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PROXIMATE, MINERAL, AMINO ACID COMPOSITION AND MINERAL SAFETY INDEX OF *CALLINECTES LATIMANUS*

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ABSTRACT

The proximate, mineral and amino acid compositions as well as mineral safety index (MSI) of *Callinectes latimanus* were determined on dry weight basis. In the proximate values, crude fat was lowest at 0.87 g/100 g whereas carbohydrate was highest at 46.2 g/100 g but crude fibre was not detected. In the total energy contribution, carbohydrate value contribution was 68.7 % but only 2.82 % from crude fat. In the minerals composition, the following were highly concentrated: Ca, Mg, K, Na and P; Se, Pb, Zn, Mn, Co and Cu were low in values whereas Fe was moderately concentrated. In the mineral ratios, Na/K, Ca/P and Ca/Mg were high. The MSI showed that Ca, P, Na and Mg were all higher than the standard whereas Fe, Cu, Zn and Se were lower. Two acidic amino acids (Glu and Asp) were the highest concentrated amino acids and the two had equivalent values of 11.4 g/100 g protein each. Val was the most concentrated essential amino acid. Whilst the total amino acid was 94.5 g/100 g crude protein, non-essential amino acid was 55.9 g/100 g cp (59.2 %) and the essential amino acid was 42.6 g/100 cp (45.1 %). Highest group amino acid was neutral amino acid at 59.2 g/100 g cp (62.7 %). BV_1/BV_2 were 61.8/63.7 and $P\text{-}PER_1/P\text{-}PER_2$ were 1.21/1.39 whilst EAAI was 1.14. Amino acid groups had the trend: Class I > Class IV > Class VI > Class V > Class II > Class VII > Class III. In the amino acid scores: Cys (0.348) was limiting under whole hen's egg comparison, Lys (0.464) was limiting in provisional essential amino acid scoring pattern and Lys (0.440) was limiting under pre-school child essential amino acid requirement with correction values of 100/34.8, 100/46.4, 100/44.0 respectively.

INTRODUCTION

Crab is an outstanding successful form of crustacean whose number of species has multiplied to such an extent that within the order Decapoda (which includes Lobster, Prawn, Shrimp) some 4,500 of the 8,500 species are crabs (Davidson, 1999). The typical crab is thought of as a creature which scuttles sideways across the sea bottom or beach; and many crabs answer to this description. However, there are also swimming crabs and land crabs, and the range of sizes and configurations is huge. The tiny oyster (pea) crab is the size of a pea, whereas the giant Japanese spider crab may measure 3.6 m (12) from claw tip to claw tip. The constant feature is possession of two claws and eight walking or swimming legs or 'feet', and that the whole creature is, like other crustaceans, contained within a hard exoskeleton which serves as protective armour except at those times when it has to be shed, as its occupant grows, and replaced by a new and larger one (Davidson, 1999). Several crabs are prized as food. They include the Alaska king crab (*Paralithodes camtschatica*); the blue crab (*Callinetes sapidus*), which is the commercially important crab occurring along the East and Gulf coasts of the United States (Bullough, 1958); the Dungenes crab (*Cancer magister*), which are present in Europe-non-swimming crabs used as food (Bullough, 1958); and the giant mangrove swimming crab (*Scyllia serrrata*) which is popular to India and as far away as Japan (Muller and Tobin, 1980). The crab is usually consumed by individuals and it is often recommended for pregnant women. Literature is available on the chemical composition of the nutritionally valuable parts of male and female common West African fresh water crab, *Sudananautes africanus africanus* (Adeyeye, 2002); the relationship in the amino acid of the whole body, flesh and exoskeleton of *S. africanus*

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africanus (Adeyeye and Kenni, 2008); proximate and mineral composition of whole body, flesh and exoskeleton of male and female *S. africanus africanus* (Adeyeye *et al*., 2010); proximate and mineral compositions of common crab species [*Callinectes pallidus* and *Cardisoma armatum*] of Badagry creek, Nigeria (Elegbede and Fasina-Bombata, 2013). There is paucity of information on the chemical composition of *Callinectes latimanus*. The study reported in this article is an attempt to assess the nutritional quality of *C. latimanus* (fam. Portunidae) (a lagoon crab) by evaluating its proximate, minerals, amino acids, mineral ratios and mineral safety index. It is hoped that this will contribute information to food composition tables.

MATERIALS AND METHODS

Collection and treatment of samples

Callinectes latimanus samples were collected from the fish trawlers from the Lagos lagoon. The samples were stored under freezing at -10°C. Two whole crabs were separated fresh. Whilst the internal organs were discarded, the other separated parts were dried in the oven at 105°C until constant weight. For the whole body sample, the following constituted it: cheliped (muscle and exoskeleton), carapace, thoracic sternum and the other four pairs of walking legs and then dried at 95°C. The samples were then blended and stored in plastic containers pending analyses. The micro-Kjedahl method as described by Pearson (1976) was followed to determine the crude protein. The crude fat was extracted with a chloroform/methanol (2:1) mixture using Soxhlet extraction apparatus (AOAC, 2005). Moisture, ash and crude fibre were also determined by the AOAC methods while carbohydrate was determined by difference. The calorific value in kilojoule (kJ) was calculated by multiplying the crude fat, protein and carbohydrate by Atwater factor of 37, 17 and 17 respectively. Determinations were in duplicate.

