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Amino Acid Profiles of Whole Organism, Flesh and Shell of *Pandalus borealis* (Krøyer 1838)

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Abstract
The amino acid profile of *Pandalus borealis* as whole organism, flesh and exoskeleton was investigated. Total amino acid values were expressed as (g/100 g crude protein, cp): whole organism (92.7), flesh (86.6) and exoskeleton (93.0). The least concentrated amino acid was Trp (5.35 e-2 to 8.06 e-1 g/100 g cp) and most varied at 96.3 % variation. The most concentrated essential amino acid was Val (6.14-7.28 g/100 g cp). Total essential amino acid (with His) was 37.9-40.9 g/100 g cp or 42.9-44.0 %. Leu/Ile range was 2.08-2.76; % Cys/TSAA range was 1.98-17.5. P-PER$_1$, range was 1.21-1.71 and P-PER$_2$ range was 1.65-2.12. Essential amino acid index ranged between 79.5-99.4 and biological value at 75.0-96.6 thereby making the flesh (highest EAAI and BV) behaving like a chicken egg in both the EAAI and BV. The Lys/Trp (L/T) was 3.05-62.5 and Met/Trp (M/T) range was 2.54-37.8. L/T for human muscle is 6.3. The limiting amino acid on egg comparison was Cys with values of 0.015-0.241 with highest variation of 138 %; on provisional amino acid scoring pattern, Trp was limiting in whole organism (0.054) and flesh (0.327) but it was Lys (0.447) in exoskeleton; this was reported in the pre-school child requirement with respective similar acid limiting values of 0.049, 0.248 and 0.424. The most concentrated amino acid group was class I (Gly, Ala, Val, Leu, Ile). In the linear correlation coefficient comparisons, 5/6 or 83.3 % were significantly different at r = 0.05 at n-2 degrees of freedom.

1. Introduction

The term *shrimp* is used to refer to some decapod crustaceans, although the exact animals covered can vary. Used broadly, it may cover any of the groups with elongated bodies and a primarily swimming mode of locomotion-chiefly Caridea and Dendrobranchiata. In some fields, however, the term is used more narrowly, and may be restricted to Caridea, to smaller species of either group, or to only the marine species. Under the broader definition, *shrimp* may be synonymous with *prawn*, covering stalk-eyed swimming crustaceans with long narrow muscular tails (abdomens), long whiskers (antennae) and slender legs [1]. They swim forwards by paddling with swimmerets on the underside of their abdomens. Crabs and lobsters have strong walking legs, whereas shrimps have thin fragile legs which they use primarily for perching [2].

More specifically, shrimps are swimming crustanceans with long narrow muscular abdomens and long antennae with well developed pleopods (swimmerets and slender walking legs; they are more adapted for swimming than walking). Historically, it was the distinction between walking and swimming that formed the primary taxonomic division

into 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 [3]. Some other groups also have common names that include the word "shrimp" [4]; any small swimming crustacean resembling a shrimp tends to be called one [2].

Shrimps are widespread, and can be found near the seafloor of most coasts and estuaries, as well as in rivers and lakes. There are numerous species, and usually there is a species adapted to any particular habitat [2]. Most shrimp species are marine, although about a quarter of the described species are found in fresh water [5]. Marine species are found at depths up to 5,000 metres (16,000 ft) [6], and from the tropics to the polar regions. They usually live from one to seven years.

Most shrimps are omnivorous, but some are specialized for particular modes of feeding. Some are filter feeders, using their setose (bristly) legs as a sieve; some scrape algae from rocks. Cleaner shrimps feed on the parasites and necrotic tissue of the reef fish they groom [6]. In turn, shrimps are eaten by various animals, particularly fish and seabirds, and frequently host bopyrid parasites [6]. 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" [7]. According to the Codex Alimentarius Commission of the FAO and WHO: The term *shrimp* (which includes the frequently used term *prawn*) refers to the species covered by the most recent edition of FAO listing of shrimp, FAO Species Catalogue, Volume 1, *Shrimps and prawns of the world, an annotated catalogue of species of interest to fisheries* FAO Fisheries Synopsis No. 125 [8]. 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 [9].

The species under study is Northern prawn, *Pandalus borealis* Krøyer , 1838. PANDL, Pandal 1. *Pandalus borealis* Kroyer, 1838, Naturhist. Tidsskr., 2:254 [10]. Synonymy: *Dymas typus* Krøyer , 1861; *Pandalus borealis typica* Retovsky, 1946. FAO Names: Northern shrimp (En), Crevette nordique (Fr), Camarón norteπo (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. They have a short life which contributes to a variable stock on a yearly basis. They are not considered overfished. Habitat: Depth 20 to 1380 m [11]. Bottom clay and mud and it is marine [12]. Size: Maximum total length 120 mm(♂) , 165 mm (♀) [9].

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

2. Experimental

2.1. 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 contamination, drained under folds of filter paper and identified. Samples were collected in crushed ice in insulated containers and brought to the laboratory for preservation prior to analysis. The washed shrimps were wrapped in aluminium foil and frozen at -4 ^{o}C for 2-5 days before analysis was carried out.

2.2. Sample Treatment

After defrosting, for about one hour whole shrimps were beheaded and the outer shells removed. The various parts were dried at 105 ^{o}C and blended.

2.3. Samples Analysis

The method of amino acid analysis was by ion-exchange chromatography (IEC) [13] using the Technicon Sequential Multisample Amino Acid Analyzer (TSM) (Technicom Instruments Corporation, New York). The sample was dried to constant weight. The mass was subsequently defatted, hydrolysed, filtered to remove the humins and evaporated to dryness at 40 ^{o}C under vacuum in a rotary evaporator. The residue was dissolved with 5 ml of acetate buffer (pH 2.0) and stored in a plastic specimen bottle kept inside the deep freezer pending subsequent analysis. The TSM is designed to separate free acidic, neutral and basic acids of the hydrolysate. The amount loaded for each sample was 5-10 µ1 and about 76 minutes elapsed for each analysis. The column flow rate was 0.50 ml/min at 60 ^{o}C with reproducibility consistent within ±3 %. The net height of each peak produced by the chart of the TSM was measured and calculated for the amino acid it was representing. All chemicals used were of analytical grade. Norleucine was used as internal standard.

