CHEMICAL COMPOSITION OF WHOLE SHRIMP, FLESH AND SHELL OF *Pandalus borealis* FROM LAGOS ATLANTIC OCEAN

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Abstract: Shrimps are eaten either whole (shell + flesh) after drying or as flesh alone (when fresh). The purpose of this work is to document data on the proximate, mineral compositions, mineral ratios and mineral safety index (MSI) of the whole shrimp, shell and flesh *Pandalus borealis*. High proximate values (g kg^{-1}): total solid (958.1-980.0); ash (295.0-310.0); protein (171.9-191.0); organic matter (690.0-705.0); carbohydrate (464.0-485.0) but low in ether extract (8.00 - 13.1), fibre (0.10-0.20). Energy ranged from 11431-11648.3 kJ kg^{-1}, utilization of 60% of proportion of energy due to protein per cent was 1 5.1 -17.0. Values of Ca, Mg, K, Na and P were high to very high but values were low to very low in Fe, Cu, Co, Mn, Zn, Pb, Se, Cd and Ni. In MSI, Mg, P and Ca were higher than the recommended standards in all the samples. The proximate trend observed: shell > flesh > whole shrimp in protein, organic matter and UEDP%. The minerals depicted signs of pollution in Mg, P, Ca and Na only in shell. Only 3.3/11(30.0%) in the mineral ratios were within standard. Shell of *P. borealis* was a good source of both protein and minerals.

Keywords: Composition; Lagos Atlantic Ocean; *Pandalus borealis*

Introduction

Shrimps are widespread, they can be found near the seafloor of most coast and estuaries, as well as in rivers and lakes (Rudloe & Rudlee, 2010). Most shrimp species are marine, about a quarter of the described species are found in fresh water (Bauer, 2004). Marine species are found at depths up to 5000 metres (16000 ft), and from the tropics to the Polar Regions. Shrimps are eaten by various animals, particularly fish and seabirds and frequently host bopyrid parasites (Bauer, 2004). They play important roles in the food chain and are important food sources for larger animals from fish to whales. The muscular tails of shrimp can be delicious to eat, and they are widely caught and farmed for human consumption.

All shrimp of commercial interest belong to the Natantia. The FAO determine the categories and terminology used in the reporting of global fisheries. They define a shrimp as a "decapod crustacean of the suborder Natantia"(De Grawe *et al*., 2008). 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 (Chace & Abbott, 1980). In turn, 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 (*Shrimp Glossary of Aquaculture*; Retrieved 24 August, 2012).

The species under study is Northern prawn, *Pandalus borealis* Krøyer, 1838. PANDL, Pandal 1. *Pandalus borealis* Kroyer, 1838, Naturhist. Tidsskr., 2:254 (Codex Alimentarius Commission, 2009). Synonymy: *Dymas typus* high Krøyer, 1861; *Pandalus borealis typica* Retovsky, 1946. FAO Names: Northern shrimp (En), Crevette nordique (Fr), Camerón norte ло (Sp). Widely fished since the early 1900s in Norway and later in other countries following Johan Hjort's practical discoveries of how to locate them. Habitat: depth 20 to 1380 m (Holthuis, 1980). Bottom clay and mud and it is marine (PANDL Pandal 1-FAO.Orgftp://ftp.fao.org/decrep/fao.009/.../AC477E22.pdf. Retrieve April, 2015). Size: Maximum total length 120 mm (♂), 165 mm (♀) (*Shrimp. Glossary of Aquaculture*. Retrieved 24 August 2012).

Shrimps, caught from fresh, marine and brackish waters and ponds of various types have become delicacies in Nigeria. They are eaten either whole (shell + flesh) after drying or as flesh alone (when fresh). Available information is lean on the chemical composition of shrimps found in Nigeria. The amino acid profiles of the various body parts of *Pandalus borealis* had recently been published (Adeyeye, 2015). The purpose of this paper is to document the data on the proximate and mineral compositions, mineral ratios and mineral safety index (MSI) of the whole shrimp, the flesh (endoskeleton) and the shell (exoskeleton, i.e. shell + head) of *Pandalus borealis* Krøyer, 1838. This information may improve information of the food composition table.

Materials and Methods

Collection of samples

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 contaminant and drained under folds of filter paper. Samples were collected in crushed ice in insulated containers and brought to the laboratory for identification and preservation prior to analysis. The shrimps were wrapped in aluminium foil and frozen at -4°C for 2-3 days before analysis was carried out.

