5/7.20-11.8);

Table I – Crude fat (CF), true-total fatty acid (T-TFA), other lipids (OLs) and their corresponding energies of whole organism, flesh and shell (exoskeleton) of *Pandalus borealis* shrimp

Parameter	Whole organism	Flesh	Shell	Mean	Standard deviation (SD)	Coefficient of variation percent (CV%)
Crude fat(CF) (g/100g)	1.30*1	1.31*2	0.80*3	1.14	0.29	25.4
T-TFA (or EP/100g)	1.01	1.02	0.53	0.85	0.28	32.9
Other lipids (OL) (g/100g)	0.29	0.31	0.27	0.29	0.02	6.90
Energy (in kJ)						
– CF (kJ/100g)	48.1	48.5	29.6	42.1	10.8	25.7
- T-TFA (kJ/100g)	37.2	37.6	19.5	31.4	10.3	32.8
– OL (kJ/100g)	10.9	11.3	10.1	10.8	0.63	5.83
Energy (in kcal)						
– CF (kcal/100g)	11.7	11.8	7.20	10.2	2.62	25.7
- T-TFA (kcal/100g)	9.05	9.14	4.75	7.65	2.51	32.8
– OL (kcal/100g)	2.65	2.75	2.45	2.61	0.15	5.75

*1 = CF x 0.774; *2 =CF x 0.775; *3 = CF x 0.660; EP = edible portion; OL = phospholipids (PHOLIP) and cholesterol (CHOLE)

Table II – Classic fatty acid indices of *Pandalus borealis* shrimp whole organism, flesh and shell (% of total fatty acids)

Index	Whole organism (%)	Flesh (%)	Shell (%)	Mean	SD	CV%
∑SFA	18.3	18.8	19.6	18.9	0.66	3.49
∑MUFA	40.0	29.2	40.6	36.6	6.42	17.5
∑TFA	1.50E-4	9.00E-5	1.00E-4	1.10E-4	3.00E-5	28.4
∑n-6 PUFA	24.0	23.5	23.1	23.5	4.51E-1	1.92
∑n-3 PUFA	17.8	18.5	16.7	17.7	9.07E-1	5.12
∑n-6 + n-3 PUFA	41.8	42.0	39.8	41.2	1.22	2.96
∑UFA	81.8	71.2	80.4	77.8	5.76	7.40
EPA	8.87	7.16	5.80	7.28	1.54	21.2
DHA	8.88	11.4	10.9	10.4	1.33	12.8

Table III – Relevant saturated fatty acid (SFA) (% of total fatty acid) for this study in the three samples of *Pandalus borealis* shrimp

Saturated fatty acid (SFA)	Whole organism	Flesh	Shell	Mean	SD	CV%
Dodecanoic acid C12:0	0.03	0.05	0.02	0.03	0.02	66.7
Myristic acid C14:0	0.02	0.02	0.01	0.01	0.01	50.0
Palmitic acid C16:0	11.2	10.2	10.3	10.6	0.55	5.20
Stearic acid C18:0	7.01	8.62	9.19	8.28	1.13	13.6
Total	18.3	18.9	19.5	18.9	0.60	3.17

T – TFA or EP/100g (19.5 – 37.6/4.75 – 9.14); OL (10.1 - 11.3/2.45-2.75). The CV% of each series had virtually similar values shown as follows: CF(25.4), CF (kJ/100g) (25.7), CF (kcal/100g) 25.8); T-TFA (32.9), T-TFA (kJ/100 g) (32.8), T-TFA (kcal/100 g) (32.8) and OL (6.90), OL (kJ/100 g) (5.65), OL (kcal/100 g) (5.73).

Table II contained the classic fatty acid indices of the samples. The indices were ∑MUFA, ∑TFA, ∑n-6 PUFA, ∑ n-3 PUFA, ∑n-6 + ∑n-3 PUFA, ∑UFA, EPA and DHA. For these indices the CV% values were generally low at 1.92 to 28.4%, showing ∑TFA to have the highest CV% (28.4) and ∑n-6 PUFA the lowest CV% (1.92). The ∑SFA amounted to about half of its corresponding ∑MUFA per sample, shown as follows [∑SFA/∑MUFA (%total fatty acid)]: whole organism (18.3/40.0), flesh (18.8/29.2) and shell (19.6/40.6), respectively. There appeared to be parity between ∑SFA/∑n-3 PUFA seen as follows: whole organism (18.3/17.8), flesh (18.8/18.5) and shell (19.6/16.7). The ∑SFA values were simply lower than their corresponding ∑n-6 PUFA: whole organism (18.3/24.0), flesh (18.8/23.5) and shell (19.6/23.1). Hence, in all the samples, the following was observed: ∑SFA < ∑n-3 PUFA except (in the shell where we have 19.6/16.7) < ∑n-6 PUFA < ∑MUFA. The ∑TFA values were highly insignificant as they were at ultra-trace levels at 9.00E-5 to 1.5E-4% total fatty acid; this had no dietary significance and is not deleterious in any form. It could be seen that the ∑n-6+n-3 PUFA were high at 39.8 to 42.0% of total fatty acids. These results were nutritionally highly positive. On the whole, the ∑UFA/∑SFA showed that total energy density is shared between the samples as follows: ∑SFA: 18.3% to 19.6% energy content (kJ/100g/kcal/100g), whereas ∑UFA exhibits percentage values of 71.2% to 81.8% energy content (kJ/100g/kcal/100g). These energy sources were highly complemented by 5.80% to 8.87% energy (EPA) and 8.88% to 11.4% energy (DHA). The general low levels of (kJ/100g/kcal/100g) SFA and low energy density in the P*andalus borealis were* nutritionally advantageous to the consumer. Since every other parameter originated from the CF, the lipid profiles (and their other parameters) followed this trend (g/100g); shell (19.6) > flesh (18.8) > whole organism (18.3), although the values were highly close with a CV% of 3.49.

The SFA values relevant to this study were depicted in Table III. They were dodecanoic acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0), and stearic acid (C18:0). The SFA values were relatively low, but close in values depicted as follows. Total sample values were (%total fatty acid): shell (19.5) > flesh (18.9) > whole organism (18.3) with mean of 18.9 ± 0.60% and CV% of 3.17. Relatively close values existed in the following SFA pairs in the samples: C12:0/C14:0 (0.02 to 0.05/0.01 to 0.02); and C16:0/C18:0 (10.2 to 11.2/7.01 to 9.19). The percentage values of C16:0, C18:0 and C16:0+C18:0 on the overall sample SFA reading made interesting readings. The C16:0/C18:0 percentage value on the overall SFA per sample showed the following: whole organism (61.4/38.4), flesh (54.0/45.7) and flesh (52.8/47.1); whereas, C16:0+C18:0 overall values over the total SFA values per sample had virtually similar results of whole organisms (99.8%), flesh (99.7%) and shell (99.9%). In this light it could be hypothesized that the nutritional behaviors of the SFAs in the whole organism ≡ flesh ≡ shell. More specifically, however, the following could be concluded in the SFAs of P. *borealis. SFA*s responsible for raising serum cholesterol are C12:0, C14:0 and C16:0, thereby inhibiting the activity of low density lipoprotein receptors (LDLRs); C18:0 appeared to be biologically neutral as it can easily be metabolized to oleic acid and have no effect on circulating LDL-C levels [56]. In these results, the total C12:0 +C14:0 was 0.20% total SFA (whole organism), 0.30%

total SFA (flesh) and 0.10% total SFA (shell); all these were trace values, hence only C16:0 could be nutritionally recognized in the SFA activity in the P. *borealis. He*nce, the pro-atherogenic and the pro-thrombogenic potentials of P. *borealis oil* are very low [58].

