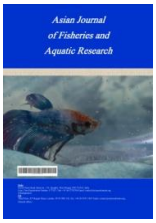

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Evaluation of Proximate, Fatty Acids, Amino Acids and Total Cholesterol Contents of Selected Decapod Crustaceans from Badagry Creek, Lagos, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAB designed the study. Author OBA sourced for the samples while authors NUA and GON managed the analyses. Authors AAB and GON wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Three decapod crustaceans (*Penaeus notalis*, *Procambarus clarkii* and *Callinectes pallidus*) were selected in this study due to their low cost and wide distribution across tropical and temperate regions of the world. The proximate, fatty acids, amino acids and total cholesterol contents of *Penaeus notalis*, *Procambarus clarkii* and *Callinectes pallidus* from Badagry Creek, Lagos, Nigeria were evaluated for their nutritional importance in diet and to human health especially as the demand for these resources is increasing worldwide due to increase in human population, low cost and nutritional benefits. The proximate composition of the selected crustaceans was determined using standard methods of analysis, the cholesterol content was determined using enzymatic kit method, the fatty acid composition was analysed using Gas Chromatography- Mass Spectrophotometer and the amino acid composition was analysed using Amino Acid Analyzer. The proximate composition (moisture, crude fat, crude fibre, crude protein, ash and carbohydrate

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contents) analysed showed significant difference ($p<0.05$) among the three selected crustaceans studied, so also the cholesterol content. All the fatty acids in the results obtained except (Palmitic acid (C16:0), magaric acid (C17:0), myristoleic acid (C14:1), (C18:1n-9t), (C22:1n-9), cetoleic acid (C22:1n11c), C18:2n-6t, rumenic acid (C18:2n-7), γ-Linolenic acid (GLA) (C18:3n-6), eicosatrienoic acid (ETE) (C20:3n-3), docosadienoic acid (C22:2n-6) and docosapentaenoic acid (DPA) (C22:5n-3)) showed significant difference ($p<0.05$). All the essential amino acids indicated significant difference ($p<0.05$). Moreover, all the non-essential amino acids except cystine were also significantly difference ($p<0.05$) among the three selected crustaceans. This study revealed that all the selected decapod crustaceans studied are good source of high quality protein, essential amino acids, low cholesterol levels, omega 3 and 6 polyunsaturated fatty acids thereby making them of high nutritional benefits to consumers.

Keywords: Evaluation; decapods; crustaceans; Penaeus notalis; Procambarus clarkii; Callinectes pallidus.

1. INTRODUCTION

The demand for seafood is increasing rapidly all over the world due to increases in population and their nutritional value [1]. They have been recognized to possess interesting bioactivities and many health benefits [2,3,4]. The seafood belonging to the Decapoda order includes crayfish, shrimps and crabs which are the most familiar of all crustaceans. These animals are invertebrates with segmented bodies shaving hard external shell called an exoskeleton made of chitin which provides some protection and gives rigidity to their bodies [5]. They occur in wide varieties but despite the difference in varieties, they all have the same basic body plan with three body regions (head, thorax and abdomen), the head and thorax are closely joined together or fused to form the cephalothorax. Decapods are omnivorous and act as scavengers, they eat both plant and animal materials. They are found in brackish and fresh waters in Nigeria, they are of great importance to human health due to their richness in essential lipids, proteins, and other nutrients such as minerals, vitamins and omega-3 fatty acid, a daily nutrient requirement recommended by the American Heart Association which helps in brain development and gives protection against stroke and heart diseases [6,7,8].

Procambarus clarkii are dark red swamp crayfish which originated from the southern United States and northern Mexico but now widely established in Europe, Africa, central and south America and southeast Asia [9]. They are usually found in slow moving streams, swamps and ponds avoiding streams and ditches with a strong flow where they are replaced by other species. They are benthic and omnivorous, feeding on insects, larvae and detritus with a preference for animal matter [10]. *P. clarkii* in natural habitats are classified as obligate carnivores due to the fact that while they can subsist on living and detrital plant matter, they require some form of animal matter in the diet for optimal growth and health [10].