Sample treatment

After defrosting, for about one hour, whole shrimps (head-on) were divided into two parts: one-third whole, two-third separated into flesh and outer shell (exoskeleton) after beheading. The various parts were dried at 105°C and blended.

Sample digestion

Samples that ranged from 0.2278 to 0.9720 g were weighed accurately prior to digestion. Two millilitres of concentrated nitric acid was added to each sample in a beaker, which was covered with a watch glass and allowed to stand overnight in a fume cupboard. The beakers were heated gently on a hotplate until frothing stopped and no visible solid material was observed.

Heating was continued at a temperature of about 75°C to near dryness. The digests were removed and covered with glasses. Two millilitres of 50 g l^{-1} lanthanum chloride solution was added and the beakers were heated for a second time until dryness. Each of the final solution was washed into a 25- ml standard flask with 0.1M HNO_3 (10 ml) and made up to the mark with distilled de-ionised water (Varian Techtron, 1975; Harper *et al*., 1989). All the digested samples were sub-sampled into pre-cleaned borosilicate glass containers for atomic absorption spectrophotometer analysis.

Sample analysis

Moisture, total ash, fibre and ether extract of the samples were determined by the methods of the AOAC (AOAC, 2006). Nitrogen was determined by a micro-Kjeldahl method (Pearson, 1976) and the crude protein content was calculated as N x 6.25. Standards of Fe, Cu, Co, Mn, Zn, Pb, Ni, Cd, Se, Ca, Mg, K and Na solutions of 0.2, 0.4, 0.6, 0.8 and 1.0 mg l^{-1} were made from each of the metal solution of 1000 mg l^{-1} stock solutions and the filtrate of the digested samples were analysed by AAS. The detection limit of the metals in the sample was 0.0001 mg l^{-1} by means of the UNICAM 929, London, atomic absorption spectrophotometer powered by the solar software. The optimal analytical range was 0.1 to 0.5 absorbance units with coefficient of variation from 0.9 % to 2.21 %. P was determined colorimetrically (Pearson, 1976) using a Spectronic 20 (Gallenkamp, London, UK) instrument, with KH_2P0_4 as a standard. All determinations were made in duplicate. All chemicals used were of analytical grade, and were obtained from British Drug Houses (BDH, London, UK). All the results were on dry weight basis.

Statistical analysis

Data obtained were subjected to statistical evaluation (Oloyo, 2001). Parameters evaluated for were correlation coefficient (r_{xy}), variance (r_{xy}^2), regression coefficient (R_{xy}), coefficient of alienation (C_A) and index of forecasting efficiency (IFE). Standard deviations and coefficient of variation per cent were also calculated.

Results and Discussion

Table 1 shows the proximate composition of the shrimp samples. Fibre is low at values of 0.10-0.20 g kg^{-1} in the samples. The protein is high at values of 171.9-191.0 g kg^{-1} with the shell + head contributing the highest value. The protein of shrimps has been found to be of high quality similar to that of meat and fish. The protein efficiency ratio (PER) is of the order of 2.2 and the biological value (BV) 0.75-0.85 (Muller & Tobin, 1980). In *P. borealis*, the calculated PER and BV have respective values of 1.65-2.12 and 75.0-96.6 (Adeyeye, 2015). This means that *P. borealis* can substitute for meat and/or fish. The protein from the samples may be appropriate as a weaning food for children since fibre content is very low. The ether extract is generally low at 8.00-13.1 g kg^{-1}. This means *P. borealis* will be good for people who are very conscious of their fat intake from food sources. The ash content varies from 295.0-310.0 g kg^{-1}, this could be described as being high; this could likely be due to high levels of chitin and calcium. The ash levels in *P. borealis* compares favourably with levels of 245.6-320.3 g kg^{-1} in three different types of prawns from Lagos lagoon (Adeyeye & Adubiaro, 2004). The carbohydrate levels were high (464.0-485.0 g kg^{-1}) and next to total solid (958.1-980.0 g kg^{-1}) and organic matter (690.0-705.0 g kg^{-1}). The carbohydrate levels in *P. borealis* are much higher than in the literature values (g kg^{-1}): *Macrobrachium vollenhovenii* [shell + head (39.4), flesh (16.1)]; *Palaemon* species A [shell + head (19.4), flesh (7.1)] and *Penaeus notialis* [shell+head (46.3), flesh (8.1)](Adeyeye & Adubiaro, 2004).The coefficient of variation (CV%) values are low except in moisture and fibre whose values are slightly above 40.0%.