Table IV contained the monoenoic fatty acids (% total fatty acids) in the samples. The monoenoic fatty acids ultra-trace levels were myristoleic acid [C14:1 (cis-*9)]* (2.00E-5 to 3.00E-4%) with CV% of 24.8; and nervonic acid [C24:1 (cis-*15)*] (2.00E-5 to 2.00E-4%) with CV% of 0.00; trace level was erucic acid [C22:1 (cis-*13)*] (0.01 to 0.26%) and highest CV% (86.7). Average MUFA values (less than two units) were observed in palmitoleic acid [C16:1 (cis-*9)]* (3.69 to 4.63%) with low CV% (11.2), petroselinic acid [C18:1 (cis-*6)]* (5.12 to 6.77%) with low CV% (14.4) and gadoleic acid [C20:1 (cis-*11)*] (9.99 to 15.9) with CV% (22.7). Arguably, the highest monoenoic fatty acid in the samples was oleic acid [C18:1 (cis-*9)]* (14.8 to 18.4%) with CV% (11.2, lowest CV% value). However, oleic and gadoleic fatty acids were very close or even similar values, particularly in flesh and shell; see the following comparisons (%) in oleic/gadoleic fatty acids: whole organism (18.4/9.99), flesh (14.8/13.5) and shell (15.9/15.9). The total MUFAs per sample had this close range of 39.2 to 40.6% with the Table IV closest (lowest) CV% (1.75). The high MUFA values specifically contribute to the UFAs that are considered to be anti-antherogenic, as they inhibit the accumulation of plaque and reduce levels of phospholipids, cholesterol and esterified fatty acids [58], while also contributing positively to lowering the thrombogenicity index, which is beneficial for CVH.

Table V presents the tr*ans fat*ty acids. They were exclusively part of the monoenoic fatty acids, but because of their negative nutritional effects, they were separately discussed. The TFAs in P. *borealis were* due to microbial activity within the shrimp and were insignificant to the fatty acids content in the samples. Values were all at ultra-trace levels in the samples (total = 9.00E-5 to 1.50E-4%, 0.1.10E-4 ± 3.20E-5% and CV% = 28.4). Consumption of P*andalus borealis wou*ld not cause deleterious effects in its consumers.

In Table VI, dienoic fatty acid profiles were shown. Four fatty acids were exhibited. Two of the fatty acids were in ultra-trace levels and their values were completely insignificant as they ranged as follows: eicosadienoic acid [C20:2 (cis-*11,* 14)] (2.00E-5 to 3.00E-5%) and rumenic acid [C18:2 (cis-*9,* trans -12)] (6. 00E-5 to 9. 00E-5%); they both have a close CV% of 24.8/24.7. Docosadienoic acid [C22:2 (cis-*13,* 16)] ranged from trace level to low level (0.10 to 0.34%) with highest CV% (89.5). Significant levels were measured in linoleic fatty acid [C18:2 (cis-*9,* 12)] (18.0 to 19.0%) and lowest CV% (2.88). The total dienoic fatty acids in the samples ranged from 18.2 to 19.3% (of total fatty acid). Of these values, linoleic acid comprised the following percentages: whole organism (98.2%), flesh (99.5%), and shell (95.8%), leaving these values for the other three members of the dienoic fatty acids: 1.80 (whole organism), 0.50 (flesh), and 1.20 (shell). The high dienoic acid values contribute to a low index of atherogenicity (IA), low index of thrombogenicity (IT), high level of hypocholesterolemic/hypercholesterolemic ratio (HH), health-promoting index, unsaturation index, low

Table IV – Monoenoic fatty acid (%total fatty acid) in the whole organism, flesh and shell of the *P. borealis* shrimp samples

Monoenoic fatty acid	Whole organism	Flesh	Shell	Mean	SD	CV%
Myristoleic acid C14:1 (*cis*-9)	3.00E-5	2.00E-5	2.00E-5	2.33E-5	5.77E-6	24.8
Palmitoleic acid C16:1 (*cis*-9)	4.63	4.17	3.69	4.16	0.47	11.3
Petroselinic acid C18:1 (*cis*-6)	6.77	6.45	5.12	6.11	0.88	14.4
Oleic acid C18:1 (*cis*-9)	18.4	14.8	15.9	16.4	1.85	11.3
Gadoleic acid C20:1 (*cis*-11)	9.99	13.5	15.9	13.1	2.97	22.7
Erucic acid C22:1 (*cis*-13)	0.18	0.26	0.01	0.15	0.13	86.7
Nervonic acid C24:1 (*cis*-15)	2.00E-5	2.00E-5	2.00E-5	2.00E-5	-	-
Total	40.0	39.2	40.6	39.9	0.70	1.75

Table V – *Trans* fatty acids (part of monoenoic fatty acids) in the three samples of the *P. borealis* shrimp samples

Trans fatty acid	Whole organism	Flesh	Shell	Mean	SD	CV%
Trans – petroselinic acid C18:1 (*trans*-6)	8.00E-5	5.00E-5	5.00E-5	6.00E-5	1.73E-5	28.8
Elaidic acid C18:1 (*trans*-9)	7.00E-5	4.00E-5	5.00E-5	5.33E-5	1.53E-5	28.7
Vaccenic acid C18:1 (*trans*-11)	0.00	0.00	0.00	0.00	-	-
Total	1.50E-5	9.00E-5	1.00E-4	1.13E-4	3.21E-5	28.4

Table VI – Dienoic fatty acids (%total fatty acids) in the samples of *P. borealis* shrimp

Dienoic fatty acid	Whole organism	Flesh	Shell	Mean	SD	CV%
Linoleic acid C18:2(*cis*-9,12)	19.0	18.2	18.0	18.4	0.53	2.88
Eicosadienoic acid C20:2(*cis*-11,14)	3.00E-5	2.00E-5	2.00E-5	2.33E-5	5.77E-6	24.8
Docosadienoic acid C22:2(*cis*-13,16)	0.34	0.10	0.22	0.19	0.17	88.5
Rumenic acid C18:2(*trans*-9, *cis*-12)	9.00E-5	6.00E-5	6.00E-5	70.00E-5	1.73E-5	24.7
Total	19.3	18.3	18.2	18.6	0.61	3.28

n-6/n-3 and relatively low PUFA/SFA (which were all nutritionally positive) in P*andalus borealis.*

*T*he trienoic acid levels in Table VII had four members which were gamma-linoleic acid [C18:3 (c*is-6,9*,12)], dihomo-gamma-linolenic acid, DGLA [C20:3 (c*is-8,11*,14)], alpha-linolenic acid [C18:3 (c*is-9,12*,15)] and eicosatrienoic acid [C20:3 (c*is-11,*14,17)], but only gamma-linoleic acid had low but relatively significant levels at 0.16 to 0.24%, 0.19±0.04% and CV% (21.1). Gamma-linoleic acid percentages (in the overall levels) were 99.7% (whole organism), 99.6% (flesh), and 98.0% (shell). Trienoics were very active in determining the values of unsaturation index (UI) and the peroxidizability index (PI).

