Pakistan Journal of Nutrition 7 (6): 741-747, 2008
ISSN 1680-5194
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Comparability of Chemical Composition and Functional Properties of Shell and Flesh of *Penaeus notabilis*

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Abstract: The chemical composition and the food properties of shell and flesh *of Penaeus notabilis* were evaluated. The protein, ash and energy were high whereas carbohydrate and fibre were low in the proximate composition. In the mineral composition, the mineral elements in shell were corresponding higher than the level in flesh. The total essential amino acids in shell was 740mg/g protein and 865mg/g protein in flesh. The limiting amino acid in both shell and flesh was threonine. In the functional properties, both water absorption, oil absorption and oil emulsion capacities were all high with foaming stability at 25% (90min) in both tissues. The lowest gelation was low in both tissues. The protein solubility was high at both sides of pH with isoelectric point being 5.0 (shell) and 7.0 (flesh). The followings: proximate, mineral, amino acids and essential amino acids composition, functional properties and protein solubility, all showed that correlation coefficients $r_{\text{-values}} > t$ ", n-2 meaning that the correlations were significant with high positive values at $r_{0.05}$.

Key words: *Penaeus notabilis*, chemical composition, functional properties

Introduction

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).

The usage of the terms "shrimp' and "prawn' varies in different parts of the world. For scientific purposes, they should be taken as synonymous. Holthuis (1980) gave a most useful discussion on the usage of the word in different countries. What are referred to as "crayfish' in West African English are actually shrimps. True crayfish (*Decapoda reptantia*) do not occur in mainland tropical Africa, except as introduced populations in East Africa.

The Lagos lagoon forms an economically important fishery resource for the mostly fishing communities around it. The sample for this work was from the Lagos lagoon and it is a "true' shrimp (Crustacea *Decapoda natantia*) (Powell, 1982; Yoloye, 1988). Literature reports are scarce on the chemical composition and functional properties of shrimps in Nigeria, it is particularly so for the shell and flesh as separate samples. Adeyeye and Adubiaro (2004) reported only on the chemical composition of shell and flesh of three shrimp samples (*Macrobrachium vollenhovenii* (Herklots), *Palaemon* species A (Powell) and *Penaeus notialis*) from Lagos lagoon. The present work is to report on the proximate, mineral and amino acid compositions and the functional properties of the shell and flesh of *Penaeus notabilis*, a pink shrimp from the Lagos lagoon in Nigeria.

Materials and Methods

Shrimp samples were purchased from trawler catches at Makoko market (along Lagos lagoon). The samples were purchased in the month of May. Samples were then identified. Samples were washed with de-ionized water to remove any adhering contamination, drained under folds of filter paper. Samples were then put in crushed ice in insulated containers and brought to the laboratory for preservation prior to analysis. The washed shrimps were wrapped in aluminum foil and frozen at-4°C for two days before samples were prepared for analysis.

After defrosting, the shrimps were separated into the exoskeleton (head and the outer body shell) (now to be called simply as shell) and the endoskeleton (now to be called simply as flesh). The various parts were oven-dried at 95-105°C until dried and ground into fine powder.

Determination of proximate composition: Moisture, ash, crude fibre and ether extract (crude fat) were determined by the methods of the Association of Official Analytical Chemists AOAC (1990). Nitrogen was determined by the micro-Kjeldahl method (Pearson, 1976) and the crude protein was taken as N % × 6.25. Carbohydrate was determined by difference. The calorific values in kilojoules were calculated by multiplying the crude fat, protein and carbohydrate by Atwater factor of 37, 17 and 17 respectively. Determinations were in duplicate.

Sugar content determination: The determination of the various sugar contents was as described by Lane and Eynon's method in the Manual of Chemical Methods of Food Analysis (Usoro *et al*., 1982).