Penaeus notalis (pink shrimp) belongs to the family Penaeidae. They can be distinguished from other families of shrimp due to their antennae, which are longer than their body lengths [11]. The carapace has a medial carina that extends nearly to the posterior end of carapace and is bordered by a broad, rounded groove on either side [12]. They are usually found in estuaries and live on muddy bottom by day migrating upward from the region by night [13]. *Penaeus notalis* is sexually on dimorphic, with large males attaining a length of 169 mm and large females reaching over 280 mm [12, 13].

Callinectes pallidus (Gladiator swimming crab) is a coastal marine species that penetrates mesohaline brackish waters. It occurs in both seawater and lagoon [14]. The genus Callinectes is distinguished from other portunid crabs by the lack of an internal spine on the carpus [15]. It feeds on fish, molluscs, crustaceans, macroscopic plants, algae and sand particles [16,17] with males consuming more fish while females consume more plants.

In developing countries such as Nigeria, highly valued animal proteins such as fish, beef and poultry are been restricted to some classes of people due their high cost [2]. However, the three crustaceans selected in this study are widely distributed in the tropical and temperate regions of the world and serve as alternative cheap sources of animal protein. This research work

focused on the evaluation of the nutritional importance of these decapod crustaceans in diet and to human health especially as the demand for these resources is increasing worldwide due to increase in human population, low cost and nutritional benefits.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Freshly catch *Procambarus clarkii*, *Callinectes pallidus* and *Penaeus notalis* samples were collected from fishermen using trawlers within Badagry creek Lagos State, Nigeria between June and October, 2019. 30 individuals each of *Procambarus clarkii*, *Callinectes pallidus* and *Penaeus notalis* was collected for this experiment. These decapod samples were transferred to the laboratory using ice box, washed properly, wrapped in sample bags and kept in the freezer for further analysis.

2.2 Description of Sample Area

Badagry is situated on the southwest coast of Nigeria, bordered by the Gulf of Guinea to the south, it is 43 miles southeast of Lagos and 32 miles west of Seme, a border town in Benin Republic [18]. Like Lagos Island, it is on the bank of inland Lagoons, a system of creeks, waterways that are navigable to Lagos and Port Novo. The depth of the Lagoon varies according to the season consisting of brackish and freshwater with seasonal variability. West of Badagry and Yewa River provides water inflow to the lagoon. There is diversity of fin and shell fishes in the creek [19]. Vegetation such as Raphia palm (*Raphia sudanica*), the African oil palm (*Elaeis guineensis*), and the coconut palm (*Cocos nucifera*) are found covering the swamp with which the lagoon is surrounded [20]. The major economic activities of the inhabitants along the creek are fishing, crop farming and mat weaving [19].

2.3 Determination of Proximate Components of the Decapod crustaceans

The crude fat, crude fibre, ash content and carbohydrate content of the samples were determined according to the methods of [21] while the crude protein was determined according to the method of [22] with some modifications.

Fig. 1. Map of Lagos State, Nigeria showing sampling site
Source: Lawson et al. [19]

2.3.1 Moisture content

The samples (5g) each was dried in an oven at 105°C for 6 hours, it was cooled in the desiccator and weighed again. This process was repeated until constant weight was obtained. The percentage moisture content was calculated as:

$$\% \text{ Moisture} = \frac{(Weightlossduetodrying) X\ 100}{(Weightofsample)}$$

2.3.2 Crude fat

The samples (5g) each were weighed into a thimble and placed in a Soxhlet apparatus. A 500ml round bottom flask was attached to the base of the extractor and clamped to a retort stand. 300 mL petroleum ether was poured into the thimble. The set up was placed on heating mantle with the top of the extractor connected to the reflux condenser. The source of heat was turned on as well as water source supplied to enable the solvent in the flask to boil and extract the lipid in the sample. The extraction was completed in 12 hours and the solvent was recovered using rotary evaporator. The extracted lipid in the flask was placed in an oven at 70°C for 30 mins to completely remove all the solvent residues and then placed in a desiccator to cool. The percentage of lipid was calculated using the equation below:

Weight of lipid = Weight of flask and content after extraction – Weight of flask before extraction.