Table VIII contained a member in each of these groups: tetraenoic acid, arachidonic acid [C20:4 (c*is-5,* 8 11, 14), 4.45 to 5.02%, CV% (6.09)]; pentaenoic acid, EPA [C20:5 (c*is-5,* 8, 11, 14, 17), 5.80 to 8.87%, CV%(21.2)]; hexaenoic acid, DHA[C22:6 (c*is-4,7*,10,13,16,19), 8.88 to 11.4%, CV% (12.8)]. All the fatty acids in Table VIII were involved in the calculations for: PUFA/SFA, IA, IT, HH, HPI, UI and n-6/n-3 ratio; EPA and DHA were further involved in the determination of EPAT + DHA and FLQ, whereas only arachidonic acid (ARA, a tetraenoic) was involved in the calculation of PI.

Statistical analysis of the classic fatty acid indices of P*andalus borealis sam*ples (see Table II) were explained in detail, as shown in Table IX. Table IX depicts: rxy, rxy2, Rxy, mean, SD, CV%, CA and IFE; value of level of significance was also set at rxy=0.01 at n-2(df). The pairs compared were whole body/flesh (W/F), flesh/shell (F/S) and whole organism /shell (W/S. The rxy values were positive, high (0.9856 to 0.9979) and significantly different since all rxy values were each higher than the critical value of 0.798. The rxy2 followed the trend observed in the rxy and their values were high at 0.9715 – 0.9958. The Rxy values were high at 0.8492 to 1.131. The Rxy values deserve further explanation. The Rxy could be written as Rx:y or Rx:Ry. Where X represents the left hand member of a pair, as in Table IX, X would be as follows: W(in W/F), F(in F/S) and W(in W/S), whereas y represents letters in the right hand side of a pair: F(in W/F), S(in F/S) and S(in W/S). Values of x were permanent one unit (or 100%) in each Rxy value, whereas y could be seen in the Table IX as ranging from 0.8492 to 1.131. This showed that the real expression of Rxy would be, taking W/F as an example: Rxy= Rx(=1.00): Ry(0.8492). That is, for each 1

Table VII – Trienoic fatty acids (% total fatty acids) in the whole organism, flesh and shell samples of *P. borealis* shrimp samples

Trienoic fatty acid	Whole organism	Flesh	Shell	Mean	SD	CV%
Gamma-linoleic fatty acid C18:3 (*cis*-6,9,12)	0.24	0.18	0.16	0.19	0.04	21.1
DGLA C20:3 (*cis*-8,11,14)	4.00E-4	6.00E-4	3.00E-4	4.33E-4	1.53E-4	35.3
Alpha-linolenic acid C18:3 (*cis*-6,12,15)	1.00E-4	8.00E-5	1.00E-4	1.27E-4	6.43E-5	50.6
Eicosatrienoic acid C20:3 (*cis*-11, 14,17)	1.00E-4	8.00E-5	9.00E-5	9.00E-5	1.00E-5	7.87
Total	0.24	0.18	0.16	0.19	0.04	21.1

Table VIII – Tetraenoics, pentaenoics and hexaenoics fatty acids (% total fatty acids) in the *P. borealis* samples

Enoic fatty acid	Whole organism	Flesh	Shell	Mean	SD	CV%
Tetraenoic Arachidonic acid C20:4 (*cis*-5,8, 11,14)	4.45	5.02	4.80	4.76	0.29	6.09
Pentaenoic EPA C20:5 (*cis*-5,8,11,14,17)	8.87	7.16	5.80	7.28	1.54	21.2
Hexaenoic DHA C22:6 (*cis*-4,7,10,13,16,19)	8.88	11.4	10.9	10.4	1.33	12.8

Table IX – Statistical analysis of classic fatty acid indices of *Pandalus borealis* samples (whole organism, flesh, shell) [Data from Table II.]

Statistics	Whole body/flesh (W/F)			Flesh/shell (F/S)			Whole body/shell (W/S)		
	Whole body	W/F	Flesh	Flesh		Shell	Whole organism		Shell
r_{xy}		0.9885*		F/S	0.9856*	W/S		0.9979*	
r_{xy}^2		0.9770			0.9715			0.9958	
R_{xy}		0.8492			1.13			0.9841	
Mean	26.8		24.6	24.6		26.3	26.8		26.3
SD	24.9		21.4	21.4		24.5	24.9		24.5
CV%	92.7		86.7	86.7		93.2	92.7		93.2
C_A		0.1517			0.1688			0.0648	
IFE		0.8483			0.8312			0.9352	

r_{xy} = linear correlation coefficient; r_{xy} = coefficient of determination; R_{xy} = regression coefficient; SD = standard deviation; CV% = coefficient of variation percent; C_A = coefficient of alienation; IFE = index of forecasting efficiency; * = values significantly different at n-2 = 9-2 = 7(df) and r_{xy} critical = 0.798 at $r_{xy=0.01}$

unit increase in the X value, there was a corresponding increase of 0.8492 in the y value. It could then be written as Rxy (W/F=W(1.00): F(0.8492)). This scenario holds for other pairs in Table IX. Unlike the rxy, rxy2 and Rxy that joined a pair as one unit, the mean, SD and CV% had individual readings for each member in a pair group. Three means, three SDs and three CV%s were shown in Table IX, but each of these values appears twice depending on the three pairs of the comparisons. Mean, SD and CV% in W were 26.8 ± 24.9%, CV% (92.7); in F, it was (24.6 ± 21.4%, CV% (86.7); S was 26.3 ± 24.5%, CV% (93.2), respectively. Mean, SD and CV% values in W were closer to S than F, with all these values being lowest in F. The CA was low in all the pair groups with values ranging from 0.0648 to 0.1688. The CA represents values of non-relationship or alienation within a group. It also represents error of prediction of relationship in a compared relationship. The CA statistical partner is IFE. CA+IFE=1.00 (if fraction is the considered model of comparison) or CA + IFE=100% (if percentage is the model of comparison). IFE represents the reduction of error in the prediction of relationship in a compared entity. Hence, when CA is high, IFE is low or in the reverse situation. In the situation here, since all CA(0.0648-0.1688) values were low, all the corresponding IFE (0.8312 – 0.9352) values were high, or, CA(6.48%-16.88%) <<< IFE (83.12%-93.52%). The high values of IFE showed that high nutrition/biochemical relationships existed in the pairs of W/F, F/S and W/S. Furthermore, due to the high IFE values, it followed that the member of a pair could carry out all the food properties of the other member of the group and vice-versa. [Note that CA and IFE treated a pair as a unit, just as occurred in rxy, rxy2 and Rxy.]