2.4. Some Calculations from Analytical Results

(i.) Estimation of Isoelectric Point (pI)

The estimation of the isoelectric point (pI) for a mixture of amino acids can be carried out by the equation of the form [14]:

$$IPm = \sum_{i=1}^{n} IPi\ Xi$$

where IPm is the isoelectric point of the mixture of amino acids, IPi is the isoelectric point of the i^{th} amino acid in the mixture and Xi is the mass or mole fraction of the i^{th} amino acid in the mixture.

(ii.) Estimation of Predicted Protein Efficiency Ratio (P-PER)

Computation of protein efficiency ratio (C-PER or P-PER) was done using the equations suggested by Alsmeyer et al. [15]:

$$P\text{-}PER_1 = -0.468 + 0.454\ (Leu) - 0.105\ (Tyr)$$

$$P\text{-}PER_2 = -0.684 + 0.456\ (Leu) - 0.047\ (Pro)$$

(iii.) Leucine/Isoleucine Ratio

The leucine/isoleucine ratios, their differences and their percentage differences were calculated.

(iv.) Estimation of Essential Amino Acid Index (EAAI)

The method of EAAI calculation due to Oser [16] using the egg protein amino acids as the standard.

(v.) Estimation of Biological Value (BV)

Computation of biological value (BV) was calculated following the equation of Oser [16] as follows:

$$Biological\ value = 1.09\ (EAAI) - 11.73$$

(vi.) Computation of Lys/Trp and Met/Trp

The ratios of Lys/Trp (L/T) and Met/Trp (M/T) were computed.

(vii.) Computation of the differences in the Anatomical Parts

Differences in the amino acid profiles between whole organism and flesh, and between whole organism and exoskeleton were calculated.

(viii.) (viii) Computation of Amino Acid Scores

The amino acid scores were computed using three different procedures:

- Scores based on amino acid values compared with whole hen's egg amino acid profile [17].
- Scores based on essential amino acid scoring pattern [18].
- Scores based on essential amino acid suggested pattern of requirements for pre-school children [19].

2.5. Statistical Evaluation

Data results in Tables 1, 2, 3, 4, 5, 6 were subjected to statistical analysis of correlation coefficient (r_{xy}), coefficient of alienation (C_A), index of forecasting efficiency (IFE), regression coefficient (R_{xy}) and coefficient of determination or variance (r_{xy}^2).

The r_{xy} was converted to critical Table value to see if significant differences existed among the sample results at $r = 0.05$ [20]. Other descriptive statistics done were the determination of mean, standard deviation and coefficient of variation percent [20].

Table 1. *Amino acid profiles of whole organism (Who-org.), endoskeleton and exoskeleton of Pandalus borealis (g/100 g crude protein).*

Amino acid	Who-org	Endoskeleton	Exoskeleton		Mean	SD	CV %	
Glycine (Gly)	5.28	4.45	6.21		5.31	0.880	16.6	
Alanine (Ala)	7.06	7.42	7.64		7.37	0.293	3.97	
Serine	(Ser)	5.49	4.49		5.31	5.10	0.534	10.5
Proline (Pro)	5.27	4.48	5.45		5.07	0.516	10.2	
Valine (Val)*	6.26	6.14	7.28		6.56	0.628	9.57	
Threonine (Thr)*	5.95	4.88	5.42		5.42	0.539	9.96	
Isoleucine (Ile)*	2.23	2.46	2.46		2.38	0.134	5.64	
Leucine (Leu)*	6.14	5.23	5.11		5.49	0.564	10.3	
Aspartic acid (Asp)	9.16	8.97	10.6		9.59	0.917	9.56	
Lysine (Lys)*	3.34	3.34	2.46		3.05	0.510	16.7	
Methionine (Met)*	2.03	2.30	2.05		2.12	0.150	7.05	
Glutamic acid (Glu)	14.8	13.6	10.3		12.9	2.33	18.3	
Phenylalanine (Phe)*	5.47	5.35	6.17		5.66	0.443	7.82	
Histidine (His)*	3.56	3.48	4.00		3.68	0.283	7.67	
Arginine (Arg)*	4.78	4.39	5.14		4.77	0.375	7.87	
Tyrosine (Tyr)	5.78	5.01	6.13		5.64	0.572	10.1	
Tryptophan (Trp)*	5.35e-2	3.27e-1	8.06e-1	3.96e-1	0.381	96.3		
Cystine (Cys)	4.10e-2	2.73e-1	4.34e-1	2.49e-1	0.198	79.2		
Total amino acid	92.7	86.6	93.0		90.8	3.60	3.97	
Protein	17.2	18.3	19.1		18.2	0.954	5.24	

*Essential amino acid

Table 2. *Concentrations of essential, non-essential, neutral, aromatic, etc. (g/100 g crude protein) of Pandalus borealis samples (dry matter of sample).*

Amino acid	Whole organism	Endoskeleton	Exoskeleton	Mean	SD	CV %
1	2	3	4	5	6	7
Total amino acid (TAA)	92.7	86.6	93.0	90.8	3.61	3.98
Total non-essential amino acid (TNEAA)	52.9	48.7	52.1	51.2	2.23	4.36
% TNEAA	57.1	56.2	56.0	56.4	0.586	1.04
Total essential amino acid (TEAA) with His	39.8	37.9	40.9	39.5	1.52	3.85
no His	36.3	34.4	36.9	35.9	1.31	3.65
% TEAA with His	42.9	43.8	44.0	43.6	0.586	1.34
no His	39.2	39.7	39.7	39.5	0.289	0.732
Total essential aliphatic amino acid (TEAIAA)	14.6	13.8	14.8	14.4	0.529	3.67
% TEAIAA	15.7	15.9	15.9	15.8	0.115	0.728
Total essential aromatic amino Acid (TEArAA)	9.09	9.16	11.0	9.75	1.08	11.1
%TEArAA	9.81	10.6	11.8	10.7	1.00	9.35
Total neutral amino acid (TNAA)	51.7	50.2	59.7	53.9	5.11	9.48
% TNAA	55.8	58.0	64.2	59.3	4.36	7.35
% Cys in TSAA	1.98	10.6	17.5	10.0	7.78	77.8
Leu/Ile ratio	2.76	2.13	2.08	2.32	0.379	16.3
(Leu - Ile) difference	3.92	2.78	2.65	3.12	0.699	22.4
% (Leu-Ile)/TAA	4.23	3.21	2.85	3.43	0.716	20.9
% (Leu-Ile)/Leu	63.8	53.2	51.9	56.3	6.53	11.6
P-PER$_1$[a]	1.71	1.38	1.21	1.43	0.254	17.8
P-PER$_2$[a]	2.12	1.70	1.65	1.82	0.258	14.2
pI[b]	5.21	4.85	5.28	5.11	0.231	4.52
EAAI[c]	79.5	99.4	89.7	89.5	9.95	11.1
Biological value (BV)	75.0	96.6	86.0	85.9	10.8	12.6
Lys/Trp or L/T	62.5	10.2	3.05	25.3	32.5	128
Met/Trp or M/T	37.8	7.02	2.54	15.8	19.2	122

[a]Predicted protein efficiency ratio.
[b]Isoelectric point.
[c]Essential amino acid index.