Table 1: Proximate composition (g kg^{-1}) of *Pandalus borealis*

Parameter	Whole shrimp	Flesh	Shell + head	Mean	SD*	CV%†
Moisture	20.0	24.0	41.9	28.6	11.7	40.7
Total solid	980.0	976.0	958.1	971.4	11.7	1.20
Ash	310.0	307.8	295.0	304.3	8.10	2.66
Organic matter	690.0	692.2	705.0	695.7	8.10	1.16
Crude protein	171.9	183.0	191.0	182.0	9.59	5.27
Ether extract	13.0	13.1	8.00	11.4	2.92	25.7
Fibre	0.10	0.20	0.10	0.1333	0.060	43.3
Carbohydrate	485.0	471.9	464.0	473.6	10.6	2.24

*SD = standard deviation. †CV % = coefficient of variation. All determinations on dry weight basis

Table 2: Differences in proximate composition of the *Pandalus borealis* samples

Parameter	Whole shrimp-flesh	Whole shrimp - shell +head	Flesh - shell + head
Moisture	-4.00 (-20.0%)	-21.9 (-109.5%)	-17.9 (-74.6%)
Total solid	+4.00 (+0.408%)	+21.9 (+2.23%)	+17.9 (+1.83%)
Ash	+2.20 (+0.710%)	+15.0 (+4.84%)	+12.8 (+4.16%)
Organic matter	-2.20 (-0.319%)	-15.0 (-2.17%)	-12.8 (-1.85%)
Crude protein	-11.1 (-6.46%)	-19.1 (-11.1%)	-8.00 (-4.37%)
Ether extract	-0.10 (-0.769%)	-5.00 (+38.5%)	+5.10 (+38.9%)
Fibre	-0.10 (-100.0%)	0.00 (0.00%)	+0.10 (+50.0%)
Carbohydrate	+13.1 (+2.70%)	+21.0 (+4.33%)	+7.90 (+1.67%)

\+ = whole shrimp > flesh; - = whole shrimp < either flesh or shell + head as the case may be. Percentages in brackets represent percentage differences. Similar information holds for flesh versus shell + head.

The calculated differences between the proximate composition of whole shrimp versus the flesh, whole shrimp versus the shell + head and flesh versus shell + head are shown in Table 2. In the Table, positive sign preceding the numeral indicates that the value of whole shrimp is greater than the other sample being compared, whereas a negative sign indicates that the whole shrimp value is less than the other sample being compared with; each preceding sign goes for both the numeral before and within the bracket; this information holds also for flesh versus shell + head. In the whole shrimp versus the flesh, 3/8 or 37.5% of the proximate parameters are better concentrated in the whole shrimp than in the flesh, in whole shrimp versus shell+head, 4/7 (fibre is 0.00 or 0.00 %) or 57.1 % are better concentrated in whole shrimp whereas in flesh versus shell + head, 5/8 or 62.5 % are more concentrated in the flesh than shell + head. On the whole, the proximate parameter concentration trend is whole shrimp > flesh > shell + head.

The energy contribution due to ether extract, protein and carbohydrate to the total metabolizable energy in *P. borealis* can be seen in Table 3. Total energy range is 11431 - 11648.3 kJ kg^{-1}; this shows that *P. borealis* is a lean source of concentrated energy. Fat contributed the least energy thereby making the shrimp a nutritional friend of the heart. The utilizable energy due to protein (UEDP%) ranges between 15.1 and 17.0 (assuming 6% of protein utilization). This is higher than the recommended safe level of 8% for an adult man who requires about 55 g protein per day with 60% utilization. The UEDP % in *Callinectes latimanus* (a lagoon crab) is 17.1(Adeyeye *et al*., 2014) almost similar to the value of 17.0 in shell + head of *P. borealis*. The entire CV% are low ranging from 1.02 – 25.7.

