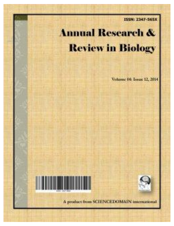

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Proximate Composition and Mineral Contents of Edible Part of Four Species of Shellfishes from the Calabar River, Nigeria

Ivon, Ettah Akpang[1] and Eyo, Victor Oscar[2*]

[1]Department of Science Laboratory Technology, Faculty of Biological Science, University of Calabar, P.M.B. 1115, Calabar, Nigeria.
[2]Department of Fisheries and Aquaculture, Faulty of Marine Environmental Management, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author EVO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author IEA managed the literature searches and analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the proximate composition and mineral contents of edible part of four species of shellfishes (*Callinectes amnicola*, *Thais coronata*, *Tympanotonus fuscatus* and *Egeria radiata*) from the Calabar River, Nigeria.
Place and Duration of Study: Institute of Oceanography, University of Calabar, Nigeria, between October 2016 and May 2017.
Methodology: The proximate composition was analyzed following standard methods recommended by AOAC, while mineral contents were determined using Atomic Absorption Spectrophotometric (AAS) method.
Results: Protein and ash contents were highest in *E. radiata* (32.10 ± 0.06% and 3.80 ± 0.01%) and least in *T. coronata* (14.88 ± 0.01% and 2.57 ± 0.02%). Fat, fibre and moisture contents were highest in *T. coronata* (1.50 ± 0.01%, 0.06 ± 0.01% and 76.35 ±0.01%) and least in *T. fuscatus*

**Corresponding author: E-mail: sirvick2003@yahoo.com;*

(1.18 ± 0.01%), *E. radiata* (0.04 ± 0.01% and 61.20 ± 0.11%). Nitrogen-free extract was highest in *C. amnicola* (6.42 ± 0.25%) and least in *E. radiata* (1.50 ± 0.10%). Sodium content was highest in *C. amnicola* (108.34 ± 0.08 mg/100 g) and least in *T. fuscatus* (16.33 ± 0.01 mg/100 g). Calcium content was highest in *T. coronata* (188.42 ± 0.09 mg/100 g) and least in *T. fuscatus* (49.86 ± 0.01 mg/100 g). Copper, iron and manganese contents were highest in *T. coronata* (10.03 ± 0.02 mg/100 g, 14.83 ± 0.01 mg/100 g and 1.65 ± 0.01 mg/100 g) and least in *C. amnicola* (0.49 ± 0.01 mg/100 g), *E. radiata* (8.76 ± 0.01 mg/100 g) and *T. fuscatus* (0.21 ± 0.01 mg/100 g). All proximate composition and mineral contents except fibre content were significantly different ($P < 0.05$) among the four species.

Conclusion: The nutritional values of the four species of shellfishes studied are suitable for human consumption, and the species could have potential alternative for animal feed industries. Therefore, aquaculture activities related to shellfishes should be encouraged to reduce pressure and total dependence on wild stock.

Keywords: Shellfishes; proximate composition; mineral contents; Calabar River and edible part.