Table 3. *Differences in the amino acid profiles between whole organism (Who-org.) and endoskeleton (Endos.), and between whole organism and exoskeleton (Exos.) samples of Pandalus borealis.*

Amino acid	Who-org.-endos.	Who-org.-exos.	Mean	SD	CV %
Gly	+0.830(15.7 %)	-0.934 (-17.7 %)	0.881	0.076	8.59
Ala	-0.360(-5.10 %)	-0.580(-8.22 %)	0.470	0.156	33.2
Ser	+1.00(18.3 %)	+0.185(3.38 %)	0.593	0.576	97.1
Pro	+0.786 (14.9 %)	-0.187(3.55 %)	0.487	0.424	87.1
Val	+0.126(2.01 %)	-1.02(-16.3 %)	0.573	0.632	110
Thr	+1.08(18.1 %)	+0.534(8.97 %)	0.807	0.386	47.8
Ile	-0.232(-10.4 %)	-0.233(-10.5 %)	0.233	0.001	0.429
Leu	+0.907(14.8 %)	+1.03(16.8 %)	0.969	0.087	8.98
Asp	+0.191(2.09 %)	-1.48(-16.2 %)	0.834	0.911	109
Lys	+0.008(0.225%)	+0.887(26.5 %)	0.448	0.622	139
Met	-0.270(-13.3 %)	-0.024(-1.18 %)	0.147	0.174	118
Phe	+0.114(2.09 %)	-0.703(-12.9 %)	0.409	0.416	102
His	+0.086(2.40 %)	-0.441(-12.4 %)	0.264	0.251	95.1
Arg	+0.393(8.22 %)	-0.357(-7.47 %)	0.375	0.025	6.67
Tyr	+0.769(13.3 %)	-0.349(-6.04 %)	0.559	0.297	53.1
Trp	-0.274(-0.003 %)	-0.753(-1406 %)	0.514	0.339	66.0
Cys	-0.232(-566 %)	-0.393(-958 %)	0.313	0.114	36.4
Total	+6.09(6.57 %)	-0.277(-0.299 %)	3.18	4.11	129

+ = whole organism > endoskeleton, - = whole organism < than either endoskeleton or exoskeleton as the case may be. Percentages in brackets represent percentage differences.

Table 4. *Amino acid scores of the Pandalus borealis samples baesd on whole hen's egg amino acid.*

Amino acid	Whole organism	Endoskeleton	Exoskeleton	Mean	SD	CV %
Gly	1.76	1.48	2.07	1.77	0.294	16.6
Ala	1.31	1.37	1.42	1.37	0.054	3.94
Ser	0.695	0.568	0.672	0.645	0.068	10.5
Pro	1.39	1.18	1.43	1.33	0.136	10.2
Val	0.835	0.818	0.971	0.875	0.084	9.60
Thr	1.17	0.956	1.06	1.06	0.106	10.0
Ile	0.397	0.439	0.439	0.425	0.024	5.65
Leu	0.740	0.631	0.615	0.662	0.068	10.3
Asp	0.856	0.838	0.995	0.896	0.086	9.60
Lys	0.540	0.538	0.397	0.491	0.082	16.7
Met	0.633	0.717	0.640	0.664	0.047	7.08
Glu	1.23	1.14	0.855	1.07	0.196	18.3
Phe	1.07	1.05	1.21	1.11	0.087	7.84
His	1.49	1.45	1.67	1.53	0.118	7.71
Arg	0.784	0.719	0.842	0.782	0.061	7.80
Tyr	1.44	1.25	1.53	1.41	0.143	10.1
Trp	0.030	0.182	0.448	0.220	0.212	96.4
Cys	0.023	0.015	0.241	0.093	0.128	138
Total	0.928	0.867	0.931	0.909	0.036	3.96

Table 5. *Essential amino acid scores of Pandalus borealis samples based on FAO/WHO (1973) [18] standards.*

Amino acid	Whole organism	Endoskeleton	Exoskeleton	Mean	SD	CV %
Val	1.25	1.23	1.46	1.31	0.127	9.69
Thr	1.49	1.22	1.36	1.36	0.135	9.93
Ile	0.556	0.614	0.615	0.595	0.034	5.71
Leu	0.877	0.748	0.730	0.785	0.080	10.2
Lys	0.608	0.607	0.447	0.554	0.093	16.8
Met + Cys	0.590	0.734	0.709	0.678	0.079	11.4
Phe +Tyr	1.87	1.73	2.05	1.88	0.160	8.51
Trp	0.054	0.327	0.806	0.396	0.381	96.2
Total	1.04	0.981	1.06	1.03	0.041	3.98

Table 6. *Essential amino acid scores of the Pandalus borealis samples based on requirements of pre-school child (2-5 years).*

Amino acid	Whole organism	Endoskeleton	Exoskeleton	Mean	SD	CV %
Val	1.79	1.75	2.08	1.87	0.180	9.63
Thr	1.75	1.43	1.59	1.59	0.160	10.1
Ile	0.795	0.878	0.878	0.850	0.048	5.65
Leu	0.930	0.793	0.774	0.832	0.085	10.2
Lys	0.577	0.575	0.424	0.525	0.088	16.8
Met + Cys	0.827	1.03	0.993	0.950	0.108	11.4
Phe + Tyr	1.79	1.65	1.95	1.80	0.150	8.33
Trp	0.049	0.248	0.733	0.343	0.352	103
His	1.88	1.83	2.11	1.94	0.149	7.68
Total	1.21	1.14	1.25	1.20	0.056	4.67