Table 3: Proportion of percentage energy contribution from ether extract, protein and carbohydrate to total energy from *Pandalus borealis*

Parameter	Whole shrimp	Flesh	Shell + head	Mean	SD	CV %
Total energy (E in kJ kg^{-1})	11648.3	11618	11431	11565.8	118	1.02
PEF % (E in kJ kg^{-1})	4.13 (481)	4.17(484.7)	2.59(296)	420.6	108	25.7
PEP % (E in kJ kg^{-1})	25.1 (2922.3)	26.8 (3111)	28.4(3247)	3093.4	163	5.27
PEC % (E in kJ kg^{-1})	70.8 (8245)	69.1 (8022.3)	69.0 (7888)	8051.8	180	2.24
UEDP %	15.1	16.1	17.0	16.1	0.9504	5.92

PEF = proportion of total energy due to fat. PEP = proportion of total energy due to protein. PEC = proportion of total energy due to carbohydrate. UEDP = utilization of 60 % of PEP %.

Table 4: Statistical analysis of the data from Table 1 pertaining to proximate composition of *Pandalus borealis*

Statistics	Whole shrimp/Flesh		Whole shrimp/Shell +head		Flesh/Shell +head	
	Whole shrimp	Flesh	Whole shrimp	Shell +head	Flesh	Shell + head
r_{xy}	0.9998		0.9989		0.9995	
r_{xy}^2	0.9997		0.9979		0.9989	
R_{xy}	2.30		6.49		4.12	
Mean	333.8	333.5	333.8	332.9	333.5	332.9
SD	359.9	357.3	359.9	352.4	357.3	352.4
CV %	107.8	107.1	107.8	105.8	107.1	105.8
C_A	0.0178		0.0454		0.0328	
IFE	0.9822		0.9546		0.9672	
Remark	*		*		*	

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 $_{= 0.01}$ (critical value = 0.834). (NOTE: n-2 = 8-2 =6.)

The summary of the statistical analysis of the data from Table 1 is shown in Table 4. The correlation coefficient (r_{xy}) values and other parameters are for whole shrimp/flesh, whole shrimp/shell + head and flesh/shell + head. All the r_{xy} values were positively high (0.9989-0.9998). All the r_{xy} values are also significantly different since their r_{xy} values are individually greater than the critical Table value at r $_{= 0.01}$. The regression coefficient (R_{xy}) is positive in all the comparisons with values that range from 2.30-6.49. The variance is generally high (0.9979-0.9997). The values of coefficient of alienation (C_A) and index of forecasting efficiency (IFE) could only be viewed together since the two parameters always affect them simultaneously; this is because C_A + IFE = 1.00 or C_A + IFE = 100%.

For detail explanation of Table 4, a section will just be explained to serve as example for other members of the Table. From Table 1, whole shrimp/flesh has high and positive r_{xy} (0.9998) which is significantly different from each other (i.e. whole shrimp and flesh) at r $_{= 0.01}$. The variance (r_{xy}^2) is high at 0.9997 and a regression (R_{xy}) of 2.30 meaning that for every one unit (g kg $^{-1}$) increase in the proximate composition of the whole shrimp, there is a corresponding increase of just 2.30 in the flesh. The mean of the whole shrimp is 333.8±359.9 g kg^{-1} and CV% of 107.8 whilst the mean for shell + head is 333.5±357.3 and CV% of 107.1. The coefficient of alienation (C_A) is low at 0.0178 (1.78%) but corresponding high value of index of forecasting efficiency (IFE) of 0.9822 (98.22%). The IFE shows that the relationships between whole organism/flesh could easily be predicted because error of prediction is just 1.78% which is relatively low. The IFE is a measure of the reduction in the error of prediction of relationship between two related samples. This explanation goes down for other results.

In Table 5, minerals of major significant levels are (mg kg^{-1}): Ca (115224-172731. 174), Mg (7110.936-8461.809), K (1962.538-2233.562), Na (2241.572-9869.46) and P (19623.398-22142.683); those of moderate values are Fe, Cu, Mn and Zn whereas those with values of < 1.0 mg kg^{-1} each are Co, Pb, Se, Cd and Ni. These minerals: Fe, Cu, Co, Zn, Se and Ni would have to be sourced from other protein (animal) sources when these samples serve as the main source of animal protein. The very low level of Pb (0.002-0.003 mg kg^{-1}) and Cd (<0.001 mg kg^{-1} for each sample) in the samples could be cheering but that they are detected could be due to onset of pollution. The values of Ca, Mg, K, Na and P are just to add to other major sources of the mentioned minerals. If the amount of Ca is adequate in the diet, Fe is utilized to better advantage; this is an instance of sparing action (Fleck, 1976).