The minerals were analysed from the solution obtained by first dry ashing the samples at 550°C. The filtered solutions were used to determine Na, K, Ca, Mg, Zn, Fe, Mn, Cu, Cr, Pb and Se by means of atomic absorption spectrophotometer (Buck Scientific Model- 200 A/210, Norwalk, Connecticut 06855) and phosphorus was determined colorimetrically by Spectronic 20 (Gallenkamp, UK) using the phosphovanado molybdate method (AOAC, 2005). All chemicals used were of British Drug House (BDH, London, UK) analytical grade. The detection limits for the metals in aqueous solution had been determined previously using the methods of Varian Techtron (1975). The optimal analytical range was 0.1-0.5 absorbance units with coefficients of variation from 0.9 % to 2.21 %. Ca/P, Na/K, K/Na, Ca/Mg and the milliequivalent ratio [K/(Ca +Mg)] (Hathcock, 1985); the mineral safety index (MSI) (Hathcock, 1985) of Na, Mg, P, Ca, Fe, Se and Zn were also calculated. The method of amino acid analysis was by ion-exchange chromatography (IEC) (FAO/WHO, 1991) using the Technicon Sequential Multisample Amino Acid Analyzer (TSM) (Technicon 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 °C under vacuum in a rotary evaporator. The residue was dissolved with 5ml 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 µl and about 76 minutes elapsed for each analysis. The column flow rate was 0.50 ml/min at 60°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. For the estimation of quality of dietary protein, various methods were used for the estimation.

- The essential amino acid score was calculated using the provisional essential amino acid scoring pattern (FAO/WHO, 1973).
- Amino acid score based on pre-school child essential amino acid requirement for ages 2-5 y (FAO/WHO/UNU, 1985).
- Amino acid score (for both essential and non-essential amino acids) was calculated based on whole hen's egg (Paul *et al.,* 1978).
- Calculation of essential amino acid index (EAAI) (Nielsen, 2002).
- Computation of protein efficiency ratio (C-PER or P-PER) was done using the equations suggested by Alsmeyer *et al.* (1974):
  $P\text{-}PER_1 = -0.468 + 0.454\ (Leu) - 0.105\ (Tyr)$
  $P\text{-}PER_2 = -0.684 + 0.456\ (Leu) - 0.047\ (Pro)$
- Computation of biological value (BV) was calculated following the equation of Oser (1959) as follows:
  $BV = 49.09 + 10.53\ (PER)$
  Where, PER = Protein Efficiency Ratio.
- The ratio of total essential amino acid (TEAA) to the total amino acid (TAA), i.e. (TEAA/TAA), total sulphur amino acid (TSAA), percentage cystine in TSAA (Cys/TSAA),

total aromatic amino acid (TArAA), total basic amino acid (TBAA), total acidic amino acid (TAAA), total acidic amino acid (TAAA), total neutral amino acid (TNAA) and the Leu/Ile ratios were calculated. Theoretical estimations of isoelectric point (pI) can be carried out by the equation of the form (Olaofe and Akintayo, 2000):

Where IPm 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 (Finar, 1975). Also calculated were the various amino acid groups into classes I-VII (Nieman *et al*., 1992).

RESULTS

The proximate composition result was depicted in Table 1. Results of major significance were (g/100 g dry weight): crude protein (19.1), soluble carbohydrate (46.2), total ash (28.6) and metabolizable energy (1142 kJ/100 g). The trend of contribution to the total energy was carbohydrate (68.7 %) > protein (28.4 %) > fat (2.82 %) whilst the utilizable energy due to protein was 17.1 %. Crude fibre was not detected and the value of crude fat was < 1.0 g/100 g dry weight. In Table 2, we had the mineral elements composition and some mineral ratios. The high level of total ash in Table 1 showed a corresponding high levels of major minerals in the samples. Such very high concentration of minerals were seen in (mg/100 g dry weight): Ca (14, 853), Mg (962), K (259), Na (987) and P (2, 904).

Table 1. Proximate composition (g/100 g edible portion) of *Callinectes latimanus* (dry weight)

Parameter[a]	Value
Crude fat	0.87
Crude protein	19.1
Carbohydrate	46.2
Total ash	28.6
Crude fibre	-
Moisture	5.25
Energy (kJ/100 g)	1142
PEP %	28.4
PEF %	2.82
PEC %	68.7
UEDP %	17.1

[a]PEP = proportion of total energy due to protein.
PEF = proportion of total energy due to fat.
PEC = proportion of total energy due to protein.
UEDP = utilizable energy due to protein.