Table 7. *Amino acid groups of Pandalus borealis.*

	Value in g/100 g protein (% value)					
Class	**Whole organism**	**Endoskeleton**	**Exoskeleton**	**Mean**	**SD**	**CV %**
I [with aliphatic side chains (hydrogen and carbons) = Gly, Ala, Val, Leu, Ile]	27.0 (29.1 %)	28.7(33.1 %)	28.7 (30.9 %)	28.1	0.981	3.49
II [with side chains containing hydroxylic (OH) groups =Ser, Thr]	11.4 (12.3 %)	9.37 (10.8 %)	10.7 (11.5 %)	10.5	1.03	9.81
III [with side chains containing sulphur atoms = Cys, Met]	2.07 (2.23 %)	2.57 (2.97 %)	2.48 (2.67 %)	2.37	0.267	11.3
IV [with side chains containing acidic groups or their amides =Asp, Glu]	24.0 (25.9 %)	22.6 (16.1 %)	20.9 (22.5 %)	22.5	1.55	6.89
V [with side chains containing basic groups = Arg, Lys, His]	11.7(12.6 %)	11.2 (12.9 %)	11.6 (12.5 %)	11.5	0.265	2.30
VI [containing aromatic rings = His, Phe, Tyr, Trp]	14.9 (16.1 %)	14.2 (16.4 %)	17.1 (18.4 %)	15.4	1.51	9.81
VII [imino acids = Pro]	5.27 (5.69 %)	4.48 (5.17 %)	5.45 (5.86 %)	5.07	0.516	10.2

Table 8. *Summary of the amino acid profiles into factors A and B.*

	***Pandalus borealis* body parts (Factor A)**			
Amino acid composition	**Whole organism**	**Endoskeleton**	**Exoskeleton**	**Factor B means**
Total essential amino acid	39.8	37.9	40.9	39.5
Total non-essential amino acid	52.9	48.7	52.1	51.2
Factor A means	46.4	43.3	46.5	45.4

Table 9. *Statistical summary of the data in Tables 1-6.*

Table	Parameter	r_{xy}	r_{xy}^2	R_{xy}	X±SD(CV %)	Y±SD(CV %)	C_A	IFE	Remark
1	Who-org./Endos.	0.9907	0.98	0.16	5.16±3.37 (65.3)	4.82±3.07 (63.8)	13.6	86.4	*
	Who-org./Exos.	0.9293	0.86	1.14	-	5.16±2.83 (54.9)	36.9	63.1	*
	Endos./Exos.	0.9319	0.87	1.02	-	-	36.3	63.7	*
2	(pI) Who-org./Endos.	0.9826	0.97	1.54	28.9±14.4 (49.8)	27.0±12.9 (47.8)	18.6	81.4	*
	Who-org./Exos.	0.9334	0.87	3.13	-	29.4±14.0 (47.7)	35.9	64.1	*
	Endos./Exos.	0.9290	0.86	2.16	-	-	37.0	63.0	*
3	Who-org.-Endos./								
	Who-org.-Exos.	0.3443	0.19	0.37	0.490±0.386 (78.8)	0.813±1.00(123)	93.9	6.11	NS
4.	Who-org./Endos.	0.9770	0.95	0.09	0.912±0.493 (54.0)	0.856±0.424 (49.6)	21.3	78.7	*
	Who-org./Exos.	0.9359	0.88	0.10	-	0.973±0.503 (51.7)	35.2	64.8	*
	Endos./Exos.	0.9273	0.86	0.03	-	-	37.4	62.6	*
5	Who-org./Endos.	0.9783	0.96	0.21	0.912±0.589 (64.6)	0.901±0.455 (50.4)	20.7	79.3	*
	Who-org./Exos.	0.8636	0.75	0.29	-	1.02±0.546 (53.4)	36.9	63.1	*
	Endos./Exos.	0.9266	0.86	0.36	-	-	37.6	62.4	*
6	Who-org./Endos.	0.9764	0.95	0.18	1.15±0.664 (57.6)	1.13±0.560 (49.5)	21.6	78.4	*
	Who-org./Exos.	0.9147	0.84	0.24	-	1.28±0.652 (50.9)	40.4	31.2	*
	Endos./Exos.	0.9500	0.90	0.03	-	-	59.6	68.8	*

Who-org.-whole organism, Endos. –endoskeleton, Exos. – exoskeleton, r_{xy} – linear correlation coefficient, r_{xy}^2 – coefficient of determination, R_{xy} – linear regression coefficient, C_A – coefficient of alienation, IFE – index of forecasting efficiency, * - singnificant at $r_{=0.05}$ at n-2 degrees of freesom, NS – not significant at $r_{=}0.05$.

3. Results and Discussion

The amino acids composition of whole organism, flesh (endoskeleton) and shell (shell + head or exoskeleton) of *Pandalus borealis* (dry weight) in g/100g crude protein (cp) can be seen in Table 1. The highest concentrated amino acid was an acidic amino acid, glutamic acid (Glu) in whole organism and flesh with respective values of 14.8 and 13.6 g/100 g cp; but it was aspartic acid (Asp) in shell with a value of 10.6 g/100 g cp. Cystine (Cys) was the lowest concentrated amino acid (AA) with a range of 4.10 e-2 to 4.34 e-1 with the second highest coefficient of variation per cent (CV %) of 79.2. Tryptophan (Trp) of 5.35 e-2 to 8.06 e-1 had the highest CV % of 96.3 whereas both total amino acid (86.6-93.0 g/100 g cp) and alanine (Ala) of 7.06-7.64 g/100 g cp shared the position of the lowest value of CV % (3.97 each). The most concentrated essential amino acid (EAA) was valine (Val) in all the samples with values of (g/100 g cp): exoskeleton (7.28) > whole organism (6.26) > endoskeleton (6.14) with low CV % (9.57). With the exception of CV % in Cys and Trp (79.2-96.3), the others were close at a range of 3.97-18.3 showing the closeness of the amino acids values across the samples on individual basis.