Phosphorus is always found with Ca in the body, both contributing to the supportive structures of the body. It is present in cells and in the blood as soluble phosphate ion, as well as in lipids, proteins, carbohydrates and energy transfer enzymes (NAS, 1974). Phosphorus is an essential component in nucleic acids and the nucleoproteins responsible for cell division, reproduction and the transmission of hereditary traits (Hegsted, 1973). Potassium is primarily an intracellular cation, in large part this cation is bound to protein and with sodium influences osmotic pressure and contributes to normal pH equilibrium (Sandstead, 1967). Plants and animal tissues are rich sources of potassium, thus a dietary lack is seldom found. The Ca, Na, K and P in the present samples are as high as observed in three different types of prawns flesh and shell + head (Adeyeye & Adubiaro, 2004). Similar high values of minerals are observed in the following prawns whole organism: Ca (4690-31500 µg g^{-1}) in *M. vollenhovenii*, *Palaemon* species A, *Penaeus notialis* and *Penaeus kerathurus;* Mg (400-2800 µg g^{-1}) in *M. vollenhonii*, *P.* species A, *P. notialis* and *P. kerathurus*; Na (585.06-6255.50 µg g^{-1}), K (881.49-11468.50 µg g^{-1}) and P (6600-19920 µg g^{-1}) in the four whole prawns (Adeyeye, 2000).

Table 5: Mineral composition of the *Pandalus borealis* (at mg kg^{-1} on dry weight basis)

Mineral	Whole shrimp	Flesh	Shell + head	Mean	SD	CV %
Fe	58.074	53.618	63.256	58.316	4.824	8.27
Cu	4.283	3.974	4.826	4.361	0.4313	9.89
Co	0.034	0.031	0.042	0.0357	0.0057	15.9
Mn	12.283	11.172	8.537	10.664	1.924	18.0
Zn	16.594	15.993	13.289	15.292	1.760	11.5
Pb	0.002	0.002	0.003	0.0023	0.0006	24.7
Ca	172731.174	166843.65	115224	151599.608	31639.44	20.9
Mg	8461.809	8112.172	7110.936	7894.97	701.14	8.88
K	1962.538	2014.643	2233.562	2070.25	143.81	6.95
Na	2241.572	2361.672	9869.46	4824.23	4369.71	90.6
P	21093.527	19623.398	22142.683	20953.20	1265.49	6.04
Se	0.127	0.1160	0.102	0.115	0.0125	10.9
Cd	<0.001	< 0.001	<0.001	0.001	0.00	0.00
Ni	0.004	0.003	0.001	0.0027	0.0015	57.3

Table 6: Differences in the mineral concentrations between whole shrimp and flesh, between whole shrimp and shell + head, and between flesh and shell + head pertaining to results from Table 5

Mineral	Whole shrimp-flesh	Whole shrimp – shell +head	Flesh-shell + head
Fe	+4.456(+7.67%)	-5.182(-8. 92%)	-9.638(-18.0%)
Cu	+0.3090(+7.21%)	-0.543(-12.7%)	-0.852(-21.4%)
Co	+0.0030(+8.82%)	-0.008(-23.5%)	-0.011(-35.5%)
Mn	+1.111(+9.05%)	+3.75(+30.5%)	+2.64(+23.6%)
Zn	+0.601(+3.62 %)	+3.31(+19.9 %)	+2.70(+16.9 %)
Pb	0.00(0.00 %)	-0.001(-50.0 %)	-0.001 (-50.0 %)
Ca	+5887.5(+3.41 %)	+57507 (+33.3 %)	+51619.65 (+30.9 %)
Mg	+349.637(+4.13 %)	+1350.873 (+15.96 %)	+1001.236(+12.3 %)
K	-52.105(-2.65 %)	-271.024(-13.8 %)	-218.919 (-10.9%)
Na	-120.1 (-5.36 %)	-7627.888(-340.3 %)	-7507.788 (-317.9 %)
P	+1470.129 (+6.97 %)	-1049.156(-4.97 %)	-2519.285(-12.8 %)
Se	+0.011(+8.66 %)	+0.025 (+19.7 %)	+0.014(+12.1 %)
Cd	0.00 (0.00 %)	0.00 (0.00 %)	0.00 (0.00 %)
Ni	+0.001 (+25.0 %)	+0.003(+75.0 %)	+0.002 (+66.7 %)