2.3.3 Crude protein

The crude protein content was determined using microkjeldahl method. The digested samples were diluted, made alkaline with NaOH and distilled water. Liberated ammonia gas was trapped in a conical flask containing boric acid solution. The conical flask was positioned such that the stem of the condenser dipped into the boric acid solution. After collecting about 50cm³of the distillate, the receiver was lowered and the tip of the condenser was washed with distilled water, the ammonia solution in the distillate was titrated against 0.1M Hcl. A blank determination was carried out using the same amount of the reagents in the absence of the sample.

$$\% \text{ Nitrogen Content} = \frac{(TitrevalueXMX\ 0.0014\ XDfXCf)}{(Weightofsample)}$$

Where:

M = Molarity of Hcl = 0.01M
Df = Dilution factor = 50
Cf = Correction factor = 10
% Crude protein = % Nitrogen x 6.25

% Nitrogen was converted to percent crude protein by multiplying with 6.25, the conversion factor. Most proteins contain 16% Nitrogen, hence, the conversion factor is 6.25 (100/16 = 6.25).

2.3.4 Crude fibre

100 ml of 0.25M H_2SO_4 was added to 2g each of the samples and brought to boil for 30 mins after which the hot mixture was filtered. The residue was washed free of acid with plenty of warm water. Each residue was then transferred into round bottom flasks to which 100ml of 0.25M of NaOH was added and boiled for again for 30minutes. The mixture was then filtered and the residue washed free of alkali with warm water. The residue was then transferred to a dried, weighed silica dish and dried to a constant weight at 105°C for 90 mins, cooled in a desiccator and weighed. The weighed samples were burnt off and reweighed. The percentage crude fibre content was determined as follows:

Initial weight of residue - Final weight of residue x 100.

2.3.5 Ash content

The sample (5g) each was weighed into a previously dried, cooled and weighed silica crucible. The crucible containing the sample was transferred into a muffle furnace and ignited at 550°C until a white ash was obtained. The ash was moistened with distilled water, dried on steam bath and then on hot–plate and re ashed at 550°C to constant weight. The percentage ash content was calculated as follows:

$$\text{Ash content} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \text{ X } 100$$

2.3.6 Carbohydrate

The carbohydrate content was determined by difference i.e.

% Carbohydrates= 100 - (%Mo + % As + % Cf + % Cp)
Where; %Mo= Percentage moisture content
%As= Percentage ash content
%Cf= Percentage crude fat

%Cp= Percentage crude protein

2.4 Determination of Cholesterol Content of the Decapod Crustaceans

The cholesterol content was determined following the method of [23]. Accurately weighed sample (2g) was placed in a round bottomed flask and 10 mL of methanolic potassium hydroxide solution (1M) was added. The solution was heated under reflux for 25 min, cooled and transferred to a 25 mL volumetric flask. The round-bottomed flask was rinsed three times with small quantities of isopropanol and added to the volumetric flask. 1mL of HCl (8M) was added and the flask filled to the line with isopropanol and placed in an ice bath for 10 min. The turbid solution was quickly filtered through Whatman No 1 filter paper. The samples and one blank was analyzed with an enzymatic kit (Cat. 10 139 050 035; Boehringer Mannheim/RBiopharm, Darmstadt, Germany) and read at 405 nm. The total cholesterol content, expressed in mg cholesterol/100g, was calculated as follows:

$$\text{Total Cholesterol Content} = \frac{C}{\text{Weight of Sample}} \text{ X } 100$$

$$\text{Where } C = \frac{V.Mw}{\varepsilon \cdot d \cdot v \cdot 100} \text{ X } \Delta A$$

V = final volume (mL)
v = sample volume (mL)
Mw = molecular weight of the substance to be assayed (g/mol)
d = light path [cm]
ε = extinction coefficient of the lutidine-dye at 405 nm = 7.4 [l × mmol-1 × cm-1]
Δ =Absorbance of sample – absorbance of blank