Table 2. Minerals (mg/100 g dw) and calculated mineral ratios of *Callinectes latimanus*

Parameter	Value
Fe	8.06
Cu	0.618
Co	0.103
Mn	1.41
Zn	1.81
Pb	0.001
Ca	14,853
Mg	962
K	259
Na	987
P	2,904
Se	0.027
Na/K	3.82
K/Na	0.262
[K/(Ca +Mg)]	0.033
Ca/P	5.11
Ca/Mg	15.4

dw = dry weight.

Table 3. Mineral safety index of Ca, P, Na, Fe, Cu, Zn, Se and Mg of *Callinectes latimanus*

Mineral	CV	TV	D	%D
Ca	124	10	114	1140
P	24.2	10	-14.2	142
Na	9.47	4.80	-4.68	97.5
Fe	3.60	6.70	+3.10	46.3
Cu	6.80	33	+32.2	97.6
Zn	3.99	33	+29.0	87.9
Mg	36.1	15	- 21.1	141
Se	5.40	14	+8.60	61.4

CV = Calculated value; TV = Table value; D = Difference. No MSI standard for K, Mn, Co and Pb.

However, all the trace metal (except Fe) had low values ranging from 0.001-1.81 mg/100 g dry weight but Fe had a value of 8.06 mg/g dry weight. These mineral ratios were low: K/Na (0.262) and [K/ (Ca + Mg)] (0.033). The high levels of Na/K (3.82) and Ca/Mg (15.4) were undesirable whereas (Ca/P 5.11) was desirable. Values of mineral safety index (MSI) in Table 3 showed the values of Ca, P, Na and Mg to be all higher than their corresponding standard values. Those MSI level less than the standards came from Fe, Cu, Zn and Se. The amino acid profile of the sample could be seen in Table 4. The two acidic amino acids (Glu and Asp) in the sample were of equivalent value of 11.4 g/100 g cp each and they also form the highest concentrated amino acid in the samples. Both Cys and Trp were each less than 1.0 g/100 g cp in the sample. The most concentrated essential amino acid was Val.

Table 4. Amino acid composition (g/100 g protein edible portion) of *Callinectes latimanus* (dw)

Amino acid	Value
Lysine (Lys)*	2.55
Histidine (His)*	4.01
Arginine (Arg)*	5.13
Aspartic acid (Asp)	11.4
Threonine (Thr)*	5.42
Serine (Ser)	5.29
Glutamic acid (Glu)	11.4
Proline (Pro)	5.45
Glycine (Gly)	6.10
Alanine (Ala)	7.11
Cystine (Cys)	0.626
Valine (Val)*	7.28
Methionine (Met)*	2.05
Isoleucine (Ile)*	2.46
Leucine (Leu)*	5.11
Tyrosine (Tyr)	6.13
Phenylalanine (Phe)*	6.17
Tryptophan (Trp)*	0.772
Protein (g/100 g)[a]	19.1

*Essential amino acid.
[a]Dry weight and fat free basis.

Table 5. Essential, non-essential, acidic, neutral, sulphur, aromatic (g/100 g protein) of *C. latimanus*

Amino acid	Value
Total amino acid (TAA)	94.5
Total non-essential amino acid (TNEAA)	55.9
Total essential amino acid (TEAA) TEAA – with His	42.6
-without His	38.6
% TNEAA	59.2
% TEAA – with His	45.1
-without His	40.8
Total neutral amino acid (TNAA)	59.2
%TNAA	62.7
Total acidic amino acid (TAAA)	22.8
%TAAA	24.1
Total basic amino acid (TBAA)	11.7
% TBAA	12.4
Total sulphur amino acid (TSAA)	2.68
% TSAA	2.83
% Cys/TSAA	23.4
Total aromatic amino acid (TArAA)	17.1
% TArAA	18.1
Biological value (BV_1)	61.8
Leu/Ile	2.08
% Leu-Ile	2.80
Isoelectric point (pI)	5.47
BV_2	63.7
$P\text{-}PER_1$	1.21
$P\text{-}PER_2$	1.39
Essential amino acid index (EAAI)	1.14

P-PER = Predicted protein efficiency ratio.

Generally the non-essential amino acids were more concentrated than the essential amino acids. The most concentrated amino acid group was total neutral amino acid having a value of 59.2 g/100 g cp (62.7 %) and followed slightly by the total acidic amino acids (22.8 g/100 g cp; 24.1 %); total sulphur amino acid was least at 2.68 g/100 g cp (2.83 %). The two values of P-PER$_1$/P-PER$_2$ were close at 1.21/1.39 and also the two biological values results were close as: BV$_1$/BV$_2$ being 61.8/63.7. The essential amino acid index was slightly low at 1.14 and the isoelectric point (pI) showed that the sample was in the acidic pH range since it had a pI value of 5.47. The Leu/Ile value of 2.80 might not cause any deleterious effect. The various amino acid class groups were shown in Table 6. The concentration trend of the classes could be seen to follow as shown in g/100 g cp: class I (28.1) > class IV (22.8) > class VI (17.1) > class V (11.7) > class II (10.7) > class VII (5.45) > class III (2.67).