3.1. LIPID SAMPLES' NUTRITIONAL INDICES WERE SHOWN IN TABLE X

The index of atherogenicity (IA) values in the samples were low at 0.13 to 0.14 and CV% of 13.3. These values were mostly lower than many literature results. Yurchenko et al. [59] concluded that consumption of food or products with a low IA can reduce the levels of total cholesterol and LDL-C in human blood plasma. Nantapo et al. [78] analyzed fatty acid consumption of milk at different stages of lactation, finding IA to range from 4.08 to 5.13 in different lactation stages. Akintola [79] investigated the techniques of smoking and sun drying to assess the nutritional quality of southern pink shrimp (P*enaeus notialis), r*eporting IA values of 0.71 to 0.82. Seaweeds range from 0.03 to 3.58 [80], crops from 0.08 to 0.55 [81], fish from 0.21 to 1.41 [82], meat from 0.17 to 1.32, and dairy products from 1.42 to 5.13 [83, 78]. The Eskimo diet has an AI value of 0.39. The index of thrombogenicity (IT) in Table X had values ranging from 0.21 to 0.24 and CV% value of 8.70; these values were also low, as in AI. TI value in the Eskimo diet is 0.28 (higher than in the present report). Foods or products with low IT are beneficial for CVH [84]. Chen et al. [85] conducted a comparative study on the fatty acid profiles of four different Chinese medicinal S*argassum seaw*eeds; results showed IT was between 0.46 and 1.60. Calabrò et al. [81] worked on fatty acid profiles of three cultivars of Lu*pinus albus (Lut*eur, Lublanca, Multitalia). Further literature on IT shows seaweeds had values ranging from 0.04 to 2.94 (except G*racilaria salicornia, wh*ich had an IT value of 5.75) [80]. IT values for crops, fish, meat, and dairy products are 0.14-0.56 [81, 86], 0.14-087 [87], 0.29-1.69 [88] and 0.39-5.04 [83, 89], respectively. Any fatty acid composition with a low IT has a better nutritional quality and its consumption may reduce the risk of coronary heart disease (CHD) [84].

The hypocholesterolemic/hypercholesterolemic (HH) ratio values in Table X range from 5.35 to 5.53. Paiva et al. [90] worked on the fatty acids in selected four Azorean macroalgae and found the HH values to range from 1.26 to 2.09. Ratusz et al. [91] analyzed fatty acids content in 29 cold-pressed camelina (C*amelina sativa) oi*ls and found relatively high HH that ranged from 11.7 to 14.7. For shellfish, HH value ranges from 1.73 to 4.75 (except for L*oxechinus albus, 0.*21) [92]; for fish, value ranges from 1.54 to 4.83 (except Op*isthonema oglinum, 0.*87) [93]. For meat and dairy products, ranges are from 1.27 to 2.79 [94, 88] and 0.32 to 1.29 [95, 83], respectively.

Health-promoting index (HPI) levels in the samples, as shown in Table X, showed range values of 6.90 to 7.76, with low CV% (5.89). HPI is the reverse of AI. Literature on dairy products had an HPI range of 0.16 to 0.68. Dairy products with high HPI values are assumed to be more beneficial to human health [84]; this might be true for P*andalus borealis oil.*

Unsaturation index (UI) values in the samples ranged from 154 to 162 (Table X). Colombo et al. [96] used UI to compare macroalgae in cold water with those in warm water, with a high UI value that indicates a high degree of total unsaturation. Their results suggested that the fatty acids with a high level of unsaturation in a membrane lipid can maintain fluidity at a relatively low temperature. The UI values of seaweeds vary from 45 to 369 [97], which may likely be related to their species; the range for meat is 73±6 to 124 [98, 99], while for dairy products the range is 86-120 [100].

EPA + DHA is an index that is recognized worldwide. The FAO of the United Nations (UNFAO) [84] recommended amount is 0.250-2g/day. This index is mostly used to evaluate the nutritional quality of seafood and its products, particularly fish. The EPA + DHA values reported in Table X were in percentage and mg/100 g. Sample values were: whole organism (17.8% or 179 mg/100 g), flesh (18.6% or 188 mg/100 g) and shell (16.7%, 88.2mg/100g). Rincón-Cervera et al. [92] studied the fatty acid composition of fish and shellfish captured in South Pacific. The results showed that

EPA + DHA ranged between 115 and 137 mg/100 g in all studied fish species and between 63.6 and 523 mg/100 g in all studied shellfish species.

The fish lipid quality/flesh lipid quality (FLQ) in the samples ranged between 13.4 and 24.3 (Table X). Marine products have higher proportions of EPA and DHA; hence, this index may be more appropriate for them [84]. Literature reports on fatty acid profiles of the fillet of farmed sea beam (Sp*arus aurata) ha*rvested in different seasons found FLQ to be lowest in April. FLQ values in fish varies between 13.0 to 36.4 [66] (for closely related species); present results were highly comparable to these literature results.

The linoleic acid/α-linolenic acid (LA/ALA) ratio values were not shown in Table X. The paired values of LA/ALA are demonstrated as follows (in percentages): whole organism (19.0/.2.00E-4), flesh (18.2/0.8.00E-5), and shell (18.0/1.00E-4). These values resulted in these ratios of LA/ALA: whole organism (95,000:1.00), flesh (227, 500:1.00) and shell (180,000:1.00). C20:4n-6, c*is val*ues were each less than one-third of their corresponding LA depicting values of 4.45-5.02% and in the n-3 PUFA, both C20: 5n-3 and C22:6n-3 were already preformed in the samples, as already depicted in the relevant tables. Hence, while LA might exhibit essentiality in the present result, ALA was virtually non-essential. The Definitions and Nutrient Composition Section of the Guidelines for Infant Formula published by Food Standards Australia New Zealand (FSANZ) sets the minimum and maximum proportions of LA and ALA, specifying an LA/ALA ratio within 5:1 - 15:1 [84].

The n-*6/ n-3 v*alues in Table X showed the range as 1.27 to 1.38 and CV% of 4.51. Recent dietary guidelines are focused on n-6 and n-3 PUFA balance. The recommendations of Bellagio's report on healthy agriculture, healthy nutrition, and healthy people indicated that a ratio (4:1) of n-6 PUFA to n-3 PUFA in the diet should be the goal [101]. A balance existed between omega-6 and omega-3 fatty acids during the long evolutionary history of the genus Homo [102]. During evolution, omega-3 fatty acids were found in all consumed foods: particularly meat, fish, wild plants, nuts, and berries [102, 103]. A diet rich in omega-6 fatty acids shifts the physiological state to one that is proinflammatory, prothrombotic, and proaggregatory, with increases in blood viscosity, vasospasm, vasoconstriction, and cell proliferation [104].

Tr*ans fatt*y acids (TFAs) were present in ultra-traces (9.00E-5% to 1.50E-4%) in the samples as shown in Table X. According to population nutrient intake figures from the WHO/FAO, the intake of TFA should constitute < 1% of total energy. For pregnancy and lactation, the lowest possible intake of industrially-produced TFAs is required [84]. According to the EFSA, TFA in the diet is provided by several sources that contain EFAs and other nutrients [105]. The EFSA panel concluded that the intake of TFA should be sufficiently reduced within a nutritionally adequate diet to lower the intake of TFA, while ensuring the nutrient intake [105]. The 2015-2020 Dietary Guidelines for Americans emphasize that individuals should reduce their intake of tr*ans fatt*y acid to as low as possible by limiting their consumption of foods that contain synthetic sources of tr*ans fats* [84]. There may be no need to eliminate meat and dairy products that contain small quantities of natural TFA from the diet. In the United Kingdom, the recommended intake of TFA is < 2% of the total daily energy or 5 g/day [84]. The TFA index is presently used in seaweed [90], lamb [106], milk [95], fish [107], and plant oil [108]. Skaleckì et al. [107] reported similar values of TFA in Prussian carp fish (C*arassius gibelia) fi*llets with and without skin; TFA values were 1.06%±0.06%, 10.6-37.2 mg/100 g. The present TFA values were 9.00E-5% - 1.50E-4%, 7.00E-5 mg/100 g – 1.20E-4 mg/100 g, which were all less than in Prussian carp fish.