Table 7: Statistical analysis of the results from Table 5

Statistics	Whole shrimp/Flesh			Whole shrimp/Shell +head			Flesh/Shell +head		
	Whole shrimp		Flesh	Whole shrimp		Shell +head	Flesh		Shell + head
r_{xy}		0.99999			0.9954			0.9951	
r_{xy}^2		0.9998			0.9907			0.9903	
R_{xy}		-31.2			1388.1			1411.96	
Mean	14755.9		14217.2	14755.9		11190.76	14217.2		11190.76
SD	45836.8		44261.06	45836.8		30592.3	44261.06		30592.3
CV %	310.63		311.32	310.63		273.37	311.32		273.37
C_A		0.0049			0.0962			0.0985	
IFE		0.9951			0.9038			0.9015	
Remark		*			*			*	

* = results significantly different at n-2 (df) and $r_{=0.01}$ since critical value is 0.661. (NOTE :n - 2 = 14-2 = 12.)

The differences in the mineral concentrations between the whole shrimp and flesh, between whole shrimp and shell + head as well as flesh and shell + head pertaining to results from Table 5 are shown in Table 6. In the whole shrimp - flesh, out of the 14 parameters determined, Pb and Cd each have a difference of 0.00 (0.00%), 10/12 (83.3%) parameters have higher concentrations in whole shrimp than the flesh; in whole shrimp-shell +head, Cd has a difference value of 0.00 mg kg^{-1} (0.00 %) whereas 7/13 (53.8 %) of the parameters are more concentrated in the whole shrimp than in the shell + head; also in flesh-shell + head, a value difference of 0.00 mg kg^{-1} (0.00 %) in Cd is observed whereas 6/13 (46.2%) of the parameters are more concentration in the flesh than in the shell + head. On the whole, the mineral concentration trend is whole shrimp > shell + head > flesh. The statistical analysis of the results in Table 5 is depicted in Table 7. The r_{xy} values are positively high (0.9951-0.99999) and significantly different; the r_{xy}^2 are also high (0.9903-0.99998). The R_{xy} ranges from -31.2 to 1411.96. Mean, SD and CV% are all high in all the comparisons. The C_A is generally low at 0.0049-0.0985 (0.49-9.85 %) with corresponding high values of IFE 0.9015-0.9951 (90.15-99.51 %).

The various mineral ratios calculated are depicted in Table 8. The following ratios are less than the ideal ratios: Na/Mg [ideal (id) = 4.00, values = 0.2649 -1.39], Zn/Cu [id = 8.00, values = 2.75-4.02], [K/(Ca +Mg)] [id = 2.2, values = 0.022-0.037] and Na/K [id = 2.40, values =1.17-1.24; except in shell + head = 4.42]. The following mineral ratios: Ca/P, Fe/Cu, Ca/Pb, Fe/Pb and Zn/Cd have ratio values much higher than the ideal. Balance in all phases of life is critically important to maintain health and this principle applies to mineral levels in animal analyses. A mineral ratio is a pure number consisting of one mineral level divided by a second mineral level. Mineral ratios are often more important in determining nutritional deficiencies and excesses than mineral levels alone, although both are important and should be considered together. The importance of ratios had been emurated (ARL, 2012): ratios are often more important than levels; ratios represent homeostatic balances; ratios are indicative of disease trends; ratios are frequently predictive of future metabolic dysfunction or hidden metabolic dysfunctions.