Table 6. Amino acid groups of *C. latimanus*

Class	Value	% value
I [with aliphatic side chains (hydrogen and carbons) = Gly, Ala, Val, Leu, Ile]	28.1	29.7
II [with side chains containing hydroxylic (OH) groups = Ser, Thr]	10.7	11.3
III [with side chains containing sulphur atoms = Cys, Met]	2.67	2.83
IV [with side chains containing acidic groups Groups or their amides = Asp, Glu]	22.8	24.1
V [with side chains containing basic groups =Arg, Lys, His]	11.7	12.4
VI [containing aromatic rings = His, Phe, tyr, Trp]	17.1	18.1
VII [imino acids = Pro]	5.45	5.77

Table 7. Total amino acid scores of *C. latimanus* based on whole hen's egg score

Amino acid	Score
Lys	0.412
His	1.67
Arg	0.842
Asp	1.06
Thr	1.06
Ser	0.669
Glu	0.953
Pro	1.43
Gly	2.03
Ala	1.32
Cys	0.348
Val	0.971
Met	0.641
Ile	0.439
Leu	0.615
Tyr	1.53
Phe	1.21
Trp	0.429
Total	0.946

Table 8. Essential amino acid scores of *C. latimanus* based on FAO/WHO (1973) and FAO/WHO/UNU (1985) scores

Amino acid comparison	Fao/Who(1973) comparison	Fao/Who/Unu(1985)
Ile	0.615	0.878
Leu	0.730	0.774
Lys	0.464	0.440
Met+Cys	0.765	1.07
Phe+Tyr	2.05	1.95
Thr	1.36	1.59
Trp	0.772	0.702
Val	1.46	2.08
His	-	2.11
Total	1.07	1.26

It could be seen that the percentage values were close to their individual principal values, e.g. value (percentage): class I, 28.1 (29.7); class II, 10.7 (11.3); class III, 2.67 (2.83); class IV, 22.8(24.1); class V, 11.7 (12.4); class VI, 17.1 (18.1) and class VII, 5.45 (5.77). The percentage levels were close ranging from 2.83-29.7. The amino acid scoring pattern based on the whole hen's egg comparison was shown in Table 7. The limiting amino acid (LAA) here was Cys with a value of 0.348. Many scores were greater than 1.0 showing them to be better concentrated than in the whole hen's egg, such amino acid scores came from His, Asp, Thr, Ser, Pro, Gly, Ala, Tyr, and Phe. In Table 8, essential amino acid scores as obtained from provisional essential amino acid scoring pattern and pre-school child essential amino acid comparisons showed that Lys was limiting in both standards. Whilst the limiting Lys had a value of 0.464 in the provisional scoring pattern, it had a score of 0.440 in the pre-school child requirement. Again the following essential amino acids had each score greater than 1.0: Phe +Tyr, Thr and Val (in provisional score) and Met + Cys, Phe + Tyr, Thr, Val and His (in pre-school child requirement).

DISCUSSION

The calculation of the organic matter (OM) gave a value of 71.4 g/100 g. This OM value was lower than 98.97 g/100 g in ostrich muscles (Sales and Hayes, 1996), 91.07 g/100 g in trunk fish (Adeyeye and Adamu, 2005) and the values reported for four fresh water fishes of *Mormyrops delicious* (86.4 g/100 g), *Bagrus bayad* (75.0g/100 g), *Synodontis budgetti* (84.0 g/100 g) and *Hemischronis fasciatus* (76.0 g/100 g) (Abdullahi and Abolude, 2002). The crude protein level of 19.1 g/100 g was much lower than the crude protein of most conventional animal protein but close to the value of 17.7 g/100 g in the eyes of guinea-fowl but much better than the value in the skin of guinea-fowl having a value of 1.08 g/100 g (Adeyeye, 2014). The protein content *Callinectes pallidus* is 24.38 % and in *Cardisoma armatum* it is 23.94 % (Elegbede and Fashina-Bombata, 2013), it ranges from 18.40-87.57 g/100 g from various parts of male and female West African fresh water crab *Sudananautes africanus africanus* (Adeyeye, 2002); protein values were g/100 g: 32.5 (whole body), 24.8 (flesh) and 24.2 (exoskeleton) from the male body of *S. africanus africanus* (Adeyeye and Kenni, 2008). The crude fat content of 0.87 g/100 g gave an indication that the sample would be good for people avoiding animal protein with high level of fat. The crude fat level falls within the range of 0.12-4.50 g/100 g in guinea-fowl samples (Adeyeye, 2014). The ash content of 28.6 g/100 g doubles the range of 13.41-14.96 in *C. pallidus* and *C. armatum* respectively (Elegbede and Fasina-Bombata, 2013) but higher but mostly lower than in the various parts of *S. africanus africanus* having values of 2.45-61.94 g/100 g (Adeyeye, 2002). The energy level in the sample was 1142 kJ/100 g or 1.14 MJ. This value is lower than in the following literature values (MJ/100 g): 1.61-1.71 (from eight organs of guinea-fowl) (Adeyeye, 2014), turkey muscle and skin (1.33-1.37) (Adeyeye and Ayejuyo, 2007), sheep lean meat (2.06) (Fornias, 1996) and lean pork (2.29) (Fornias, 1996). The lower level of fat in the sample could have been responsible for the lower level of total energy than in the literature results. The energy value is even lower than we have from cereals (1.3-1.6 MJ/100 g) (Paul *et al*., 1978) showing the sample to be lean source of energy. The carbohydrate value in the sample is higher than in *S. africanus africanus* (1.15-3.13 g/100 g) (Adeyeye, 2002), 5.40 % in *C. pallidus* and 7.13 % in *C. armatum* (Elegbede and Fasina – Bombata, 2013), but lower than in the eyes (80.6 g/100 g), skin (98.3 g/100 g) and egg shell (81.0 g/100 g) in guinea-fowl (Adeyeye, 2014). The carbohydrate contributed the highest level of energy to the total energy density of the proximate components. Table 1 still contains other parameters calculated from the proximate values. It shows the various energy values as contributed by protein, fat and carbohydrate. The daily energy requirement for an adult is between 2500-3000 kCal (10455-12548 kJ) depending on his physiological state while that of infants is 740 kCal (3094.68 kJ) (Bingham, 1978).