2.5 Determination of Fatty Acids Composition of the Decapod crustaceans

The lipids gotten from the crude fat determination was evaluated for the fatty acid compositions according to the method of [24] with some modifications. Fatty acids were transesterified to methyl esters with 0.5 M KOH in methanol solution. 50 µL each of oil samples was placed into 10 mL centrifugal tubes to which 5 mL of the prepared KOH–MeOH solution was added. The fatty acid methyl esters were recovered with hexane. For the identification of the methyl esters of fatty acids a Hewlett Packard HP 6890 Series gas chromatograph coupled with a Hewlett Packard 5973 mass spectroscopy detector (GC-MS) system was used equipped with a methyl lignoserate-coated stationary phase, capillary column (30 m length, 0.25 mm i.d., 0.25 µm film thickness) and a flame ionization detector. The temperature program was set up from 50°C to 250°C with 4°C/min, both the injector and detector temperatures were 280°C respectively. The oven temperature was programmed for 3.5 min at an initial temperature of 150C, was increased at a rate of 20C/min to 200C, was further increased at a rate of 5C/min to 280C, and then held at that temperature for 6 min. Helium was used as a carrier gas at a pressure of 290 kPa, with a flow velocity of 1 mL/min. The values of fatty acids are presented as area percentage of total fatty acids.

2.6 Determination of Amino Acid Composition of the Decapod crustaceans

The amino acid profile of the samples were determined using amino acid analyser, technicon TSM-1 (model: DNA 0209) and methods described by [25]. The samples were dried to constant weight, defatted, hydrolysed, evaporated in a rotary evaporator and loaded into the Technicon sequential Multi-sample Amino Acid Analyser (TSM). Approximately 200 mg each of the samples was dissolved in 0.7 mL distilled H_2O and0.5 mL 20 mM norleucine (internal standard). 500mL each of the extract was mixed with 50 mL 20 mM norleucine. Concentrated hydrochloric acid (HCl, 12 M) was added, to a final concentration of 6 M. The sample mixture was flushed with nitrogen gas for 15 s in order to minimize oxidation, before hydrolysis at 110°C for 24 h. Following hydrolysis, 100 mL aliquots of the hydrolysates were evaporated under nitrogen gas until complete dryness and re-dissolved to a suitable concentration in lithium citrate buffer at pH 2.2. All amino acids were analysed chromatographically using an ion exchange column followed by ninhydrin post column derivatization on a Biochrom 30 amino acid analyser (Biochrom Co., Cambridge, UK).

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of the Crustaceans

Table 1 shows the proximate composition of the three selected crustaceans (*P. notalis, P. clarkii* and *C. pallidus*). All the parameters (moisture,

crude fat, crude fibre, crude protein, ash content and carbohydrate content) analysed showed significant difference of ($p<0.05$). The highest values for crude protein (20.06%±0.026), ash (4.03%±0.023) and carbohydrate contents (3.06%±0.014) were obtained in *C. pallidus*. However, *P. clarkii* had the lowest value (17.70%±0.034) for crude protein while the lowest values for ash (1.98%±0.016) and carbohydrate contents (1.97%±0.013) were obtained in *P. notalis*. These results showed that all the decapod samples studied had high moisture (71.06%, 70.46% and 71.10%) and high protein contents (17.70%, 18.90% and 20.06%) for *P. clarkii, P. notalis* and *C. pallidus* respectively. The moisture and protein contents were comparable and related to those (77.11-78.50%) reported by [26] for male *C. sapidus*. The moisture content for *P. notalis* was related to 73.71% reported by [27] while the protein content reported by this author (6.09%) was lower than the one obtained for this study. The crude protein, crude fibre and ash content of *P. notalis* were in agreement with (18.4-19.1%, 1.07-1.30% and 1.10-1.86%) reported by [28] for male and female jinja shrimps. The protein content of *P. clarkii* falls within the range of 9.53-18.23% reported by [29]. The high protein content of the crustaceans studied may be attributed to their high protein dietary intake such as algae, diatoms, molluscs and partly digested fishes [30]. These crustaceans possess adequate protein which is essential for body growth and defence [31]. *P. notalis* had the highest lipid content (5.38%) while *C. pallidus* had the lowest lipid content (0.65%). In crustaceans, lipids are not useful for main organic reserve and source of metabolic energy alone but also important in maintaining cellular integrity [32]. The high ash content in *C. pallidus* showed that *C. pallidus* will be the richest source of mineral among the crustaceans studied.