A look at the results will reveal that the EAA of the samples were mostly concentrated (on pair wise comparisons) in the exoskeleton: the trend being: Val, Phe, His, Arg and Trp (five EAA, 5/10 or 50.0 %) and sharing the first position with endoskeleton in Ile (2.46 g/100 g cp in each case); whole organism: Thr and Leu (two EAA, 2/10 or 20.0 %) and sharing the first position with endoskeleton in Lys (3.34 g/100 g cp in each case); endoskeleton: Met (one EAA, 1/10 or 10.0 %) and sharing first position with exoskeleton in Ile and sharing first position with whole organism in Lys (1/2 + 1/2 = 1/10 = 10.0 %). On the whole, the EAA concentration distribution was exoskeleton (5.5/10 = 55.0 %) > whole organism (2.5/10 = 25.0 %) > endoskeleton (2.0/10 = 20.0 %). This pattern was demonstrated in the total amino acid (AA) with the values (g/100 g cp): 93.0 (exoskeleton) > 92.7 (whole organism) > 86.6 (endoskeleton). The most concentrated EAA in the samples (g/100 g cp): exoskeleton, Val (7.28), Phe (6.17) and Thr (5.42); endoskeleton, Val (6.14), Phe (5.35) and Leu (5.23); whole organism, Val (6.26), Leu (6.14) and Thr (5.95) meaning that the most concentrated AA was Val. From literature, the EAA together with Cys and Tyr had been given for the heart, kidney, liver and tongue of cattle, pig and sheep [21] and the hen [17]. In the red viscera of the three animals mentioned above, the EAA with Cys and Tyr for them were (g/100 g cp): His (2.2-2.7); Thr (4.1-4.8); Val (4.8-6.2); Met (2.0-2.6); Ile (3.9-5.3); Leu (7.1-9.4); Phe (3.7-5.3); Tyr (2.9-3.8) and Cys (0.8-2.2). Also from amino acid composition of two fancy meats (heart and liver) of domestic duck (*Anas platyrhynchos*) consumed in Nigeria, we have these values (g/100 g cp): His (2.05-2.31); Thr (2.16-2.66); Val (3.80-4.31); Met (2.72-3.07); Ile (3.02-3.06); Leu (6.82-7.05); Phe (3.94-4.32); Tyr (3.02-3.25) and Cys (1.02-1.05) [22]. With these literature values, the present

results could be said to be very favourably comparable to them as (g/100 g cp): His (3.48-4.00); Thr (4.88-5.95); Val (6.14-7.28); Met (2.03-2.30); Ile (2.23-2.46); Leu (5.11-6.14); Phe (5.35-6.17); Tyr (5.01-6.13) and Cys (4.10 e-2 to 4.34 e-1). The comparisons showed that His, Thr, Val, Phe, Tyr were better concentrated in the *P. borealis* than in cattle, pig, sheep and domestic duck viscera.

The crude protein values in the samples varied slightly with CV % of 5.24. The values were 17.2 g/100 g (whole organism), 18.3 g/100 g (flesh) and 19.1 (shell). These values were much lower than the values reported for shell and flesh of three prawn samples from Lagos lagoon: *Macrobrachium vollenhovenii*, shell (41.7 g/100 g) and flesh (86.8 g/100 g); *Palaemon* species A, shell (58.1 g/100 g) and flesh (85.1 g/100 g); *Penaeus notialis*, shell (49.9 g/100 g) and flesh (83.7 g/100 g) [23].

If we calculate the EAA of the samples using FAO/WHO/UNU [19] standards, we have whole organism as 40.9 with His (37.3, no His), flesh has 38.8 with His (35.3, no His) and shell as 42.3 with His (38.3, no His). These values are highly comparable to the values in domestic duck: egg (39.5 with His), heart (34.2 with His) and liver (34.8 with His) [22]. However, the present values were lower than in the viscera values in the cattle, pig and sheep (g/100 g): heart (42.7-46.5); kidney (42.5-46.7); liver (41.5-47.7) and tongue (39.4-49.0) [21] but highly comparable to the viscera in turkey –hen: heart (37.7); liver (43.2) and gizzard (38.1). The FAO/WHO/UNU [19] standards for pre-school children (2-5 years) are (g/100 g protein): Leu (6.6), Phe + Tyr (6.3), Thr (3.4), Trp (1.1), Val (3.5), Ile (2.8), Lys (5.8), Met + Cys (2.5), His (1.9) and total (33.9 with His) and 32.0 (no His). Based on this information, the samples would generally provide individually enough or even more than enough of Phe + Tyr, Thr, Val, His, total for each of the sample and in addition for flesh was Met + Cys. Histidine is a semi-essential AA particularly useful for children growth. It is the precursor of histamine present in small quantities in cells. When allergens enter the tissues it is liberated in larger quantities and it is responsible for nettle rash [25]. The value of Leu was 5.11-6.14 g/100 g cp in the samples. It is an EAA for the old and young. Maple Syrup Urine Disease is an Inborn Error of Metabolism in which brain damage and early death can be avoided by a diet low in Ile and two other EAA, Leu and Val [25]. Both Ile, Leu and Val were moderately high in concentrations in the samples. However, the concentrations were not at dangerous levels. The amino acids show that Ile was about one-half of the Leu in each of the samples whereas Val was close in value to Leu as seen here: Val-Leu (6.26-6.14 in whole organism); Val-Leu (6.14-5.23 in flesh) and Val-Leu (7.28-5.11 in shell). Methionine is an EAA with value range of 2.03-2.30 g/100 g cp or 2.07-2.57 g/100 g cp (with Cys) in this report. Methionine is needed for the synthesis of choline. Choline forms lecithin and other phospholipids in the body. When the diet is low in protein, for instance in alcoholism and kwashiorkor, insufficient choline may be formed; this may cause accumulation of fat in the liver [25]. Phenylalanine had a value range of 5.35-6.17 g/100 g cp of the samples. It is the precursor of some hormones and the pigment melanin in hair, eyes and tanned skin. Phenylketonuria is the commonest Inborn Error of Metabolism which can be successfully treated by diet. The absence of enzyme (phenylalanine hydroxylase) in the liver blocks the normal metabolism of Phe and the brain is irreversibly damaged unless a diet low in Phe is given in the first few weeks of life [25]. Tyrosine is the precursor of some hormones (like the thyroid hormones) and the brown pigment melanin formed in hair, eyes and tanned skin. It reduces the requirement of Phe. Permanent deficiency of the enzyme-hypertyrosinaemia, a rear Inborn Error of Metabolism-can cause liver and kidney failure unless treated with a synthetic diet low in Phe and Tyr [25]. For the vast majority of consumers, aspartame is a safe alternative to sugar. One group of people, however definitely should not use aspartame. The warning on packets of artificial sweetners and product containing aspartame is explicit: “Phenylketonurics: contains phenylalalnine”. This is a case where one person’s meat is another’s poison. As in above, Phe to Tyr conversion is blocked and Phe concentration rises with elevated Phe converted to phenylpyruvic acid by the body. Phenylpyruvic acid is termed a “keto” acid because of its molecular structure; hence, the disease is known as phenyl*keto*nuria; or PKU. People with the disease are called phenylketonurics. Infants diagnosed with PKU must be put on a diet severely limited in Phe, avoiding excess Phe from milk, meats and other sources rich in protein. Because Phe is an EAA, a minimum amount of it must be available. Supplemented Tyr may also be needed to compensate for the absence of the normal conversion of Phe to Tyr [26]. High levels of Tyr-due to a temporary insufficiency of an enzyme necessary for its normal metabolism-sometimes accumulate in the blood stream of babies. The disorder is made worse by lack of vitamin C (necessary for the action of the enzyme) and artificial milk (cow’s milk contains more Phe and Tyr than breest). Vitamin C supplements, as orange juice, minimize the possibility of resultant brain damage. Permanent deficiency of the enzyme-hypertyrosinaemia, a rare Inborn Error of Metabolism-can cause liver and kidney failure unless treated with a synthetic diet low in Phe and Tyr. Food containing tyramine, a derivative of tyrosine, must be avoided when certain tranquillisers are taken.