This implies that whilst an adult man would require 915 g (taking minimum energy of 10455 kJ), infants would require 271 g (taking energy requirement for the calculation). These sample requirements for minimum energy needs for both adults and infants fall within the range as observed in the muscle and skin of turkey: an adult man would require between 786-944 g (muscle) and 761-913 (skin) to meet his requirement, infants would require 233 g (muscle) and 225 g (skin) (Adeyeye and Ayejuyo, 2007) where our own sample weight for adult is 915 g (between 786-944 g in turkey muscle) but close to 761-913 g (turkey skin) whereas our value of 271 g (for infants) is much higher than in the turkey muscle (233 g) and skin (225 g). Our sample weight for energy requirements is much higher than in the values for guinea- fowl organs: 649-733 g (adult man) and 192 g (infants) (Adeyeye, 2014). The utilizable energy due to protein (UEDP %) was 17.1 (assuming 60 % 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 muscle of turkey is 56.4 % and 40.0 % in the skin (Adeyeye and Ayejuyo, 2007) whereas the values are 12.1-28.8 % (female and male exoskeleton), 12.5-23.8 % (female and male flesh) and 13.8-17.9 % (female and male whole body) of *S. africanus africanus* (Adeyeye *et al*., 2010).

The UEDP % of 17.1 may be more than enough to prevent energy malnutrition in children and adult fed solely on the sample as the main source of protein. The PEF % value of 2.82 is generally very low and far below the recommended level of 30 % (NACNE, 1983) and 35 % (COMA, 1984) for total fat intake, this is very useful for people wishing to adopt the guidelines for a healthy diet. Minerals of significant levels among the major elements were Ca, Mg, K, Na and P. Similar trend is observed for *C. pallidus* and *C. armatum* with values as follows (mg/kg): Ca (3843.95-18901.51), K (1489.02-5720.01), with *C. pallidus* being lower in each case except in Na; the trace elements also follow the trend in *C. pallidus* and *C. armatum* where we have (mg/kg): Fe (9.30-10.50), Mn (34.43-9.33), Zn (7.87-5.83) and Cu (84.82-84.81) (Elegbede and Fashina-Bombata, 2013). In *S. africanus africanus* (Adeyeye, 2002), Ca, Na, K and P follow the current sample trend, Cu, Fe and Zn are moderately higher than the current report; Mg is lower than in the current result but Co of 0.103 mg/100 g is close to the values of ND-1.91 in various parts of *S. africanus africanus*. The level of Mn in our result is 1.41 mg/100 g. Manganese has always been found low in the foods consumed in Nigeria. For examples, it is 29±0.01 mg/kg (*moin-moin*) and cake (2.8±0.01 mg/kg) (Adeyeye *et al*., 2012a); ND-1.81 mg/100 g in various organs of guinea-fowl (Adeyeye, 2014). It is well known (Buss and Robertson, 1976; Merts, 1981) that mineral elements are necessary for life. Cobalt (II) is a component of vitamin B_{12} (cyanocobalamin) where it forms about 4 %. B_{12} is essential for the prevention of anaemia. Iron is at reasonable level in the sample. Iron deficiency anaemia is one of the most widespread nutritional deficiencies in the world. The United Nations estimates that over three billion people in developing countries are iron-deficient (Administrative Committee, 2000). The problem for women and children is more severe because of their greater need for iron. The iron in meat is well absorbed, about 15-35 %, a figure that can be contrasted with plant foods, at 1-10 % (Bender, 1992).