The peroxidizability index (PI) values in Table X ranged from 161-174 with a mean±SD of 166±7.00 and CV% of 4.22. The highest and lowest PI was estimated in

Table X – Sample lipids nutritional indices in *Pandalus borealis* samples (whole organism, flesh, shell)

Indices	Whole organism	Flesh	Shell	Mean	SD	CV%
AI	0.1380	0.1449	0.1288	0.1372	0.0081	5.904
TI	0.2116	0.2280	0.2359	0.2252	0.0124	5.506
HH	5.354	5.534	5.393	5.427	0.0947	1.745
HPI	7.246	6.901	7.762	7.303	0.4333	5.933
UI	157.7	162.3	153.7	157.9	4.303	2.725
EPA+DHA	17.75% 178.6mg/100g	18.56% 188.4mg/100g	16.70% 88.18mg/100g	17.67% 151.7mg/100g	0.9326 55.25	5.278 36.42
FLQ	23.07	24.31	13.36	20.25	5.996	29.61
n-6/n-3	1.348	1.270	1.383	1.334	0.0578	4.333
TFA	0.00015% .0012mg/100g	0.00009% 0.00007 mg/100g	0.0001% 0.0007 mg/100g	0.00011 0.00066 mg/100g	0.00003 0.00057	27.27 86.36
PI	38.63	39.73	38.75	39.04	0.6034	1.546
PUFA/SFA	2.284	2.234	2.031	2.183	0.1340	6.138

AI = atherogenicity index; TI = thrombogenicity index; HH = hypocholesterolemic/ hypercholesterolemic ratio; HPI = health-promoting index; UI = unsaturation index; EPA+DHA = sum of eicosapentaenoic acid and eicosahexaenoic acid; FLQ = fish lipid quality/flesh lipid quality; TFA = *trans* fatty acid; PI = peroxidability index; PUFA/SFA = polyunsaturated fatty acid/saturated fatty acid ratio.

flax (129.09±0.59) and hemp (99.05±0.42) seeds, respectively [109]. In the PI index by Kang et al [110], the most favorable to reduce the risk of CVD is 80-90. It is well-known that PUFAs and particularly ALA are highly susceptible to oxidation [111], which increases the risk of oil deterioration. The ALA values in these results were of no nutritional consequence. Some literature PI values are: coconut (2), tallow (5), palm (12), olive (13), lard (15), poultry (23), canola (40), sunflower (41), corn (57), soybean (65), flaxseed (120), menhaden (214), and algae (258) [112]. Present values were within the value of 120-214.

The PUFA/SFA ratio values in Table X ranged between 2.03 and 2.28. With the aim of lowering serum cholesterol, nutrition recommendations suggested reducing levels of SFA and replacing them with PUFA in the diet [113, 110]. The target for the ratio of PUFA to SFA is 0.4 or above [101]. Other authors reported that a high PUFA/SFA ratio diet enhances oxidative stress because PUFA (particularly ALA) are highly susceptible to lipid peroxidation. They also indicated that a PUFA/SFA ratio of 1.0-1.5 and a PI value of 80-90 in the diet are within a favorable range to reduce the risk of CVD [109]. PUFA/SFA in the literature are: seaweed (0.42-2.12) [80], except for G*racilaria changii (6.9*6±0.98) [97]; meat (0.11-2.04), fish (0.50-1.79), shellfish (0.20-2.10) and dietary products (0.20-0.18) [80]. PUFA/SFA of chicken is in the range of 0.31-2.04 for different dietary treatments [89]. Fernandes et al. [94] on their report for PUFA/SFA in four species of Brazilian fish had values of 1.09-1.47.

CONCLUSIONS

In line with consumer interest, this study was based on body parts of P*andalus borealis (who*le organism, flesh and shell), depicting their crude fat (CF), total-true fatty acids (T-TFAs), corresponding energy values, classic fatty acid indices, and nutritional quality indices. Among the classic fatty acid indices, the following were observed: CF was low, other lipids were low, edible fatty (T-TFAs) acids were low, and energy density was low; percentage levels of ∑SFA (low), ∑MUFA (high), ∑TFA (ultra-trace), ∑n-6 + n-3 PUFA/∑UFA (high), EPA and DHA (reasonably advantageous nutritionally). Significant differences existed in the compared pairs of the classic fatty acid values: whole organism/flesh (W/F), flesh/shell (FS), and whole organism/shell (W/S); with high IFE, thereby making food properties interchangeable between pairs. The nutritional quality indices showed the samples' oil to be nutritionally good for favorable health reasons. These were as follows: low AI, low TI, high HH, high HPI, high UI, average levels of EPA +DHA and FLQ, low level of n-6/n-3, insignificant ultra-trace TFA, PI highly comparable to literature values and > 0.4 value in PUFA/SFA. In particular, AI and TI were better than in the Eskimo diet. The LA/ALA ratios were very poor and foods high in ALA would be required to adjust to low levels in the LA/ALA ratio values. On the whole, the oil in P*andalus borealis is* good for human consumption.

REFERENCES

[1] Wikipedia. Shrimp-Wikipedia en.m.wikipedia.org

[2] Shrimp. Encyclopedia Britannica. Retrieved 20 August 2012. Written by: The Editors of Enclopedia Bratannica. Last updated: May 25, 2023 Shrimp/crustacean/Britannica britannica.com

[3] J. Rudloe, A. Rudloe. Shrimp: The endless quest for pink gold. FT Press, Upper Saddle River, New Jersy, USA, Chapter 2, 12-32(2009).

[4] R.T. Bauer. Remarkable shrimps: Adaptation and natural history of Carideans. University of Oklahoma Press, Norman, USA, Chapter 1, pp. 3-14(2004).

[5] Shrimp. Definition of shrimp – Oxford Dictionaries (British and World English). Retrieved 18 August 2012. Web.archive.org

[6] Prawn. Definition of prawn - Oxford Dictionaries (British and World English). Retrieved 18 August 2012. Web.archive.org

[7] S. De Grave, Y. Cai, A. Anker. Estelle Virginia Balian; C. Lé vêque; H. Segers; K. Martens (eds.). Global diversity of shrimps (Crustacea: Decapoda: Caridea) in freshwater. Hydrobiologia. Freshwater Animal Diversity Assessment. 595, 287-293(2008).

[8] F. A. Chace, Jr., D. P. Abbott. Caridea: the shrimp. In R. H. Morris, D. P. Abott, E. C. Haderlie (eds.). Intertidal Invertebrates of California. Stanford University Press, 567 – 576 (1980).

[9] A. J. Bruce. The occurrence of the semi-terrestrial shrimps M*erguia oligodon (De* Man 1888) and M. *rhizosphorae (Rat*hbun 1900) (Crustacea Decapoda Hippolytidae) in Africa. Tropical Zoology 6(1), 179-187 (1993).

[10] M. A. Vannini, A. Oluoch. Notes on M*erguia oligodon (De* Man 1888) the Indo-Pacific semi-terrestrial shrimp (Hippolytidae Natantia). Tropical Zoology 6(2), 281-286 (1993).

[11] Palaeos – Wikipedia Decapoda. Palaeos. Retrieved 20 August 2012. en. m' Wikipedia.org

[12] S. De Grave, C. H. J. M. Fransen. Carideorum Catalogus: The recent species of the Dendrobrachiate, Stenopodidean, Procarididean and Cariedean Shrimps (Crustacea: Decapoda). Zoologische Mededelingen 85, 195-589, figs. 1-59 (2011).