In Table 2, we have the summary of the various parameters like the concentrations of essential, non-essential, acidic, neutral, sulphur, aromatic (g/100 g cp) and their percentages of the *P. borealis*. The total amino acid (TAA) in the samples had a reverse order in concentration when compared to the protein concentration as shown: shell (19.1 g/100 g) > flesh (18.3 g/100 g) > whole organism (17.2 g/100 g) for protein results and shell (93.0 g/100 g) > whole organism (92.7 g/100 g) > flesh (86.6 g/100 g) for amino acid results. The change in the pattern of amino acid concentration as against the crude protein concentration is a manifestation of the true protein in the samples, that is the true protein concentration would follow shell > whole organism > flesh in the shrimp samples. The total essential amino acid (TEAA) followed the above pattern of AA concentration as shell (40.9 g/100 g cp) > whole organism (39.8 g/100 g cp) > flesh (37.9 g/100 g cp) with CV % of 3.85.

Percentage TEAA was 42.9 -44.0. Other major parameters reported in Table 2 were: total non-essential amino acid (TNEAA), total essential aliphatic amino acid (TEAIAA), total essential aromatic amino acid (TEArAA), total neutral amino acid (TNAA) and their corresponding percentage levels. The CV % were generally low at 0.728-11.1. In Table 2, further calculated parameters were shown. The predicted protein efficiency ratio (P-PER) was highest in whole organism (1.71 or 2.12) but lowest in shell (1.21 or 1.65); also the Leu/Ile ratio was highest in the whole organism (2.76) but lowest in the shell (2.08); in the Leu/Ile ratio, Table 1 showed that the shell had the least value of Leu but highest value of Ile among the three samples. The isoelectric point (pI) values showed that flesh was the most acidic as shown: pI: whole organism (5.21), flesh (4.85) and shell (5.28). The essential amino acid index (EAAI) value showed that, of all the three samples flesh much superseded the other two samples in quality as flesh (99.4), shell (89.7) and whole organism (79.5) and their biological value (BV) corresponding values were 96.6, 86.0 and 75.0 respectively. The values of Lys/Trp and Met/Trp were also shown in Table 2. The % Cys in TSAA was very low at a range of 1.98-17.5 and high CV % of 77.8.

The EAA range of 37.9-40.9 g/100 g cp were far more than half or very close to the average of 56.6 g/100 g of the egg reference protein [17]. The total sulphur AA (TSAA) of the samples was 2.07 – 2.57 g/100 g cp. These values were about one-half of the 5.8 g/100 g cp recommended for infants [19]. The aromatic AA (ArAA) range suggested for infant protein (6.8-11.8 g/100 g cp) [19] was very favourably comparable with the present report where TEArAA range was 9.09-11.0 g/100 g cp showing that the samples protein could be used to supplement cereal flours [27]. The percentage ratio of EAA to the total AA (TAA) in the samples ranged between 42.9-44.0. These values were all above the 39 % considered adequate for ideal protein food for infant, 26 % for children and 11 % for adults [19]. The percentage EAA/TAA for the samples could be favourably compared with other animal protein sources: 45.9-47.1 % in meat organs of turkey-hen [24]; 46.2 % in *Zonocerus variegatus* [28]; 43.7 % in *Macrotermes bellicosus* [29]; 54.8 % in *Gymnarchus niloticus* (Trunk fish) [30] and 48.1-49.9 % in brain and eyes of African giant pouch rat [31] whereas it is 50 % for egg [32]. The percentage of neutral AA (TNAA) ranged from 55.8-64.2, indicating that this formed the bulk of the AA.

The predicted protein efficiency ratio ($P\text{-}PER_1$) was 1.21-1.71 and ($P\text{-}PER_2$) 1.65-2.12. In *Callinectes latimanus* (a lagoon crab) had $P\text{-}PER_1$ of 1.21 and $P\text{-}PER_2$ of 1.39, these values were lower than the present report [33] showing that the shrimp would likely be more physiologically utilized protein than the *Callinectes latimanus* (a crab). In general, it has been found that the better the protein, the lower the level in the diet required to produce the highest protein efficiency ratio. This is a clear reflection of the importance of the proper nutritive balance of all of the amino acids to produce optimum metabolic efficiency.

The Leu/Ile ratio was high at 2.76 in the whole organism but low at 2.13 (flesh) and 2.08 (shell) and CV % of 16.3; hence we may not experience concentration antagonism in the samples when consumed as protein source in food particularly flesh and shell; this is because 2.36 is the most ideal Leu/Ile [13]. The EAAI of 79.6-99.4 and their corresponding BV of 75.0-96.6 depict highly the quality of the protein of *P. borealis*. This is shown in the literature comparisons: milk, cow (whole, nonfat, evaporated, or dry), EAAI(88) and BV (84, predicted, 90, observed); human, EAAI(87) and BV (83); eggs, chicken (whole, raw or dried), EAAI(100), BV (97, predicted, 96, observed);whites (raw or dried), EAAI (95), BV (92, predicted, 93, observed); yolks (raw or dried), EAAI (93), BV (89, predicted); shellfish (shrimp, including prawns, raw or canned), EAAI (67), BV (61, predicted)[16]. These literature results show the quality position of shrimp under discussion. EAAI is useful as a rapid tool to evaluate food formulation for protein quality, although it does not account for difference in protein quality due to various processing methods or certain chemical reactions [34]. The isoelectric point, pI is 4.85-5.28 showing the samples to be in the acidic medium of the pH range. The calculation of pI from AA will assist in the quick production of certain isolate of organic product without going through the protein solubility determination to get to the pI.