Determination of minerals: Minerals were analyzed using the solution obtained by dry-ashing the samples at 550°C and dissolving it in 10% HC1 (25 mL) and 5% lanthanum chloride (2 mL), boiling, filtering and making up to standard volume with distilled deionized water. Mg, Ca, Cu, Zn, Co, Cr, Mn and Fe were determined with a Buck Scientific Model-200A/200 atomic absorption spectrophotometer. Na and K were determined with a Corning 405 (Corning, Halstead, Essex, UK) flame photometer (AOAC, 1990) using NaCl and KC1 to prepare standards. 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). The detection limits for the metals in aqueous solution had been determined previously using the methods of Varian Techtron (1975) giving the following values in μgml^{-1}: Fe (0.01), Cu (0.002), Na (0.002), K (0.005), Ca (0.04), Mg (0.002), Zn (0.005), Mn (0.01), Co (0.01) and Cr (0.005). The optimal analytical range was 0.1 to 0.5 absorbance units with coefficients of variation from 0.9%-2.21%.

Determination of amino acids

Defatting: About 2.0g of each sample was weighed into the extraction thimble and the fat extracted with chloroform/methanol mixture using a Soxhlet extraction apparatus (AOAC, 1990). The extraction lasted 5-6h.

Hydrolysis of samples: From 30-35 mg of the defatted samples were weighed into glass ampules. Seven milliliters of 6MHC1 were added and oxygen was expelled by passing nitrogen gas into the ampule (to avoid possible oxidation of some amino acids during hydrolysis). Each glass ampule was then sealed with a bunsen flame and put into an oven at 105°C±5°C for 22h. The ampule was allowed to cool before breaking open at the tip and the content was filtered to remove the humins. The filtrate was then evaporated to dryness at 40°C under vacuum in a rotary evaporator. Each residue was dissolved with 5 mL of acetate buffer (pH 2.0) and stored in a plastic specimen bottle and kept in the deep freezer.

Sample analysis: Our method of analysis was by ion-exchange chromatography (IEC) (FAO/WHO, 1991). The amounts loaded, for both samples, were 5-10 µL each. These were dispensed into the cartridge of the analyzer. The Technicon Sequential Multisample Amino Acid Analyzer (TSM) (Technicon Instruments Corporation, New York) was used for the analysis. The TSM analyzer was designed to separate and analyze free acidic, neutral and basic acids of the hydrolysate. The period of an analysis lasted for 76 min for each sample. 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 record of the TSM (each representing an amino acid) was measured and calculated. The values reported were averages of two determinations.

Functional properties

Protein solubility: The protein solubility was examined from pH 1-12 by the method of Adeyeye *et al*. (1994). The sample (0.2g) was thoroughly stirred with distilled water (10 mL) at room temperature and the pH was adjusted using either 0.1 MHC1 or 0.1M NaOH. Insoluble materials were removed by centrifuging for 30 min at 3500 rpm. The nitrogen content of the supernatant liquid was determined as before. The protein solubility was taken as the % of the protein in the original sample present in the supernatant layer.

Other functional property determination: The Foaming Capacity (FC) and Foaming Stability (FS) were measured by the method of Coffmann and Garcia (1977): a 2% w/v solution (50 mL) was homogenized for 1 min in a Kenwood Major blender at maximum speed and the contents were immediately poured into a graduated cylinder. FC was the foam volume immediately after mixing as a percentage of the starting volume. FS was the foam volume after standing for a given time as a percentage of the initial foam volume. Oil and water absorption capacities were measured by the Sosulski (1962) procedures: in the former, Avop vegetable oil was used. Oil emulsion capacity was determined by the procedure of Inklaar and Fortuin (1969), as modified by Adeyeye *et al*. (1994) and oil emulsion stability by the method of Beuchat (1977). All results were of duplicate determinations.

Lowest Gelation Concentration (LGC) was determined by the method of Coffmann and Garcia (1977) with slight modifications. Appropriate flour suspensions of 2, 4, 6, 8, 10, 14 and 16% (w/v) were prepared in 5 mL distilled water. The test-tubes containing these suspensions were heated for 1h in boiling water followed by rapid cooling under running tap water. The test-tubes were then cooled for 2h at 4°C. The lowest gelation concentration was determined as the concentration in which the flour from the inverted test-tube did not fall down or slip.