3.2 Cholesterol Content of the Crustaceans

The mean cholesterol contents of the selected crustaceans (*P. notalis, P. clarkii* and *C. pallidus*) were shown in Table 2. The result showed significant difference ($p<0.05$) among the three crustaceans studied. *P. notalis* had the highest cholesterol content (96.40mg/100g) while *C. pallidus* recorded the lowest cholesterol content (35.21mg/100g±0.019).The value obtained for crayfish in this study is within the range of (64.84mg/100g-72.11mg/100g) reported by [33] for *Orconectes limosus* crayfish collected during spring and summer season. Higher cholesterol content (75.88mg/100g-81.51mg/100g) was reported by [34] for captive and wild caught *Astacus leptodactylus* crayfish. This difference may be attributed to the season of collection because water temperature increases in summer period which make fish adjust cell membrane composition with increased cholesterol content in relation to temperature [35]. *P. clarkii* and *C. pallidus* had the cholesterol content of 72.10mg/100g and 35.21mg/100g respectively. Crayfish contain lower cholesterol content compared with egg, prawns, shrimp, lobster, atlantice salmon which contain 250, 195, 130, 50- 100, 56 mg/100 g, respectively [36,37]. The moderate value for cholesterol content per day is considered to be 140 mg [38] as cholesterol is highly attached to food quality [33]. This finding indicates that the crustaceans studied are safe to consume since their cholesterol contents falls within the recommended value of 140mg per day.

3.3 Fatty Acids Composition of the Crustaceans

Table 3 shows the fatty acids composition of the selected crustaceans studied (*P. notalis, P. clarkii* and *C. pallidus*). All the fatty acids except (Palmitic acid (C16:0), magaric acid (C17:0), myristoleic acid (C14:1), (C18:1n-9t), (C22:1n-9), cetoleic acid (C22:1n11c), C18:2n-6t, rumenic acid (C18:2n-7), γ-Linolenic acid (GLA) (C18:3n-6), eicosatrienoic acid (ETE) (C20:3n-3), docosadienoic acid (C22:2n-6) and docosapentaenoic acid (DPA) (C22:5n-3)) showed significant difference ($p<0.05$) among the three crustaceans.For SFA, *P. notalis* had the highest values for capric acid (C10:0) (0.47%±0.06), heneicosanoic acid (C21:0) (0.97%±0.031) and lignoceric acid (C24:0) (0.11%±0.026) while *P. clarkii* had the highest values for lauric acid (C12:0) (0.49%±0.016), arachidic acid (C20:0) (1.24%±0.016) and behenic acid (C22:0) (1.05%±0.06). Moreover, *C. pallidus* recorded the highest values for myristic acid (C14:0) (1.40%±0.05) and stearic acid (C18:0) (12.48%±0.056).

For MUFA, *P. notalis* had the highest values for palmitoleic acid (C16:1) (3.78%±0.05), vaccenic acid (C18:1n-7c) (5.12%±0.017), gondoic acid (C20:1n-9) (1.30%±0.023) and nervonic acid (C24:1n-9) (1.01%±0.041) while *P. clarkii* had the highest values for oleic acid (C18:1n-9c) (36.44%±0.019) and erucic acid (C22:1n-13c) (10.01%±0.021). Moreover, *C. pallidus* recorded