From data on the amino acid requirements of infants found under uniform and controlled dietary conditions [35], a growth pattern of AA requirements was obtained by assigning value of unity to the Trp need. A similar calculation of the AA content of mammalian tissues recorded by Mitchell showed that there exist good agreement of growth needs and tissue AA patterns. This agreement is particularly good for the Lys/Trp (L/T) and Met/Trp (M/T) ratios of muscle proteins which constitute approximately 75 % of the infant body proteins. These present results had L/T of 3.05-62.5 and M/T of 2.54-37.8. Mammalian tissue patterns have the following values: Muscle, L/T, muscle (6.3), viscera (5.3), plasma proteins (6.2), M/T, muscle (2.5), viscera (2.0), plasma proteins (1.1) [36]. The available evidence indicates that the utilization of dietary proteins increases as their Lys and Trp content approaches that of muscle tissues. This concept gains further validity from the fact that the nutritional value of some protein products with low Lys/Trp values can be enhanced by small additions of Lys. In milk protein products this increased utilization approaches that of bovine muscle and plasma digests and appears to be a linear function of the augmented Lys/Trp values. Lys supplementation of wheat gluten increases its nutritive value of that of milk protein products. In the present results it is only the flesh L/T that tried to meet the muscle standard whilst shell M/T (2.54) approached the muscle value of 2.5.

Most animal proteins are low in Cys, limiting the literature examples to fish (fin and shell), we have literature values of Cys/TSAA % as : three different Nigeria fishes (23.8-30.1) [37]; male fresh water crab body parts (13.3-15.9) [38]; female fresh water crab body parts (27.3-32.8) [39]. The present Cys /TSAA % was 1.98-17.5 corroborating these literature observations. In contrast, many vegetable proteins contain substantially more Cys than Met, examples (Cys/TSAA) %: 62.9 in coconut endosperm [40], *Anacardium*

occidentale, 50.5 [41]; 58.9-72.0 (raw, steeped, germinated sorghum) [27]; 51.2-53.1 (raw, steeped, germinated millet) [42]. Thus, for animal protein diets or mixed diets containing animal protein, Cys is unlikely to contribute up to 50 % of the TSAA [13]. Cys an spare Met in improving protein quality and also has effect on mineral absorption particularly zinc [43].

The calculated differences between the amino acid profiles of whole organism versus the flesh and whole organism versus the shell of *P. borealis* are shown in Table 3. In the Table, positive sign preceding any numeral indicates that the value of whole organism is greater than the other sample being compared, whereas a negative sign indicates that the whole organism value is less than the other sample being compared with; each preceding sign goes for both the numeral before and within the bracket. In the whole organism versus the flesh, 7/9 or 77.8 % of the EAA were better concentrated in the whole organism than in the flesh and in the whole organism versus shell, 3/9 or 33.3 % EAA were better concentrated in the whole organism than in the shell. Overall, on concentration comparison, 13/18 or 72.2 % of AAs were more concentrated in the whole organism than flesh but 4/18 or 22.2 % more in whole organism than the shell.

On some quality assessments, the shrimp samples AAs were compared with the whole hen's egg to calculate the shrimp AAs scores; such score values are shown in Table 4. Among the AAs, Gly and Ala had scores greater than 1.00 in each sample; such as: Gly, 1.76 (whole organism), 1.48 (flesh) and 2.07 (shell); and in Ala, 1.31 (whole organism), 1.37 (flesh) and 1.42 (shell). Further, Pro, Phe, His and Tyr had scores greater 1.0 in each sample; also Thr had score greater than 1.0 in whole organism whilst Glu had scores greater than 1.0 in whole organism and flesh. Cystine was the limiting AA in all the samples although with different values: whole organism (0.023), flesh (0.015) and shell (0.241). The CV % values were close (3.94-18.3) except in Trp and Cys with respective high values of CV % of 96.4 and 138. In literature, the egg, heart and liver of domestic duck, only Gly and Glu had AA scores (AAS) values greater than 1.0 among all the samples [22]. In turkey-hen viscera (gizzard, heart, liver), Lys, Glu and Gly had AAS values greater than 1.0 in all the samples [24]. Gly had the highest scores in the three samples (1.48-2.07) just like but higher than the observation in the domestic duck egg, heart and liver (1.30-1.79) [22] and almost like the observation in the turkey-hen meat organs (1.38-2.50) [24]. To make corrections for the limiting amino acid (LAA) in the samples if they serve as sole source of protein food therefore, it would be 100/2.30 (or 43.5) x protein of whole organism, 100/1.50 (or 66.7) x protein of flesh and 100/24.1 (or 4.15) x protein of exoskeleton [25].

In Table 5, the essential amino acid scores (EAAS) of the samples based on provisional amino acid scoring pattern are shown. Val, Thr and Phe+Tyr had EAAS greater than 1.00 in all the samples. The least EAAS (LAA) in samples were Trp (0.054) in whole organism, Trp (0.327) in flesh and Lys (0.447) in shell. Generally, the CV % was closer at 3.98-16.8 except in Trp where the CV % was 96.2. The highest EAAS under this comparison was Phe + Tyr with values of 1.73-2.05. In the domestic duck egg and its heart and liver, the EAAS greater than 1.0 in all the samples were observed in Met+Cys (1.08-1.51) and Phe + Tyr (1.16-1.33) [22]; in addition total sum of EAA had values greater than 1.00 in the whole shrimp and shell. For recognized critical LAA, the EAA most often acting in a limiting capacity are Met (and Cys), Lys, Thr and Trp [19]. Hence, in this result, Lys would be regarded as first LAA which will actually require correction of the AA profiles. Therefore the correction would be 100/44.7 (or 2.24) x protein of shell; for whole organism, the correction would be 100/5.4 (or 18.5) x protein of whole organism and 100/32.7 (or 3.06) x protein of flesh.