Statistical analysis: All results were subjected to statistical analyses. Correlation coefficient (C_c), coefficient of alienation (C_A), Index of Forecasting Efficiency (IFE) percent and regression coefficient (R_c) while the confidence level was at r_0.os (Oloyo, 2001). Also calculated were the amino acid scores (Bender, 1992; FAO, 1970; Orr and Watt, 1957).

Table 1: Intercorrelations in the proximate composition of shell and flesh *of P. notabilis* (% dry weight)

Parameter	Shell	Flesh	C_c	C_A	IFE	R_c
Moisture	13.3±0.0	15.4±0.0				
Total ash	28.5±0.1	19.9±0.1				
Crude protein	36.6J±1.2	44.7±0.6				
Crude fibre	9.6±0.1	8.9±0.3	0.99*	0.14	86.0	1.08
Crude fat	10.3±0.0	8.5±0.0				
Carbohydrate	1.6±1.2	2.6±0.7				
Energy (kJ)	1032.1±0.7	1119.5±2.0				

$r_{0.05}$ C_c = correlation coefficient, C_A = coefficient of alienation, IFE = Index of Forecasting Efficiency (%), R_c = regression coefficient, * = significan`

Table 2: Intercorrelations in the mineral composition of shell and flesh of *P. notabilis* (mg/100g dry weight)

Parameter	Shell	Flesh	C_c	C_A	IFE	R_c
Sodium	41.9	31.0				
Potassium	35.3	26.8				
Calcium	57.9	46.9				
Magnesium	31.5	21.4				
Zinc	47.6	42.8				
Copper	5.7	4.3	0.83*	0.56	44.0	0.96
Iron	22 2	16.4				
Cobalt	Nd[a]	ND				
Manganese	10.5	0.6				
Chromium	ND	ND				
Phosphorus	95.7	86.7				

[a]Not detected

Results and Discussion

Proximate composition: Table 1 contains the proximate composition of the shell and flesh of *Penaeus notabilis.* Both total ash, crude protein and metabolizable energy were of high concentrations. The carbohydrate was low. The r_{-value} was 0.99 which was a very high significant correlation at $r_{0.05}$. The coefficient of alienation (C_A) was low (0.14 or 14%) but with a high Index of Forecasting Efficiency (IFE) of 86.0%. The coefficient of alienation produces an index of lack of relationship while the index of forecasting efficiency gives the reduction in errors of prediction over relationship. The C_A and IFE values showed that a good relationship existed between the shell and flesh in *P. notabilis.* The regression coefficient (R_c) showed that for every unit increase in the shell proximate value, there was a corresponding increase of 1.08 units in the flesh. The overall result meant that the proximate parameters in flesh were generally more concentrated than shell. The level of protein in the shell was of good comparison with the shell of *M. vollenhovenii*, *Palaemon* species A and *P. notialis.* But the flesh protein was lower than those samples. Like *P. notabilis*, only the flesh of *P. notialis* contained crude fibre. Like these other three shrimps, *P. notabilis* had higher level of ash in the shell than in the flesh. Both the current and the literature references above had low level of carbohydrate (Adeyeye and Adubiaro, 2004). The energy value in *P. notabilis* ranged from 1.03-1.12 MJ/100g which was lower than 1.3-1.6MJ/100g from cereals (Paul and Southgate, 1978) showing *P. notabilis* to be a less concentrated source of energy.

Sugar composition: Sugar was not detected in the samples.