Not only is the iron of meat well absorbed but it enhances the absorption of iron from other sources, for example, the addition of meat to legume/cereal diet can double the amount of iron absorbed and so contribute significantly to the prevention of anaemia, which is so widespread in developing countries like Nigeria (Wheby, 1974; Bender, 1992). Lack of adequate iron in the diet is associated with poorer learning and decreased cognitive development (FAO, 1997). Iron also facilitates the oxidation of carbohydrates, protein and fats. Crab is a good substitute for conventional meat source and so is capable of carrying out the functions of meat. Selenium is an essential trace mineral incorporated into plants from soil. Consumption of selenium has been linked to reduced risk of all cancers, but particularly those of the lung, colo-rectum and prostate (El-Bayoumy and Sinha, 2004; Combs, 2004). Selenium is also important for specific enzymes and proteins in the brain and is necessary for proper immune function. However, selenium is toxic at levels only a little greater than those required in a healthy diet, so caution is warranted with supplementation and increased intakes. The Se value in the present sample is 0.027 mg/100 g, this is below toxic level (see Table 3).

Zinc is present in all tissues of the body and is a component of more than 100 enzymes. Zinc is one of the several trace minerals that can be deficint in human diets, especially where meat is not consumed (Pew Initaitive on Food and Biotechnology, 2007). Zinc deficiency is associated with impaired growth and reproduction, anorexia, immune disorders, and a variety of other symptoms. Meat is the richest source of zinc in the diet and supplies one-third to one-half of the total zinc intake of meat-eaters. Zinc dietary deficiency has been found in adolescent boys (Bender, 1992). Families and individuals who may be using vegetable and cereal sources of protein because of low incomes or as an attempt to cope with inflation may not be able to meet the zinc allowances (about 15-20 mg) per day. The zinc in these sources is not as available as animal sources (NAS, 1971). Our sample is 1.81 mg/100 g zinc which means more zinc must come from other sources in the diet. Copper is low in the samples at 0.618 mg/100 g. The blood of decapods contain haemocyanin which is the respiratory pigment and it is distinctly blue in colour: Cu is its major constituent (Grove and Newell, 1974). Cu and Fe are present in enzyme cytochrome oxidase involved in energy metabolism (Li and Vallee, 1973). Copper deficiency is of little concern since it is widely distributed in other types of food but its absorption failure can lead to Menkes's disease. It is also needed to form red blood cells (with vitamin C) (FAO, 1997). There is more calcium in the body than any other mineral element, mostly present in teeth and bones. It is also an important constituent of body fluids. It tends to be a kind of co-ordinator among inorganic elements; if excessive amounts of K, Mg or Na are present in the body, Ca is capable of assuming a corrective role. 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). Ca, P and vitamin D (which produces a hormone called 1, 25-dihydroxycholecalciferol, DHCC) (Chesworth, 1992) combine together to avoid rickets in children and osteomalacia (adult rickets). Also osteoporosis (bone thininig) is more common among older people, among females, and among whites, according to Moldawer *et al.* (1965) than younger people, males, and non-whites: Ca together with other nutrients and various hormonal environmental factors is involved. Rose (1967) and Newton-John and Morgan (1968) agreed that a relatively constant rate of bone loss occurs after the ages of 20-30 years.

They suggested that increasing the bone mass during the first 20 years of life is one way to reduce the possibility of oesteoporosis in later life. According to Hegsted (1967), the Ca in the hard tissues like bones and teeth is more metabolically stable. A dietary regime of adequate dietary Ca over the years should be a deterrent to this condition of osterporosis. The crab under study is a very good source of calcium. Very high value of phosphorus was recorded in the sample. Good value ratio existed between calcium and phosphorus. 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). The sample is a good source of Mg. Na and K. Magnesium is an activator of many enzyme systems and maintains the electrical potential in nerves (Shils, 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.

For sodium, the mineral is widely distributed in foods, with plants containing less than animal sources (Flecks, 1976). The result in Table 2 corroborates this earlier observation. Table 2 further depicts the various mineral ratios that were calculated. The Ca/P is greater than 0.5 which is the minimum ratio required for favourable Ca absorption in the intestine for bone formation (Nieman *et al.*, 1992). High level of Ca/P ratio enhances strong bone development since absorption under this condition would be high. The Ca/P ratio is reported to have some effects on Ca in the blood of many animals (Adeyeye and Faleye, 2007). The Na/K ratio is 3.82. The Na/K of 0.60 is the ratio that favours none enhancement of high blood pressure disease in man (Nieman *et al.*, 1992). To bring this ratio low, food rich in potassium should be more consumed. The Ca/Mg value is 15.4 whereas the recommended value is 1.0. Both Ca and Mg would need adjustment for good health. The milliequivalent ratio of [K/(Ca+Mg)] is less than 2.2. This means the sample will not promote hypomagnesaemia in man (NRC, 1989). The standard mineral safety index (MSI) 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 is determined. Minerals whose MSI values are higher than the table MSI (TV) are Ca, P, Na, and Mg with calculated value (CV) range of 97.5 to 1140 respectively (which are relatively high). Sodium is 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 following minerals have their TV > CV: Fe, Cu, Zn and Se giving positive difference with corresponding lower percentage difference having range values of 46.3 to 97.6. High levels of Ca, P and Mg may not cause deleterious diseases unlike Na.