Calcium and magnesium should always be in a proper balance to one another. If this normal equilibrium is upset, one mineral will become dominant relative to the other. In this case, calcium is high relative to magnesium (see high Ca/Mg ratio), which may be indicative of abnormal calcium metabolism, resulting in excessive deposition of calcium into soft tissues. This profile is indicative of a suppressing effect upon magnesium function within the body, and increased need for magnesium in the diet. High calcium relative to potassium will frequently indicate a trend toward hypothyroidism (underactive thyroid). The mineral calcium antagonizes the retention of potassium within the cell. Since potassium is necessary in sufficient quantity to sensitize the tissues to the effects of thyroid hormones, a high Ca/K ratio would suggest reduced thyroid function and/or cellular response to thyroxine. If this imbalance has been present for an extended period of time, the following associated with low thyroid function may occur: fatigue, dry skin, constipation, sensitivity, depression, over-weight and cold [Trace Elements, Inc (Tei), *Nutrient Mineral Ratios.* http://www.spectrumhealth.biz/hairanalysis/samplereport/mineral_ra...]. Phosphorus is involved in all of the cellular energy production cycles within the body. Adequate protein intake is essential in providing needed phosphorus for increased energy production, and reducing excess tissue calcium retention (see high Ca/P ratio). It is suggested that protein intake be evaluated. Protein should make up at least 40% of total caloric intake. The present energy contribution from protein in the samples ranges from 25.1-28.4%. The ratio of Na/Mg is below the normal range. The adrenal glands play an essential role in regulating sodium retention and excretion. Studies have also shown that magnesium will affect adrenal cortical activity and response, and reduced adrenal activity results in increased magnesium retention. The sodium-magnesium profile is indicative of reduced adrenal cortical function. Zinc and copper are intricately related to the hormones, progesterone and estrogens, respectively, and their tissue levels may be indirectly reflective of the status of these hormones within the body. When zinc and copper are not in normal balance with one another, certain emotional and physical changes related to hormonal imbalance may occur near the menstrual cycles, such as excessive cramping, emotional mood swings, food cravings, water retention skin, skin rashes and viral infections (http://www.spectrumhealth.biz/hairanalysis/samplereport/mineral_ra...). The milliequivalent ratio of [K/(Ca + Mg)] is less than 2.2 in each of the sample (0.022-0.037). This means the samples will not promote hypomagnesaemia in man (NRC, 1989).

Every person is exposed to toxic metals to some degree. The retention of these toxic metals, however, is dependent upon the individual's susceptibility. The balance of the protective nutrient minerals within the body in relation to the heavy metals can frequently be the determining factor to this susceptibility. As an example, the accumulation of lead will have a more detrimental effect upon body chemistry when sufficient levels of calcium and iron are not available. By examining the toxic metal levels in relation to the protective minerals, the extent to which the heavy metals may be involved in abnormal chemistry can frequently be seen [Trace Elements, Inc (Tei), *Toxic Mineral Ratios.* http://www.spectrumheaith.biz/hairanalysis/SampleReport/Toxic_Ra...]. Toxic metal ratios in *P. borealis* were Ca/Pb, Fe/Pb and Zn/Cd. The levels of both Pb (0.002-0.003 mg kg^{-1}) and Cd (all < 0.001) were very low in the samples and this could have resulted in the very high levels of Ca/Pb, Fe/Pb and Zn/Cd.

The summary of the statistical analysis of the results from Table 8 is shown in Table 9. In the r_{xy} values, there is positive perfect correlation between whole shrimp/flesh but ranges between 0.9999-0.9999 and significant in the other two comparisons. As observed in Table 9, the R_{xy} value is highly negative (-127) in whole shrimp/flesh but positively high (1411-1470) in the other two comparisons. The mean, SD and CV% are individually high. The C_A values are very low with corresponding very high IFE values with the exception in whole shrimp/flesh where both C_A and IFE have 0.00 values because a perfect correlation occurs in whole shrimp/flesh.

Table 8: Calculated mineral ratios of *Pandalus borealis*

Parameter	Ideal	Whole shrimp	Flesh	Shell + head	Mean	SD	CV%
Ca/Mg	7.00	20.4	20.6	16.2	19.1	2.48	13.0
Na/K	2.40	1.24	1.17	4.42	2.28	1.85	81.4
Ca/K	4.20	88.0	82.8	51.6	74.1	19.7	26.6
Na/Mg	4.00	0.2649	0.2911	1.39	0.648	0.641	98.9
Zn/Cu	8.00	3.87	4.02	2.75	3.55	0.694	19.5
Ca/P	2.60	8.19	8.50	5.20	7.30	1.82	5.20
Fe/Cu	0.90	13.6	13.5	13.1	13.4	0.216	1.61
Ca/Pb	84.0	86365587	83421825	38408000	69398471	26878865	38.7
Fe/Pb	4.40	29037	26809	21085	25644	4102	16.0
Zn/Cd	500	16594	15993	13289	15292	1760	11.5
[K/(Ca + Mg)]	2.2	0.022	0.023	0.037	0.0273	0.008	30.7