the highest values for C18:1n-6c (4.12%±0.017). For PUFA, *P. notalis* had the highest value for docosahexaenoic acid (DHA) (C22:6n-3) (10.33%±0.005) while *P. clarkii* had the highest values for linoleic acid (C18:2n-6c) (12.93%±0.036) and α-linolenic acid (C18:3n-3) (3.14%±0.041). Moreover, *C. pallidus* recorded the highest values for eicosadienoic acid (C20:2n-6) (2.29%±0.018), dihomo-gamma-linolenic acid (DGLA) (C20:3n-6) (0.25%±0.032), arachidionic acid (C20:4n-6) (8.88%±0.026) and eicosapentaenoic acid (C20:5n-3) (15.12%±0.044).This fatty acid composition showed that palmitic acid and stearic acid were the abundant saturated fatty acids in all the crustaceans studied. This is in agreement with the report of [39] for *Penaeus kerathurus* and *Penaeus japonicus*, [29] for *Procambarus clarkii*, [40] for *Callinectes amnicola* which also had palmitic and stearic acid as their major saturated fatty acids. Crayfish had the highest monounsaturated fatty acid (50.39%) with oleic acid as the abundant monounsaturated fatty acid which was common to all the crustaceans studied. This was in agreement with (56.56%) reported by [29] for *Procambarus clarkii*. The fatty acid composition showed the crustaceans to have n—6/n-3ratio of 0.69, 1.80 and 1.02 for *P. notalis*, *P. clarkii* and *C. pallidus* respectively. This is in close agreement with 0.549 reported by [39] for *Penaeus japonicas.* The adequate n-6 / n-3 ratio (less than 4) is critical to formation of eicosanoids, preventing the development of various diseases [41]. The type and quantity of essential fatty acid consumed and balanced intake of omega-3 and omega-6 are important for a healthy life. Food rich in omega-3 fatty acids should be made abundant in consumption than food rich in omega-6 fatty acids in order to prevent chronic disease [42]. Also, EPA and DHA play important roles in the prevention of inflammatory and cardiovascular diseases due to their serum triglycerides-lowering effects [28]. The percentage of EPA and DHA were (13.24%, 10.33%; 3.12%, 2.17%; 15.12%, 7.01%) for *P. notalis*, *P. clarkii* and *C. pallidus* respectively. The recommended minimum value of PUFA / SFA ratio is 0.45 for a balanced diet [43]. This ratio is lower than those obtained in this study (1.38, 0.84 and 1.21) for *P. notalis*, *P. clarkii* and *C. pallidus* respectively. A diet with low PUFA / SFA ratio is not recommended as it is a risk factor for the increase in serum cholesterol [44]. The fatty acid composition of these crustaceans showed they are of high nutritional benefits to consumers especially *P. notalis* and *C. pallidus* that contain high quantity of EPA and DHA.

3.4 Amino Acids Composition of the Crustaceans

Table 4 shows the amino acid of the three selected crustaceans studied (*P. notalis, P. clarkii* and *C. pallidus*). The result showed that all the essential amino acids indicated significant difference ($p<0.05$) among the three crustaceans. Moreover, all the non-essential amino acids except cystine were also significantly difference ($p<0.05$) among the three crustaceans (*P. notalis, P. clarkii* and *C. pallidus*). *P. notalis* recorded the highest values for essential amino acids such as isoleucine (11.97g/100g±0.016), lysine (14.16g/ 100g±0.023), methionine (13.82g/100g±0.027), valine (16.54g/100g±0.032) and leucine (4.86g/100g±0.035). Moreover, *C. pallidus* recorded the highest values for leucine (12.13g/ 100g±0.034) and threonine (4.22g/ 100g±0.013). It was therefore revealed that *P. notalis* contained more of essential amino acids compared to the other crustaceans in this study. For non-essential amino acids, *C. pallidus* recorded the highest values for alanine (3.82g/ 100g±0.014), aspartic acid (13.36g/100g±0.025), glutamic acid (14.12g/100g±0.033), serine (3.16g/ 100g±0.022) and tyrosine (2.74g/100g±0.03) while *P. notalis* indicated the highest values for cystine (4.22g/100g±0.06), glycine (10.15g/100g±0.021) and proline (6.04g/ 100g±0.03). Moreover, *P. clarkii* recorded the highest values for arginine (12.41g/100g±0.039).

Table 1. Proximate composition of the crustaceans

Parameters (%)	*P. notalis*	*P. clarkii*	*C. pallidus*
Moisture	$70.46±0.025^{c}$	$71.06±0.034^{b}$	$71.10±0.012^{a}$
Crude fat	$5.38±0.005^{a}$	$4.42±0.012^{b}$	$0.65±0.034^{c}$
Crude fibre	$1.31±0.015^{b}$	$1.70±0.017^{a}$	$1.10±0.024^{c}$
Crude protein	$18.90±0.028^{b}$	$17.70±0.034^{c}$	$20.06±0.026^{a}$
Ash content	$1.98±0.016^{c}$	$2.50±0.016^{b}$	$4.03±0.023^{a}$
Carbohydrate content	$1.97±0.013^{c}$	$2.62±0.022^{b}$	$3.06±0.014^{a}$

Values are mean ± standard deviation of triplicate determinations

^{abc}: Means within each row with different superscripts are significantly different ($p<0.05$)