Mineral composition: Table 2 shows the intercorrelations in the mineral composition of *P. notabilis* shell and flesh. The r_{-value} was positively high and significant. The alienation value was slightly high (0.56 or 56%) leading to lower reduction of error (44%) in the forecasting efficiency. It is eminently seen in Table 2 that for all the minerals detected each one in the shell was correspondingly more concentrated than in the flesh. Also the regression showed that for every unit increase in the mineral value in the shell there was only 0.96 increases in the flesh. Both the shell and flesh of *M. vollenhovenii*, *Palaemon* species A and *P. notialis* were better concentrated in calcium, phosphorus, iron, cobalt, copper, sodium and potassium (Adeyeye and Adubiaro, 2004) than in the shell and flesh of P. *notabilis.* However, the levels of zinc, iron and copper (except in *M. vollenhovenii*) in *P. notabilis* were higher than in the whole organisms of *M. vollenhovenii*, *Palaemon* species A, *P. notialis* and *P. kerathurus* (Adeyeye, 2000) all found in Lagos lagoon. When *P. notabilis* was compared with other non-conventional sources of protein, it was found that its mineral levels were lower than what obtained in the various parts of male and female fresh water crabs (Adeyeye, 2002) but better than the mineral levels in *Zonocerus variegatus* (variegated grasshopper) (Olaofe *et al*., 1998) and close to the levels obtained for winged termites (*Macrotermes bellicosus*) (Adeyeye, 2005a). Although it is noteworthy that it will be difficult to compare the mineral levels in various types of Nigerian snails (because they were determined on wet weight basis) with the minerals in *P. notabilis*, both the snails: *Archachatina marginata*, *Archatina archatina* and *Limicolaria* sp. and *P. notabilis* were not having detectable level of cobalt and chromium (Adeyeye, 1996).

Amino acid composition: The amino acid profile of P. *notabilis* is shown in Table 3. The r_{-value} was positively high and significant at $r_{0.05}$. While the C_A was high, the IFE was low making prediction of relationship slightly difficult. However, the R_c was high showing that the flesh was better concentrated in amino acids than the shell. The shell had total amino acid of 740mg/g crude protein with total essential amino acid of 350mg/g crude protein (47.3%) while flesh had total amino acid of 865mg/g crude protein and total essential amino acid of 396mg/g crude protein (45.7%). The essential amino acids were separately shown in Table 4. Here the r_{-value} was also significantly positively high (0.85) with slightly high C_A (0.53 or 53%) and slightly low (47%) IFE. The R_c was high showing the contribution of EAA to be more favoured in the flesh than in the shell. Table 5 shows that threonine was the limiting amino acid in the shell

Table 3: Intercorrelations in the amino acid composition of shell and flesh of *P. notabilis* (mg/g crude protein) dry weight

Amino acid	Shell	Flesh	C_c	C_A	IFE	R_c
Lysine (Lys)[a]	46.2	59.8				
Histidine(His)[a]	26.5	34.9				
Arginine (Arg)[a]	63.6	65.5				
Aspartic acid (Asp)	107.9	105.0				
Threonine (Thr)[a]	20.5	25.9				
Serine (Ser)	30.6	43.1				
Glutamic acid (Giu)	106.1	138.7				
Proline (Pro)	39.3	45.3				
Glycine (Gly)	30.7	50.2	0.81*	0.59	41.0	1.19
Alanine (Ala)	41.4	54.5				
Cystine (Cys)	8.2	7.4				
Valine(Val)[a]	34.5	43.2				
Methionine (Met)[a]	26.9	17.3				
Isoleucine (Ile)[a]	47.0	42.6				
Leucine (Leu)[a]	46.0	64.1				
Tyrosine (Tyr)	25.7	25.4				
Phenylalanine (Phe)[a]	38.8	42.3				

Table 4: Intercorrelations in the essential amino acid composition of shell and flesh of *P. notabilis* (mg/g crude protein) dry weight

Amino acid	Shell	Flesh	C_c	C_A	IFE	R_c
Lys	46.2	59.8				
His	26.5	34.9				
Arg	63.6	65.5				
Thr	20.5	25.9				
Val	34.5	43.2	0.85*	0.53	47.0	1.07
Met	26.9	17.3				
Ile	47.0	42.6				
Leu	46.0	64.1				
Phe	38.8	42.3				

Table 5: Intel-correlations in the amino acid scores of shell and flesh of *P. notabilis*

Amino acid	Shell	Flesh	C_c	C_A	IFE	R_c
Lys	0.84	1.09				
Thr	0.51	0.65				
Val	0.69	0.86				
Met+Cys (TSAA)	1.003	0.71	0.63	0.79	21.0	0.89
Ile	1.18	1.07				
Leu	0.66	0.91				
Phe+Tyr	1.08	1.13				

and flesh of P. *notabilis.* In the shell, the threonine score was 0.51 (51%) meaning that 100/51 or about 2 times more of the sample should be added in the diet to correct for the deficiency while the correction needed in the flesh would be 100/65 or about 1.64 times as much sample protein would have to be eaten when it is the sole protein in the diet (Adeyeye, 2004).