[13] Shrimp. Glossary of aquaculture. Retrieved 24 August 2012.

[14] Codex Alimentarius Commission. Codex Alimen-

tarius: Code for practice for fish and fishery products. Joint FAO and WHO Food Standards Programme, Rome, p.10, (2009).
[15] FAO species catalogue, (1980).
[16] FAO species catalogue, p.46, (1980).
[17] P*enaeus vannamei (Bo*one 1931). List of fishery statistics purposes. FAO, Species Fact Sheet. Retrieved June 2012.
[18] S. De Grave. Li*topenaeus vannamei (Bo*one 1931). WoRMS name details. WoRMS, World Register of Marine Species. Retrieved 2018-07-25.
[19] FAO species catalogue, p.50, (1980).
[20] P*enaeus monodon (Fa*bricius 1798). List of species for fishery statistics purposes. FAO, Species Fact Sheet. Retrieved June 2021.
[21] S. De Grave. P*enaeus monodon (Fab*ricius 1798). WoRMS name details. WoRMS, World Register of Marine Species, (2010). Retrieved 2018-07-25.
[22] FAO species catalogue, p.65, (1980).
[23] A*cetes japonucas (Kis*hinouye 1905). List of species for fishery statistics purposes. FAO, Species Fact Sheet. Retrieved June 2012.
[24] S. De Grave. A*cetes japonicas Kis*hinouye 1905. WoRMS name details. WoRMS, World Register of Marine Species, (2010). Retrieved 2018-07-25.
[25] FAO species catalogue, p.53, (1980).
[26] T*rachysalambria curvirostris (Sti*mpson 1860). List of species for fishery statistics purposes. FAO, Species Fact Sheet. Retrieved June 2012.
[27] C.Fransen, M. Turkay. T*rachysalambria curvirostris (Sti*mpson 1860). WoRMS name details. WoRMS, World Register of Marine Species, (2010). Retrieved 2018-07-25.
[28] P*enaeus chinensis (Osb*eck1765). List of species for fishery statistics purposes. FAO, Species Fact Sheet. Retrieved June 2012.
[29] FAO species catalogue, 41-42, (1980).
[30] S. De Grave. F*enneropenaeus chinensis (Os-b*eck1765). WoRMS name details. WORMS, World Register of Marine Species, (2010). Retrieved 2018-07-25.
[31] P*enaeus merguiensis (De* Man 1888). List of species for fishery statistics purposes. FAO, Species Fact Sheet. Retrieved June 2012.
[32] FAO species catalogue, p.43, (1980).
[33] S. De Grave Fenneropen*aeus merguiensis (De* Man 1888). WoRMS name details. WoRMS, World Register of Marine Species, (2010). Retrieved 2018-07-25.
[34] FAO species catalogue, 138-139, (1980).
[35] P*andalus borealis (Krø*yer 1838). List of species for fishery statistics purposes. FAO, Species Fact Sheet. Retrieved June 2012.
[36] M. Turkay. P*andalus borealis (Krø*yer 1838). WoRMS name details. WoRMS. World Register of Marine Species. Retrieved 2018-17-25.
[37] A. Davidson. The Oxford Companion to Food. Oxford University Press Inc., New York, USA. (Shrimp), p.722, (1999).
[38] A. Davidson. The Oxford Companion to Food. Oxford University Press Inc., New York, USA. (Blacang), p.78, (1999).
[39] D. Hartley. Food in England. Macdonald, London, UK, (1954).
[40] Y. C. Skang, P. Leung, Bith-Hong Ling. Comparative economis of shrimp farming in Asia. Aquaculture 164(1-4), 183-200 (1998).
[41] K. L. Smith, J.L. Gentzel. Mercury concentrations and omega-3 fatty acids in fish and shrimp: preferential consumption for maximum health benefits. Marine Pollution Bulletin 60(9), 1615-1618 (2010).
[42] Cholesterol Content in Seafoods. Retrieved January 7, 2007.
[43] E. R. De Oliveirae Silva, C. E. Seidman, J. J. Tian, L. C. Hudgins, F. M. Sacks, J. L. Breslow. Effects of shrimp consumption on plasma lipoproteins. American Journal if Clinical Nutrition 64(5), 712-717 (1996).
[44] H. Krøyer. Conspectus Crutaceorum Groenlandiae. Naturhistorisk Tidsckrift 2(3), 249-261.
[45] DecaNet eds. DecaNet. P*andalus borealis Krøy*er 1838. Accessed through: World Register of Marine Species at https://www.marinespecies.org/aphia.php? P=taxdetails & id=107649 on 2023-07-02.
[46] E.I. Adeyeye. Amino acid profiles of whole organism, flesh and shell of P*andalus borealis (Krø*yer 1838). American Journal of Food Science and Nutrition 2(3), 31-41 (2015).
[47] E.I. Adeyeye. The lipid composition profiles as contributed by the whole organism, flesh and shell of P*andalus borealis shri*mp and their nutritional values. EC NUTRITION 8.4, 124-144 (2017).
[48] E.B. Rimm, L.J. Appel, S.E. Chiuve, L. Djoussé, M.B. Engler, P.M. Kris-Etherton, D.Mozaffarian, D.S. Siscovick, A.H. Lichtenstein. Seafood long-chain n-3 polyunsaturated fatty acids and cardiovascular disease: A science advisory from the American Heart Association. Circulation 138, 35-47 (2018).
[49] Z. Naeini, O. Toupchian, A. Vatannejad, G. Sotoudeh, M. Teimouri, M. Ghorbani, E. Nasli-Esfahani, F. Koohdani. Effects of DHA-enriched fish oil on gene expression levels of p53 and NF-kB and PPAR-? activity in PBMCs of patients with T2DM: A randomised, double-blind, clinical trial. Nutr. Metab. Cardiovasc. 30, 441-447, (2020).
[50] J. K. Bird, P. C. Calder, M. Eggersdorfer. The role of n-3 long chain polyunsaturated fatty acids in cardiovascular disease prevention and interactions with statins. Nutrients 10, 775, (2018).
[51] Y. Tomata, S. C. Larsson, S. Hägg. Polyunsaturated fatty acids and risk of Alzheimer's disease: A Mendelian randomization study. Eur. J. Nutr. 59,