Table 2. Cholesterol content of the crustaceans

Cholesterol content	*P. notalis*	*P. clarkii*	*C. pallidus*
mg/100g	96.40±0.018[a]	72.10±0.023[b]	35.21±0.019[c]

Values are mean ± standard deviation of triplicate determinations
[abc]: Means within each row with different superscripts are significantly different (p<0.05)

Table 3. Fatty acid composition of the crustaceans

Fatty Acids (%)	*P. notalis*	*P. clarkii*	*C. pallidus*
Capric acid (C10:0)	0.47±0.06[a]	0.12±0.05[b]	ND[c]
Lauric acid (C12:0)	0.17±0.012[b]	0.49±0.016[a]	0.01±0.024[c]
Myristic acid (C14:0)	1.25±0.032[b]	1.02±0.07[c]	1.40±0.05[a]
Palmitic acid (C16:0)	17.12±0.08	17.01±0.06	20.42±0.045
Magaric acid (C17::0)	1.13±0.022	0.01±0.033	0.01±0.014
Stearic acid (C18:0)	7.56±0.028[b]	6.05±0.012[c]	12.48±0.056[a]
Arachidic acid (C20:0)	0.38±0.03[c]	1.24±0.016[a]	1.02±0.042[b]
Heneicosanoic acid (C21:0)	0.97±0.031[a]	ND[b]	ND[b]
Behenic acid (C22:0)	0.46±0.024[c]	1.05±0.06[a]	1.03±0.08[b]
Lignoceric acid (C24:0)	0.11±0.026[a]	0.01±0.031[c]	0.05±0.028[b]
∑SFA	29.62	27.00	35.39
Myristoleic acid (C14:1)	0.71±0.031	0.01±0.045	0.01±0.023
Palmitoleic acid (C16:1)	3.78±0.05[a]	1.99±0.042[b]	0.13±0.028[c]
Cis-10-heptadecanoic acid (C17:1)	0.35±0.03[a]	ND[b]	ND[b]
C18:1n-6c	0.01±0.024[c]	1.01±0.036[b]	4.12±0.017[a]
Oleic acid (C18:1n-9c)	16.46±0.021[c]	36.44±0.019[a]	16.80±0.025[b]
Vaccenic acid (C18:1n-7c)	5.12±0.017[a]	0.05±0.014[b]	0.03±0.03[c]
C18:1n-9t	0.25±0.041	0.06±0.029	0.07±0.035
Gondoic acid (C20:1n-9)	1.30±0.023[a]	0.56±0.028[b]	ND[b]
Cetoleic acid (C22:1n-11c)	ND	ND	0.04±0.016
Erucic acid (C22:1n-13c)	ND[c]	10.01±0.021[a]	0.72±0.05[b]
C22:1n-9	0.62±0.042	0.03±0.034	0.02±0.03
Nervonic acid (C24:1n-9)	1.01±0.041[a]	0.23 ±0.06[b]	0.01±0.05[c]
∑MUFA	29.61	50.39	21.95
C18:2n-6t	0.01±0.041	ND	0.01±0.036
Rumenic acid (C18:2n-7)	ND	ND	0.01±0.042
Linoleic acid (C18:2n-6c)	10.11±0.018[b]	12.93±0.036[a]	7.30±0.027[c]
α-Linolenic acid (C18:3n-3)	0.54±0.028[c]	3.14±0.041[a]	0.98±0.023[b]
γ-Linolenic acid (GLA) (C18:3n-6)	ND	ND	0.68±0.034
Eicosadienoic acid (C20:2n-6)	0.70±0.028[b]	0.03±0.039[c]	2.29±0.018[a]
Dihomo-gamma-Linolenic acid (DGLA) (C20:3n-6)	0.19±0.035[b]	0.01±0.044[c]	0.25±0.032[a]
Arachidionic acid (C20:4n-6)	5.61±0.019[b]	1.20±0.041[c]	8.88±0.026[a]
Eicosapentaenoic acid (C20:5n-3)	13.24±0.029[b]	3.12±0.031[c]	15.12±0.044[a]
Eicosatrienoic acid (ETE) (C20:3n-3)	0.01±0.024	ND	ND
Docosadienoic acid (C22:2n-6)	0.01±0.033	ND	0.13±0.036
Docosahexaenoic acid (DHA) (C22:6n-3)	10.33±0.005[a]	2.17±0.006[c]	7.01±0.048[b]
Docosapentaenoic acid (DPA) (C22:5n-3)	0.02±0.018	0.010.027	ND
∑PUFA	40.77	22.61	42.66
n-6/n-3	0.69	1.80	1.02
% EPA	13.24	3.12	15.12
% DHA	10.33	2.17	7.01
PUFA/SFA	1.38	0.84	1.21