The TEAA (with His) values in the samples were close to soya bean, i.e. 444 mg/g (Altschul, 1958). Essential Aliphatic Amino Acids (EAAA) Ile, Leu and Val which constitute the hydrophobic regions of proteins were abundant in the body parts *of P. notabilis* as follows: Val and Leu in flesh>shell while Ile in shell>flesh. This might imply better emulsification properties for flesh compared with the shell. Essential aromatic amino acids (EArAA); Phe+Tyr which are precursors of Tyrosine, Epinephrin and Thyroxin (Robinson, 1987) was found to be more abundant in the flesh (68 mg/g) than shell (65 mg/g). Level of sulphur containing amino acids (Met+Cys) was however more concentrated in the shell (35 mg/g) than the flesh (25 mg/g) in *P. notabilis.* While it is known that cystine can spare part of the requirement for methionine, FAO/WHO/UNU (1985) does not give any indication of the proportion of total sulphur amino acids which can be met by cystine. For the rat, chick and pig, the proportion is about 50% (FAO/ WHO, 1991). Most animal proteins are low in cystine, in contrast, many vegetable proteins, especially the legumes, contain substantially more cystine than methionine. Thus, for animal protein diets, or mixed diets containing animal protein, cystine is unlikely to contribute more than 50% of the total sulphur amino acids (FAO/WHO, 1991). This point is amplified by our results with the following values: shell (23.4%) and flesh (30.0%). This type of trend was also observed in three land snails consumed in Nigeria whose Cys/Met+Cys × 100 gave values of 35.3% (*Archachatina marginata*), 38.8% (*Archatina archatina*) and 21.0% (*Limicolaria sp*.) respectively (Adeyeye and Afolabi, 2004); it is also 25.6% in *Zonocerus variegatus* (Adeyeye, 2005b) and 36.34% in *M. bellicosus* (Adeyeye, 2005a). Glutamic acid was the highest concentrated acid in the flesh (139 mg/g) like in *A. archatina* (lll mg/g) and *A. marginata* (144 mg/g) while aspartic acid was the most concentrated in the shell (108 mg/g) like in *Limicolaria* sp. (76.1 mg/g) (Adeyeye and Afolabi, 2004). Also, glutamic acid was the highest concentrated acid in Z *variegatus* (Adeyeye, 2005b) and *M. bellicosus* (Adeyeye, 2005a).

The current report had total amino acids close to the values reported for the snails above; while the current values ranged between 740-865 mg/g, the values for the snails ranged between 713-874 mg/g; the total essential amino acids ranged between 350-396 mg/g in *P. notabilis* and 361-450 mg/g in snails (Adeyeye and Afolabi, 2004) and 760 mg/g amino acid and 352 mg/g protein (EAA) in *Z. variegatus* (Adeyeye, 2005b). In *M. bellicosus,* it was 802.3 mg/g crude protein for total amino acids and 350.3 mg/g crude protein EAA (Adeyeye, 2005a). All the values reported for the essential amino acids in *P. notabilis* were correspondingly higher than the values in seven shrimps: *Penaeus indicus*, *P. carinatus*, *Parapenopsis stylifera*, *Meta penaeus affmis*, *M. dobsoni* from off-shore and *P. indicus* and *M. monoceros,* from backwaters (James, 1969). Where *P. notabilis* serve as the sole protein source, it will be able to satisfy 100% and above requirement of His and Ile but only about 75% of Lys, Leu, Met+Cys, Phe+Tyr and Thr for infants (FAO, 1970; DHSS, 1997), tryptophan was not determined. It had been explained that Gly, Ala, Val, Glu and Met were most influential amino acids in combination with inosine-5-phosphate and guanosine-5-phosphate for enhancing the meaty flavour. The presence of these amino acids in free state in considerable proportion appears to be more characteristic in shell fishes (James, 1969). Hashimoto