1763-1766, (2020).
[52] J.P. Chang, S. Chang H. Yang, H. Chien, Y, Chien, B. Yang, H. Su, K. Su. Omega-3 polyunsatureted fatty acids in cardiovascular diseases comorbid major depressive disorder-results from a randomized controlled trial. Brain Behav. Immun. 85, 14-20, (2020).
[53] L. Chen, Y. Wang, Q. Xu, S. Chen. Omega-3 fatty acids as a treatment for non-alcoholic fatty liver disease in children: A systematic review and meta-analysis of randomized controlled trials. Chlin. Nutr. 37, 516-521, (2018).
[54] N. Monga, G. S. Sethi, K. K. Kondepudi, A. S. Naura. Lipid mediators and asthma: Scope of therapeutics. Biochem. Pharmacol. In press, (2020).
[55] J. Chen, H. Liu. Nutritional indices for assessing fatty acids: A mini-review. Int. J. Mol. Sci. 21, 5695, (2020).
[56] J. M. Dietschy. Dietary fatty acids and the regulation of plasma low density lipoprotein cholesterol concentrations. J. Nutr. 128, 444-448, (1998).
[57] T. Ulbricht, D. Southgate. Coronary heart disease: seven dietary factors. Loncet 338, 985-992, (1991).
[58] B. Omri, R. Chalghoumi, L. Izzo, A. Ritieni, M. Lucarini, A. Durazzo, H. Abdouli, A. Santini. Effect of dietary incorporation of linseed alone or together with tomato-red pepper mix on laying hens' egg yolk fatty acids profile and health lipid indexes. Nutrients 11, 813, (2019).
[59] S. Yurchenko, A. Sats, V. Tatar, T. Kaart, H. Mootse, I. Jöudu. Fatty acid profile of milk from Saanen and Swedish Landrace goats. Food Chem. 254, 326-332, (2018).
[60] J. Santos-Silva, R. Bessa, F. Santos-Silva. Effect of genotype, feeding system and slaughter weight on the quality of light lambs: II. Fatty acid composition of meat. Livest. Prod. Sci. 77, 187-194, (2019).
[61] D. Mierlitä. Effects of diets containing hemp seeds or hemp cake on fatty acid composition and oxidative stability of sheep milk. S. Afr. J. Amin. Sci. 48, 504-515, (2018).
[62] S. Chen, G. Bobe, S. Zimmerman, E. G. Hammond, C. M. Luhman, T. D. Boylston, A.E. Freeman, D.C. Beitz. Physical and sensory properties of diary products from cows with various milk fatty acid compositions. J. Agric. Food. Chem. 52, 3422-3428, (2004).
[63] J. A. Logue, A. L. De Vries, E. Fodor, A. R. Cossina. Lipid compositional correlates of temperature-adaptive interspecific differences in membrane physical structure. J. Exp. Biol. 203, 2105-2115, (2000).
[64] G. C. Burdge, A. E. Jones, S. A. Wootton. Eicosapentaenoic and docosapentaenoic acids are the principal products of ?-linolenic acid metabolism in young men. Br. J. Nutr. 88, 355-363, (2002).
[65] G. Abrami, F. Natiello, P. Bronzi, D. McKenzie, L. Bolis, E. Agradi. A comparison of highly unsaturated fatty acid levels in wild and farmed eels. (An*guilla anguilla). C*omp. Biochem. Physiol. 101, 79-81, (1992).
[66] J. Luczyńska, B. Paszczyk, J. Nowosad, M. J. Luczyński. Mercury, fatty acids content and lipid quality indexes in muscles of freshwater and marine fish on the Polish market. Risk assessment of fish consumption. Int. J. Environ. Res. Public Health 14, 1120, (2017).
[67] Food and Drug Administration, H. Final determination regarding partially hydrogenated oils. Notification: declaratory order; extension of compliance date. Fed. Regist. 83, 23358-233589, (2018).
[68] A. L. Lock, B. A Cori, D. M. Barbano, D. E. Bauman, C. Ip. The anticarcinogenic effect of t*rans -11 1*8:1 is dependent on its conversion to cis-9, t*rans -11* CLA by Δ9-desaturase in rats. J. Nutr. 134, 2698-2704, (2004).
[69] D. Kritchevsky, S. A. Tepper, S. Wright, S. K. Czarnecki, T. A. Wilson, R. J. Nicolosi. Conjugated linoleic acid isomer effects in atherosclerosis: Growth and regression of lesions. Lipids 39, 611, (2004).
[70] J. X. Kang. The importance of omega -6/omega-3 fatty acid ratio in cell function. The gene transfer of omega -3 fatty acid desaturase. In: Omega-6/omega-3 Essential Fatty Acid Ratio: The Scientific Evidence; Simopoulos, A. P., Cleland, L. G., Eds; Karger: Basel, Switzerland 92, 23-36, (2003).
[71] A. P. Simopoulos. The importance of omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. Exp. Biol. Med. 233, 674-688, (2008).
[72] D. Kromhout, J. de Goede. Update on cardiometabolic health effects of omega-3 fatty acids. Curr. Opin. Lipidol. 25, 85-90, (2014).
[73] N. Kromann, A. Green. Epidemiological studies in the Upernavik district, Greenland. Incidence of some chronic diseases 1950-1974. Acta Med. Scand. 208, 401-406, (1980).
[74] C. D. Schraer, P. M. Risica, S. O. Ebbesson, O. T. Go, B. V. Howard, A. M. Mayer. Lowfasting insulin levels in Eskimos compared to American Indians: are Eskimos less insulin resistant. Int. J. Circumpolar Health 58, 272 – 280, (1999).
[75] H. Greenfield, D. A. T. Southgate. Food Composition Data: Production, Management and Use. Food and Agriculture Organization of the United Nations, (2003).
[76] FAO. FAO/INFOODS Density database version 2.0. FAO, Rome, (2012).
[77] C. I. Chase. Elementary Statistical Procedures, 2nd ed. McGraw-Hill Kogakusha Ltd, Tokyo, Japan, (1976).