The amino acids composition shows that Asp and Glu are the most concentrated amino acid (AA) in the sample with each of them having a level of 11.4 g/100 g crude protein (cp). The position of the Asp and Glu AA follows the trend in the whole egg, heart and liver of domestic duck (*Anas platyrhynchos*) consumed in Nigeria (Adeyeye and Ayeni, 2014); this is also the trend in the AA profile of ostrich, beef and chicken (Sales and Hayes, 1996) and in the muscle and skin of turkey-hen (Adeyeye and Ayejuyo, 2007). Essential amino acids (EAA) of prominent concentration are Phe, Val, Leu, Thr, Arg and His. Our histidine level of 4.01 g/100 g cp is higher than in turkey-hen muscle and skin (2.47-2.60 g/100 g cp) and the levels in ostrich (2.03), beef (3.20) and chicken (3.04). These non-essential amino acids (NEAA) are also high in their values: Tyr, Ala, Gly, Pro and Ser. The FAO/WHO/UNU (1985) standards for pre-school children (2-5 years) are (g/100 g cp): Leu(6.6), Ile (2.8), Lys (5.8), Met + Cys (2.5), His (1.9) and total (33.9). Based on this information, the crab would provide enough or even more than enough of Met + Cys, His and total EAA.

The following values would show the position of the quality of the crab sample; the EAA requirements across board are (values with His) (g/100 g cp): infant (46.0), pre-school (2-5 y) (33.9), school child (10-12 y) (24.1) and adult (12.7) and without His: infant (43.4), pre-school (32.0), school child (22.2) and adult (11.1) (FAO/WHO/UNU, 1985). From our own results based on these standards, we have 42.6 g/100 g (with His) and 38.6 g/100 g cp (no His). Our results are not too far from the following literature values of the total EAA: egg, 51.2 (with His) and 49.0 (no His); cow's milk 50.4 (with His) and 47.7 (no His); beef, 47.9 (with His) and 44.5 (no His) (FAO/WHO/UNU, 1985). The total sulphur AA (TSAA) of the sample is if 2.68 g/100 g cp which is about one-half of the 5.8 g/100 g cp recommended for infants (FAO/WHO/UNU, 1985). The aromatic AA (ArAA) range suggested for infant protein (6.8-4.8 g/100 g cp) is even less than the value of 17.1 g/100 g cp in the present result showing that the crab sample protein can be used to supplement cereal flours (Adeyeye, 2008a). The percentage ratio of EAA to the total AA (TAA) in the sample is 45.1. This value is well above the 39 % considered adequate for ideal protein food for infants, 26 % for children and 11 % for adults (FAO/WHO/UNU, 1985). The percentage EAA/TAA for the sample can be favourably compared with other animal protein sources: 45.9-47.1 % in meat organs of turkey-hen (Adeyeye and Ibigbami, 2012), 46.2 % in *Zonocerus variegatus* (Adeyeye, 2005a), 43.7 % in *Macrotermes bellicosus* (Adeyeye, 2005b), 54.8 % in *Gymnarchus niloticus* (Trunk Fish) (Adeyeye and Adamu, 2005), 48.1-49.5 % in brain and eyes of African giant pouch rat (Oyarekua and Adeyeye, 2011), 45.1 % (liver), 47.8 % (heart), 49.8 % (egg) of *A. platyrhynchos* consumed in Nigeria (Adeyeye and Ayeni, 2014) whereas it is 50 % for whole hen's egg (FAO/WHO, 1990). The percentage of neutral AA (TNAA) result is 62.7 indicating that it forms the bulk of the AA; total acidic AA (TAAA) is 24.1 % which is far much lower than % TNAA, whilst the percentage in total basic AA (TBAA) is 12.4 making it the third largest group among the sample.