Table 6: Intercorrelations in some functional properties of shell and flesh of *P. notabilis* (% dry weight)

Property	Shell	Flesh	C_c	C_A	IFE	R_c
Water absorption capacity	190±14.1	200±28.3				
Oil absorption capacity	187±11.5	228±0.0				
Oil emulsion capacity	51±0.7	48±3.5				
Oil emulsion stability (5 min)	35±0.2	45±0.3	0.89*	0.21	79.0	1.10
Foaming capacity	12±0.3	16±0.2				
Foaming stability (90 min)	25±0.2	25±0.3				
Lowest gelation concentration	4±0.0	6±0.0				

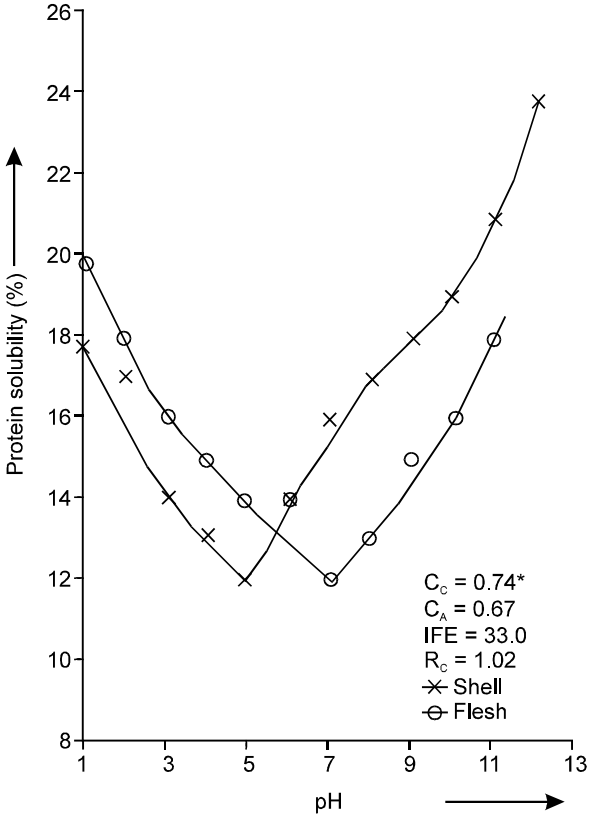

Fig. 1: Protein solubility of *P. notabilis*

(1964) demonstrated that the higher amount of Gly, Pro, Val and Met in the shrimp muscle contributes to flavour. These amino acids were high in *P. notabilis.*

Functional properties: The effect of pH on the protein solubility of *P. notabilis* is shown in Fig. 1. There was high solubility in both acid and alkali, with an isoelectric point (the minimum solubility) of 5.0 (shell) and 7.0 (flesh). The level of protein solubility in the flesh was lower than in the shell, this might be due to protein denaturation as a result of pH effect. The differences in the amino acids composition in the shell and flesh (Table 3) would result in different forms of proteins; this could have resulted into the different isoelectric points. The $r_{\text{-value}}$ showed that positive and high significant correlation existed between the shell and flesh of *P. notabilis.* However, the C_A was high while the IFE was low but the R_c was high. The solubility in both acid and alkali indicated that *P. notabilis* may be useful in formulating carbonated beverages (Kinsella, 1976) and very low-acid foods such as meat products (Olaofe *et al*., 1993). The presence of only one isoelectric point in either the shell and the flesh suggested that *P. notabilis* had only one major protein constituent in each body part. The shape of the curve of the solubility in the shell followed the trend in *Zonocerus variegatus* (Olaofe *et al*., 1998) and in defatted kernel of *Gossypium barbadense* flour (Adeyeye, 2007).