Values are mean ± standard deviation of triplicate determinations
[abc]: Means within each row with different superscripts are significantly different (p<0.05)

It was therefore revealed that *C. pallidus* contained more of non-essential amino acids compared to other crustacean in this study. Some non-essential amino acids such as

Table 4. Amino acid composition of the crustaceans

Amino Acids (g/100g)	*P. notalis*	*P. clarkii*	*C. pallidus*
Histidine	1.35±0.031^{c}	3.99±0.005^{a}	1.98±0.022^{b}
Isoleucine	11.97±0.016^{a}	5.87±0.035^{b}	4.26±0.023^{c}
Leucine	4.86±0.035^{c}	11.45±0.018^{b}	12.13±0.034^{a}
Lysine	14.16±0.023^{a}	8.11±0.016^{c}	11.45±0.018^{b}
Methionine	13.82±0.027^{a}	7.23±0.056^{b}	4.11±0.026^{c}
Phenylalanine	2.11±0.012^{c}	5.97±0.016^{a}	4.50±0.05^{b}
Threonine	0.78±0.05^{c}	2.23±0.03^{b}	4.22±0.013^{a}
Tryptophan	2.03±0.04^{a}	1.31±0.018^{c}	1.51±0.013^{b}
Valine	16.54±0.032^{a}	8.42±0.036^{b}	3.14±0.015^{c}
∑EAA	67.62	54.58	47.30
Alanine	2.01±0.04^{c}	2.86±0.017^{b}	3.82±0.014^{a}
Arginine	1.34±0.046^{c}	12.41±0.039^{a}	8.19±0.05^{b}
Aspartic acid	1.63±0.03^{c}	10.12±0.034^{b}	13.36±0.025^{a}
Cystine	4.22±0.06^{a}	0.56±0.023	1.40±0.014^{b}
Glutamic acid	3.45±0.043^{c}	11.97±0.024^{b}	14.12±0.033^{a}
Glycine	10.15±0.021^{a}	2.02±0.036^{b}	2.03±0.05^{b}
Proline	6.04±0.03^{a}	1.960.045^{c}	3.66±0.05^{b}
Serine	1.37±0.016^{b}	1.01±0.018^{c}	3.160±0.022^{a}
Tryosine	1.92±0.015^{a}	1.92±0.017^{a}	2.74±0.03^{b}
∑NEAA	32.13	44.83	52.48
TAA	99.75	99.41	99.78

Values are mean ± standard deviation of triplicate determinations

^{abc}*: Means within each row with different superscripts are significantly different (p<0.05)*

cysteine, tyrosine, glycine, arginine, glutamine, or proline, are termed conditionally indispensable since they became essential under specific pathological or physiological conditions [45]. The amino acid composition of the crustaceans revealed they all contain high amount of essential amino acids. Crustacean muscles contain high concentration of free amino acids, such as arginine, glycine, proline, glutamine and alanine which support osmoregulatory functions [46,47]. Valine is involved in many metabolic pathways, protein synthesis and optimal growth [48]. Tryptophan plays an important role in the brain as a precursor of the neurotransmitter: Histidine is also involved in many metabolic functions including the production of histamines, which take part in allergic and inflammatory reactions. It also aids osmoregulation and metabolic pathways during certain emergencies/ harsh conditions [46].

4. CONCLUSION

The results obtained in this study revealed that *C. pallidus* had the highest protein and lowest total cholesterol contents, *P. notalis* and *C. pallidus* recorded high quantity of EPA and DHA while *P. notalis* had the highest quantity of essential amino acids. However, all the crustaceans studied are good source of high quality protein, essential amino acids, low cholesterol levels, omega 3 and 6 polyunsaturated fatty acids thereby making them of high nutritional benefit to consumers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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