[78] C. Nantapo, V. Murchenje, A. Hugo. Atherogenecity index and health-related fatty acids in different stages of lactation from Friesian, Jersey and Friesian x Jersey cross cow milk under a pasture-based dairy system. Food Chem. 146, 127-133, (2014).
[79] S. L. Akintola. Effects of smoking and sun-drying on proximate, fatty and amino acids composition of southern pink shrimp (P*enaeus notialis). J*. Food Sci. Technol. 52, 2646-2656, (2015).
[80] M. Kumar, P. Kumari, N. Trivedi, M. K. Shukla, V. Gupta, C. Reddy, B. Jha. Minerals, PUFAs and antioxidant properties of some tropical seaweeds from Saurashtra coast of India. Appl. Phycol. 23, 797-810, (2011).
[81] S. Calabrò, M. I. Cutrignelli, V. Lo Presti, R. Tudisco, V. Chiofalo, M. Grossi, F. Infascelli, B. Chiofalo. Characterization and effect of year of harvest on the nutritional properties of three varieties of white lupine (L*upinus albus L.)*. J. Sci. Food Agric. 95, 3127-3136, (2015).
[82] H. Hosseini, M. Mahmoudzadeh, M. Rezaei, L. Mahmoudzadeh, R. Khaksar, N. K. Khosroshah, A. Babakhani. Effect of different cooking methods on minerals, vitamins and nutritional quality indices of k*utum roach (Rutilus fristii kutum). F*ood Chem. 148, 86-91, (2014).
[83] N. Ahmad, M. F. Manzoor, U. Shabbir, S. Ahmed, T. Ismail, F. Saeed, M. Nisa, F. M. Anjum, S. Hussain. Health lipid indices and physicochemical properties of dual fortified yogurt with extruded flaxseed omega fatty acids and fibres for hypercheolesterolemic subjects. Food Sci. Nutr. 8, 273-280, (2019).
[84] J. Chen, H. Liu. Nutritional indices for assessing fatty acids: A mini-review. Int. J. Mol. Sci. 21, 5695, (2020).
[85] Z. Chen, Y. Xu, T. Liu, L. Zhang, H. Liu, H. Guan. Comparative studies on the characteristic fatty acid profiles of four different Chinese medicinal S*argassum sea*weeds by GC-MS and chemometrics. Mar. Drugs 14, 68, (2016).
[86] S. Pandey, M. K. Patel, A. Mishra, B. Jha. Physio-biolchemical composition and untargeted metabolics of cumin C*uminum cyminum L.)* make it promising functional food and help in mitigating salinity stress. PLoS ONE 10, e0144469, (2015).
[87] I. B. Tonial, D. F. Oliveira, A. R. Coelho, M. Matsushita, F. A. G. Coró, N. E. De Souza, J. V. Visentainer. Quantification of essential fatty acids and assessment of the nutritional quality indexes of lipids in tilapia alevins and jivenle tilapia fish (O*reochromis niloticus). J*. Food Res. 3, 105-114, (2014).
[88] A. Winiarska – Mieczan, M. Kwiecień, K. Kwiatkowska, E. Baranowska-Wójcik, D. Szwajgier, E. Zaricka. Fatty acid profile, antioxidative status and dietary value of the breast muscle of broiler chickens receiving glycine-Zn chelates. Anim. Prod. Sci. 60, 1095-1102, (2020).
[89] E. Vargas-Bello-Perez, G. Íñiguez-González, K. Fehrmann-Cartes, P. Toro-Mujica, P. C. Garnsworthy. Influence of fish oil alone or in combination with hydrogenated palm oil on sensory characteristics and fatty acid composition of bovine cheese. Anim. Feed Sci. Technol. 205, 60-68, (2015).
[90] L. Paiva, E. Lima, A. I. Neto, M. Marcone, J. Baptista. Health-promoting ingredients from four selected Azorean macroalgae. Feed Res. Int. 89, 432-438, (2016).
[91] K. Ratusz, E. Symoniuk, M. Wroniak, M. Rudzińska. Bioactive compounds, nutritional quality and oxidative stability of cold-pressed Camelina (C*amelina sativa L.)* oils. Appl. Sci. 8, 2606, (2018).
[92] JM. Á. Rincón-Cervera, V. González-Barriga, J. Romero, R. Rojas, S. López-Arana. Quantification and distribution of omega-3 fatty acids in south pacific fish and shellfish species. Foods 9, 233, (2020).
[93] C. E. Fernandes, M. A. Da Silva Vasconcelos, M. de Almeida Ribeiro, L. A. Sarubbo, S. A. C. Andrade, A. B. de Melo Filho. Nutritional and lipid profiles in marine species from Brazil. Food Chem, 160, 67-71, (2014).
[94] K. M. Wójciak, D. M. Stasiak, K. Ferysiuk, E. Solska. The influence of sonication on the oxidative stability and nutritional value of organic dry-fermented beef. Meat Sci. 148, 113-119, (2019).
[95] S. Ivanova, L. Angelov. Assessment of the content of dietary t*rans fat*ty acids and biologically active substances in cow's milk and curd. Generations 4, 5, (2017).
[96] M. L. Colombo, P. Rise, F. Giavarini, L. De Angelis, C. Galli, C. L. Bolis. Marine macroalogae as sources of polyunsaturated fatty acids. Plant Foods Human. Nutr. 61, 64-69, (2006).
[97] P. T. Chan, P. Matanjun. Chemical composition and physicochemical properties of tropical red seaweed, G*racilaria changii. F*ood Chem. 221, 302-310, (2017).
[98] J. Segura, R. Escudero, M. R. de Ávila, M. I. Cambero, C. J. López-Bote. Effect of fatty acid composition and positional distribution within the triglyceride on selected physical properties of dry-cured ham subcutaneous fat. Meat Sci. 103, 90-95, (2015).
[99] C. E. Realini, M. Pérez-Juan, P. Gou, I. Diaz, C. Sárraga, P. Gatellier, J. A. Garcia-Regueiro. Characterization of L*ongissimus thoracis, Semitendinosus and Masseter mus*cles and relationships with technological quality in pigs. 2. Composition of muscles. Meat Sci. 94, 417-423, (2013).
[100] M. Rodriguez, R. M. Garcia-Garzia, M. Arias-Álvarez, P. Millán, N. Febrel, N. Formoso-Rafferty, J.

Lopéz-Tello, P. L. Lorenzo, P. G. Rebollar. Improvements in the conception rate, milk composition and embryo quality of rabbit does after dietary enrichment with n-3 polyunsaturated fatty acids. Animal 12, 2080-2088, (2018).
[101] J. D. Wood, M. Enser, A. V. Fisher, G. R. Nute, P. R. Sheard, I. Richardson, S. I. Hughes, F. M. Whittington. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci. 78, 343-358, (2008).
[102] S. B. Eaton, M. Konner. Paleolithic nutrition. A consideration of its nature and current implications. N. Engl. J. Med. 312, 283-289, (1985).
[103] A. P. Simopoulos, N. Salem, Jr. Egg yolk as a source of long polyunsaturated fatty acids in infant feeding. Am. J. Clin. Nutr. 55, 411-414, (1992).
[104] A. P. Simopoulos. An increase in the omega-6/omega-3 fatty acid ratio increases the risk for obesity. Nutrients 8, 128, (2016).
[105] European Food Safety Authority (EFSA). Opinion of the scientific panel on dietetic products, nutrition and allergies on a request from the commission related to the presence of tr*ans fatt*y acids in foods and the effect on human health of the consumption of tr*ans fatt*y acids. EFSA 81, 1-49, (2004).
[106] D. M. Brogna, S. Nasri, H. B. Salem, M. Mele, A. Serra, M. Bella, A. Priolo, H. Makkar, V. Vasta. Effect of dietary saponins from Qu*illaja saponaria L.* on fatty acid composition and cholesterol content in muscle L*ongissimus dorsi of* lambs. Animal 5, 1124-1130, (2011).
[107] P. Skalecki, A. Kaliniak-Dziura, P. Domaradzki, M. Florek, M. Kepka. Fatty acid composition and oxidative stability of the lipid fraction of skin-on and skinless fillets of prussian carp (C*arassius gibelio). A*nimals 10, 778, (2020).
[108] D. Farajzadeh Alan, M. H. Naeli. M. Naderi, S. M. Jafari, H. R. Tavakoli. Production of tr*ans- fr*ee fats by chemical interesterified blends of palm stearin and sunflower oil. Food Sci. Nutri. 7, 3722-3730 (2019).
[109] V. Razmaité, V. Pileckas, S. Bliznikas, A. Šiukščius. Fatty acid composition of C*anabis sativa, Linum usitatissimum and Camelina sativa see*ds harvested in Lithuania for food use. Foods 10, 1902, (2012).
[110] M. J. Kang, M. S. Shin, J. N. Park, S.S. Lee. The effects of polyunsaturated fatty acids ratios and peroxidisability index values of dietary fats on serum lipid profilies and hepatic enzyme activities in rats. Brit. J. Nutr. 94, 526-532, (2005).
[111] M. Grajzer, K. Szmalcel, L. Kuźmiński, A. Kulma, A. Prescha. Characteristics and antioxidant potential of cold-pressed oils – Possible strategies to improve oil stability. Foods 9, 1630, (2020).
[112] ResearchGate, https://www.researchgate.net>figure; Bernacchia et al., (2014).
[113] F. H. Chilton, R. Dutta, L. M. Reynolds, S. Sergeant, R. A. Mathias, M. C. Seeds. Precision nutrition and omega-3 polyunsaturated fatty acids: A case for personalised supplementation approaches for the prevention and management of human diseases. Nutrients 9, 1165, (2017).