The Water Abosorption Capacities (WAC) (190%, shell; 200%, flesh), Table 6, were higher than that of sunflower flour (107%), soya flour (130%; Lin *et al*., 1974) and *Z. variegatus* (127.5%) (Olaofe *et al*., 1998), so *P. notabilis* could be a useful replacement in viscous food formulations such as soups or baked goods. The WAC was however lower than the results in crickets with values of 260% (male) and 240% (female) (Adeyeye and Ogunalde, 2006). The Oil Absorption Capacities (OAC) are also in Table 6. The values were higher than those of pigeon pea flour (89.7%; Oshodi and Ekperigin, 1989), wheat and soya flour (84.2 and 84.4% respectively; Lin *et al*., 1974), Z. *variegatus* (33.3%; Olaofe *et al*., 1998) but lower than in cowpeas (281-310%; Olaofe *et al*., 1993) close to the values in crickets (204.8-223.4%) (Adeyeye and Ogunlade, 2006). OAC is important, as oil acts as a flavour retainer and improves the mouth feel of foods (Kinsella, 1976), so the shrimp product would be better in these respects than most other materials cited. Both the WAC and OAC were better in the flesh than the shell of P. *notabilis* (Table 6).

The Oil Emulsion Capacities (OEC) (51%, shell; 48%, flesh) were better than the 7.0-11.0% reported for wheat flour and 18.0% for soya flour (Lin *et al*., 1974); 25.6% in *Z. variegatus* (Olaofe *et al*., 1998), but close to the values in crickets: 46% (male) and 45% (female) (Adeyeye and Ogunlade, 2006) and *G. barbadense* flours: 49.2% (whole kernel) and 55.4% (defatted kernel) (Adeyeye, 2007) so *P. notabilis* might be useful in the production of sausages, soups and cakes (Altschul and Wilcke, 1985). The oil emulsion collapsed within 1h, which suggested that the protein would be of little use in products that depend on the formation of stable emulsions. The foaming capacities and foam stabilities were also low, with only 12% (shell) and 16% (flesh) of foam being formed and that collapsing completely within

2h, most commercial products are stable for more than 2h. Consequently, *P. notabilis* would not be attractive for products like cakes or whipping toppings where foaming is important (Kinsella, 1979).

The Lowest Gelation Concentration (LGC) is also in Table 6. The LGC ranged from 4-6% w/v. These values were lower than the values reported for African yam beam (8-10% w/v) (Adeyeye *et al*., 1994); pigeon pea (12% w/v) (Oshodi and Ekperigin, 1989); great Northern bean flour (10%w/v) (Sathe and Salunkhe, 1981); lupin flour (14% w/v) (Sathe *et al*., 1982); mung bean protein isolate (10% w/v) (Coffmann and Garcia, 1977); three varieties of lima beans (8-12% w/v) (Oshodi and Adeladun, 1993) and full fat fluted pumpkin seed flour (36% w/v) (Fagbemi and Oshodi, 1991); 10-12% in crickets (Adeyeye and Ogunlade, 2006); 14.5-21.5 in *G. barbadense* flours (Adeyeye, 2007). Protein gels provide a structural matrix for holding water, flavours, sugars and food ingredients, this is useful in food applications and in new product development. The gelation results obtained for *P. notabilis* showed that the sample may be better than other cited samples in terms of this property. This may make it more useful in the production of curd or as an additive to other materials for gel formation in food products. The $r_{\text{-value}}$ was significantly high with a value of 0.89, low C_A (0.21), high reduction in the error of prediction (79.0%) of relationship with a R_C of 1.10.

Conclusion: *Penaeus notabilis* is a good source of proteins and metabolizable energy and average mineral supply. Most of the amino acid values were either greater than or close to the recommended values. The following functional properties were also favourable: WAC, LGC, OEC, OAC and protein solubility, making it potentially useful in many food formulations.

Acknowledgement

The authors acknowledge the assistance of Professor V. L. Yoloye of Zoology Department, University of Ado-Ekiti, Ado-Ekiti, Nigeria for identifying the shrimp sample.

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