The other calculated parameters from the amino acid profile are further shown in Table 5. The predicted protein efficiency ratio (P-PER) are: P-PER$_1$ (1.21) and P-PER$_2$ (1.39). These values are lower than the literature levels of 2.16-2.42 in domestic duck (Adeyeye and Ayeni, 2014), 2.6-3.4 in fresh water female crab (Adeyeye, 2008b), 2.4-2.9 fresh water male crab (Adeyeye and Kenni, 2008), cattle body parts are mostly lower in P-PER except in the brain (2.56) and 0.99-1.20 in other parts (Adeyeye *et al*., 2012b), etc. meaning that the sample may be more likely less physiologically utilized protein than most of the cited literature samples. The Leu/Ile ratio is low at 2.08, hence no concentration antagonism might be experienced in the sample when consumed as protein source in food because 2.36 is the most ideal Leu/Ile (FAO/WHO, 1991). The essential AA index (EAAI) is 1.14 which is better than in the domestic duck samples of 1.05-1.22 (Adeyeye and Ayeni, 2014). The EAAI of defatted soybean is 1.26 (Nielsen, 2002); 1.12 in francolin egg, 1.16 in turkey (Adeyeye, 2013); 1.54 in guinea fowl, 1.55 in the domestic fowl (Adeyeye, 2010); 1.11 in guinea fowl brain, 1.15 in guinea fowl eyes (Adeyeye and Aremu, 2010), 1.10 (brain) and 1.10 (eyes) of African giant pouch rat (Oyarekua and Adeyeye, 2011); the EAAI values are much better than most of the cited literature values.

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 (Nielsen, 2002). The isoelectric point, pI is 5.47 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. Most animal proteins are low in Cys, examples of literature values of Cys/TSAA % are: *M. bellicosus* (36.3); *Z. variegatus* (25.6); *Archachatina marginata* (35.5), *Archatina archatina* (38.8), *Limicolaria* sp. (21.0) (Adeyeye and Afolabi, 2004), three different Nigeria fishes (23.8-30.1) (Adeyeye, 2009); turkey-hen meat (26.0-26.5); male fresh water crab body parts (13.3-15.9); female fresh water crab body parts (27.3-32.8); African giant pouch rat (skin and muscle), 22.0-28.1 (Adeyeye and Falemu, 2012), etc. The present (Cys/TSAA % is 23.4 which corroborates these literature observations. In contrast, many vegetable proteins contain substantially more Cys than Met, examples (Cys/TSAA) %: 62.9 in coconut endosperm (Adeyeye, 2004); *Anacardium occidentale*, 50.5 (Adeyeye *et al*., 2007); 58.9-72.0 (raw, steeped, germinated sorghum) (Adeyeye, 2008a); 51.2-53.1 (raw, steeped, germinated millet) (Adeyeye, 2011). Thus, for animal protein diets or mixed diets containing animal protein, Cys is unlikely to contribute up to 50 % of the TSAA (FAO/WHO, 1991). Cys can spare Met in improving protein quality and also has effect on mineral absorption, particularly zinc (Mendoza, 2002). The two calculated biological value levels are BV$_1$ (61.8) and BV$_2$ (63.7). The Biological Value (BV) is a scale of measurement used to determine what percentage of a given nutrient source is utilized by the body. The theoretical highest BV of any food source is 100 %. In short-BV refers to how well and quickly your body can actually use the protein you consume. A low BV can be compensated by consuming other proteins. Some BV values are: whole egg (93.7); milk (84.5); fish (76.0); beef (74.3); soybeans (72.8); rice, polished (64.0); wheat, whole (64.0); corn (60.0) and beans, dry (58.0) (food-info.net/uk/protein/bv.htm)

The amino acid classes in Table 6 shows that essential amino acids are 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 (2EAA) 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 6. In the scores of the AA (AAS) of the sample based on whole hen's egg, these scores have values greater than 1.0: His, Asp, Thr, Ser, Pro, Gly, Ala, Tyr and Phe; means only 3/9 (33.3 %) EAA have AAS > 1.0. Gly has the highest score in the sample (2.03) just like in three samples from *A. platyrhynchos* (1.30-1.79) (Adeyeye and Ayeni, 2014) and in turkey-hen meat organs (1.38-2.50); the least score is in Cys (0.348). To make correction for the limiting amino acid (LAA) in the sample if it serves as sole source of protein food therefore, it will be 100/34.8 (or 2.97) x protein of sample (Bingham, 1977).

Next is the result of the EAA scores (EAAS) based on provisional essential amino acid scoring pattern (FAO/WHO, 1973) where the scores of Phe + Tyr, Thr, Val and total are each greater than 1.0. Lys is limiting (0.464) here and the correction value is 100/46.4 (or 2.16) x protein of sample. In the pre-school child comparison (FAO/WHO/UNU, 1985), Met +Cys, Phe +Tyr, Thr, Val, His and total EAAS have EAAS greater than 1.0 each. Lys is also limiting under this standard with a value of 0.440; correction is 100/44.0 (or 2.27) x protein of sample. Whilst Phe +Tyr has the highest score

(2.05) in the provisional EAA scoring pattern, His has the highest score (2.11) in the pre-school child comparison.

Conclusion

This study showed that *Callinectes latimanus* is not a fatty animal protein source with moderate source of energy and good utilizable energy due to protein. *C. latimanus* is a very good source of essential major minerals and trace element Fe. The Ca/P shows that both minerals will be highly absorbed in the body. The MSI shows that sodium may cause deleterious diseases. The sample is good in many of the essential and non-essential amino acids but good enough to supplement food sources with deficient levels of many of the essential amino acids.

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