Table 9: Statistical analysis of the results from Table 8

Statistics	Whole shrimp/Flesh		Whole shrimp/Shell +head		Flesh/Shell +head	
	Whole shrimp	**Flesh**	**Whole shrimp**	**Shell +head**	**Flesh**	**Shell + head**
r_{xy}	1.00		0.9999		0.9951	
r_{xy}^2	1.00		0.9999		0.9903	
R_{xy}	-127		1411		1411.96	
Mean	7855578	7587705	7855578	3494770	7587705	3494770
SD	26038826	25151334	26038826	11579410	25151334	11579411
CV %	331	331	331	331	331	331
C_A	0.00		0.00025		0.00026	
IFE	0.00		0.99975		0.99974	
Remark	#		*		*	

= a perfectly positive correlated relationship, * = results significantly different at n-2 (df) and $r_{= 0.01}$ since critical value is 0.735. (NOTE :n - 2 = 11-2 = 9.)

Table 10: Mineral safety index of Na, Mg, P, Ca, Fe, Se, Zn, Cu of *Pandalus borealis*

Mineral	RAI (mg)	TV of MSI	Whole shrimp			Flesh			Shell + head		
			CV	D%	D	CV	D	% D	CV	D	% D
Na	500	4.8	2.15	2.65	55.2	2.27	2.53	52.7	9.47	-4.67	-97.3
Mg	400	15	31.7	-16.7	-111	30.4	-15.4	-103	26.7	-11.7	-78.0
P	1200	10	17.6	-7.60	-76.0	16.4	-6.40	-64.0	18.5	-8.50	-85.0
Ca	1200	10	144	-134	-1340	139	-129	-1290	96.0	-86.0	-860
Fe	15	6.7	2.62	4.08	60.9	2.39	4.31	64.3	2.83	3.87	57.8
Se	0.07	14	2.54	11.5	81.9	2.32	11.7	83.4	2.04	12.0	85.4
Zn	15	33	3.65	29.4	88.9	3.52	29.5	89.3	2.92	30.1	91.2
Cu	3	33	4.71	28.3	85.7	4.37	28.6	86.8	5.31	27.7	83.9

CV = calculated value; TV = Table value; D = difference; RAI = recommended adult intake. No MSI standard for K, Mn, Co, Cd, Ni and Pb.

The mineral safety index (MSI) values of Na, Mg, P, Ca, Fe, Se, Zn, Cu of *P. borealis* are shown in Table 10. The standard mineral safety index values for the elements are Na (4.8), Mg (15), P (10), Ca (10), Fe (6.7), Zn (33), Cu (33) and Se (14). The explanation of the MSI can be understood as follows taking Ca as example: the recommended adult intake (RAI) of Ca is 1,200 mg; its minimum toxic dose (MTD) is 12,000 mg or 10 times the recommended daily average (RDA) which is equivalent to MSI of Ca. This reasoning goes for the other minerals whose MSI are determined. Minerals whose MSI values are higher than the Table MSI (TV) are Mg, P and Ca in all the samples as well as Na in shell + head with calculated value (CV) range per cent of 76.0-1340 (which are relatively high). Sodium is the least in the value that is higher than the TV in which it is 9.47 times the RDA, hence more K would be consumed to compensate for the high Na intake from the sample. The TV of 9.47 in shell + head in *P. borealis* has similar value of 9.47 in *Callinectes latimanus* (Adeyeye *et al*., 2014). The following minerals have their TV > CV: Fe, Se, Zn and Cu giving positive difference with corresponding lower percentage difference having range values of 52.7- 97.3. The range of 46.3-97.6 % observation of TV > CV in the samples is also observed in *Callinectes latimanus* (Adeyeye *et al*., 2014). The TV > CV is observed in Fe, Cu, Zn, Na, Mg, P, Ca and Se in two types of Lagos lagoon fish (*Acanthurus monroviae* and *Lutjanus goreensis*) (Adeyeye *et al*., 2014), the percentage difference being between 32.0 and 100.

Conclusion

In summary, this study indicates that the (shell + head) protein will contribute significantly to the nutritional qualities of *Pandalus borealis* when they are processed and consumed whole. The shell+ head contribution to the nutritional values occurs in all the parameters determined.

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