In Table 6, the essential amino acid scores on the suggested requirements for pre-school children (2-5 years) are depicted. The highest score in the whole organism was His (1.88) and the least score was Trp (0.049) making it the LAA in the whole organism; the highest EAAS was also His (1.83) in the flesh whilst the lowest EAAS was also Trp (0.248) making it the LAA; in the exoskeleton, the highest score was His (2.11) and the lowest EAAS was Lys (0.424), hence LAA in shell. It is observed that what was the EAAS in Table 5 also corresponded to the EAAS in Table 6. In all, Val, Thr, Phe + Tyr, His and total AA had EAAS greater than 1.00 in each case in all the samples. The CV % values in Table 6 were replica of Table 5. In the domestic duck samples of egg, heart and liver, Met + Cys and Phe + Tyr were the only EAA that had EAAS greater than 1.00 in each of the samples [22]. Amomg the duck samples, Thr was the LAA (although Trp was not determined) [22]. For correction on the EAAS: in whole organism, Trp would be corrected as 100/4.9 (or 20.0) x protein of whole organism; also Trp in flesh would be 100/24.8 (or 4.03) x protein of flesh and Lys in shell would be 100/42.4 (or 2.36) x protein of shell.

The following values would show the position of quality of shrimp samples protein: the EAA requirements across board are (values with His) (g/100 g protein): infant (46.0), pre-school (2-5 years) (33.9), school child (10-12 years) (24.1) and adult (12.7) and without His: infant (43.4), pre-school (32.0), school child (22.2) and adult (11.1) [19]. From the present results based on these standards, we have: 40.9 g protein (with His) and 37.3 (no His) in whole organism; 38.8 g protein (with His) and 35.3 (no His) in flesh; 42.3 g protein (with His) and 38.3 (no His) in exoskeleton. While the present results would satisfy a high percentage of infant needs, they would satisfy the requirements of pre-school children and above.

The various amino acid class groups are shown in Table 7 [44]. The concentration trend of the classes could be seen to follow as shown in g/100 g cp: class I (27.0-28.7) > class IV (20.9 – 24.0) > class VI (14.2-17.1) > class V (11.2-11.7) > class II (9.37-11.4) > class VII (4.48-5.45) > class III (2.07-2.57). It could be seen that the percentage values were close to their individual principal values, e.g. value (percentage): class I, 27.0-28.7 (29.1-33.1) ; class II, 9.37-11.4 (10.8-12.3); class III, 2.07-2.57 (2.23-2.97), class IV, 20.9-24.0 (22.5-25.9); class V, 11.2-11.7 (12.9-12.6); class VI, 14.2-17.1 (16.4-18.4) and class VII, 4.48-5.45 (5.17-5.86).

The percentage levels were close ranging from 2.23-33.1. The CV % values were generally low in all the class groups ranging between 2.30-11.3.

The literature available on this type of class grouping is highly interesting. It is coming from the study of a sample of *Callinectes latimanus* (a lagoon crab) [33]. It goes thus with class, value (% value): class I, 28.1 (29.7), close to 28.7 (30.9) in shell; class II, 10.7 (11.3), close to 10.7 (11.5) in shell; class III, 2.67 (2.83), close to 2.57 (2.97) in flesh; class IV, 22.8 (24.1), close to 22.6 (26.1) in flesh; class V, 11.7 (12.4), close to 11.7 (12.6) in whole organism; class VI, 17.1 (18.1), close to 17.1 (18.4) in shell and class VII, 5.45 (5.77), close to 5.45 (5.86) in shell.

The amino acid in Table 7 shows that EAAs were distributed into the various classes as follows: class I (3EAA), class II (one EAA), class III (one EAA), class IV (no EAA), class V (3EAA), class VI (3EAA) and class VII (no EAA). This means in terms of essentiality, class I ≡ class V ≡class VI > class II ≡ class III; for non-essentiality, class IV ≡ class VII. Details of the groups concentrations, percentage values of the concentrations and each class composition are all shown in Table 7.

The summary of the AA profile of the samples into factors A and B can be seen in Table 8. Factor A means are AA values of the three samples along the vertical axis whilst Factor B are the values along the horizontal axis; both containing the essential and non-essential amino acids. Column under Factor B means showed that the values there were close at a range of 39.5-51.2 g/100 g cp. However the mean of Factor A means gave a value of 45.4 g/100 g cp as in Factor B means as a total summary.

The summary of the statistical analysis of the data from Tables 1, 2, 3, 4, 5 and 6 are shown in Table 9. The correlation coefficient (r_{xy}) values and other parameters were for whole organism/endoskeleton, whole organism/exoskeleton and endoskeleton/exoskeleton. All the r_{xy} values were positively high (0.8636-0.9907) but value from Table 3 was low at 0.3443. All the r_{xy} values (except from Table 3) were also significantly different since their r_{xy} values were individually greater than the critical Table value at $r_{=0.05}$. The regression coefficient (R_{xy}) was positive in all the comparisons with values that ranged from 0.03-3.13. The variance was generally high (0.75-0.98) except in results from Table 3 with r_{xy}^2 of 0.19. 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 9, a section will just be explained to serve as example for other members of the Table. From Table 1, whole organism/endoskeleton had high and positive r_{xy} (0.9907) which was significantly different from each other (i.e. whole organism and endoskeleton) at $r_{=0.05}$. The variance (r_{xy}^2) was high at 0.98 and a regression (R_{xy}) of 0.16 meaning that for every one unit (g/100 g cp) increase in the AA of the whole organism, there was a corresponding increase of just 0.16 in endoskeleton. The mean of the whole organism was 5.16±3.37 g/100 g cp and CV % of 65.3 whilst the mean for endoskleleton was 4.82 ±3.07 g/100 g cp and CV % of 63.8. The coefficient of alienation (C_A) was low at 13.6 % but corresponding high value of index of forecasting efficiency (IFE) of 86.4 %. The IFE shows that the relationships between whole organism/endoskeleton could easily be predicted because error of prediction was just 13.6 % which was 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.

4. Conclusion

The study showed that both the flesh and the shell will contribute positively to the protein quality of the whole organism of Pandalus borealis. The samples were very good sources of Val, Thr, Leu, Phe, His, Arg and more than average Lys. These values were high across board: EAAI, BV, Lys/Trp and Met/Trp. The difference in the AA composition in the whole organism/flesh was higher than in whole organism/shell. The samples were better concentrated in Gly, Ala, Pro, Glu, Phe, His and Tyr than in the whole egg. The EAAS were greater than 1.0 in Val, Thr, Phe + Tyr and total essential amino acids. Out of the seven classes of AAs, the EAA was distributed into only five classes. Out of 16 parameters compared between whole organism/flesh, whole organism/shell and flesh/shell, 15 of them (i.e. 15/16 = 93.8 %) were significantly different at r = 0.05.

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