1. INTRODUCTION

Shellfishes such as blue crab (*Callinectes amnicola*), bivalve (*Egeria radiata*), rock snail (*Thais coronata*) and mud-flat periwinkle (*Tympanotonus fuscatus*) are commonly found in the Calabar river, Nigeria. The local names of the shellfishes as given by the Efik and Ibibio tribes who inhabits the river area are; Isobo (Blue crab – *C. amnicola*), Nkop (Clam – *E. radiata*), Nkoko (Rock snail – *T. coronata*) and Mfi (Periwinkle – *T. fuscatus*). The blue crab (*C. amnicola)*, member of the family Portunidae, is a valuable source of shell fisheries for the inhabitants of the Cross river estuary in Nigeria [1]. The nutritional qualities of this crab reported by Udo and Arazu [2] shows that its flesh is rich in protein and moisture content, but has low carbohydrate and fat. According to Ekanem et al. [3] crab meat provides a valuable source of protein, vitamins, minerals such as sodium, phosphorus, calcium, zinc, iron, manganese and a small amount of fat. *Egeria radiata* is a freshwater clam that inhabits the lower reaches of some large rivers in West Africa [4]. They are commonly found in rivers, coastal areas and seas in West Africa countries including Nigeria. According to Ogogo [5] clam meat is widely consumed because of its protein content and essential mineral such as sodium, phosphorus, calcium, zinc, iron and manganese. The rock snail (*T. coronata*) belonging to the family Muricidae, is a primary freshwater snail [6]. As reported by Zalloua et al. [7] rock snail is rich in nutritional quality including essential fatty acid, proteins, iron, selenium, iodine, Vitamin A, Vitamin D, Vitamin E, Vitamin B6 and Vitamin B12. Periwinkle (*T. fuscatus*) has high commercial value in coastal areas including the Calabar river. The increase in demand for periwinkle meat over the years could be attributed to its nutritional composition, cheap nature and its availability all year round. As reported by Adebayo-tayo et al. [8] periwinkles have successfully invaded a variety of habitats with majority of them dominate the aquatic habitats. In Nigeria and other African coastal states, they are found in lagoons, estuaries and mangrove swamps, represented by *Pachymelania aurita* and *Tympanostonus fuscatus* [8]. Due to the wide consumption of periwinkles in the Niger Delta area of Nigeria, Job and Ekanem [9] assessed the nutritional status of two periwinkle species (*Tympanostonus fuscatus* and *Pachymelania aurita*) from a tropical creek in Nigeria and concluded that the two gastropods have high nutritional quality. Generally, shellfishes have low contents of fat and cholesterol [3]. Ekpenyong et al. [10] reported that the consumption of seafood on regular basis will result in good health among consumers. Shellfishes are consumed by the inhabitants of the Calabar River and other coastal areas because the meat is tasty, contain high nutritional value and are abundant in nature. Shellfish meat are popular due to their high protein content, low carbohydrate values, low fat/cholesterol profile, significant amounts of omega-3-fatty acids, good lipids profile, essential amino acids, vitamins and some vital minerals such as copper, calcium, sodium, zinc, iron, and manganese [11,12,13]. High nutritional values in shellfish has resulted in an increase in demand for the resources which eventually influence the economic growth in both local and international markets [14,15,16,17,18]. Minerals such as calcium, sodium, iron, zinc and manganese are very essential to human health. Calcium and iron are useful in maintaining an optimal bone development and according to Valverde et al. [19] they help to prevent rickets and osteomalacia during early childhood and growing stages. Calcium also plays a vital role in blood clotting, nerve transmission and muscle contraction. Iron helps the red blood cells to supply oxygen to the rest of the body [20]. Iron also plays a major role in the proper functioning of the liver [21]. According to Ehigiator and Akise [22] the nutritive value of shellfishes can be assessed by evaluating the levels of carbohydrates, proteins, fats and minerals in their tissues. Although, there has been a lot of study on the nutritional value of shellfishes in water bodies in Nigeria and other parts of the world, information on the nutritional value of some shellfishes from the Calabar river is scarce. Therefore, this study aims at examining the nutritional values of selected species of shellfishes (*C. amnicola*, *E. radiata*, *T. coronata* and *T. fuscatus*) from the Calabar River.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

This study was carried out in Calabar River geographically located between Latitude: N 40 57’ 326’’ and Longitude: E 8018’ 557’’ [23]. The sampling station was Nsidung beach (Fig. 1) which is a major fish landing site of the Calabar River. The Calabar river has a climate characterized by a long wet season ranging from April to October and a dry season occurring between November and March [24]. The annual total rainfall of the study area is about 2000 mm. A short period of drought known as August drought occurs in the wet season around August/September [25]. Between December and January, there is usually a cold, dry and dusty period known as harmattan season [26]. Air temperature around the study area ranges from 22ºC in wet season to 35ºC in the dry season with the relative humidity of over 60% at all seasons and about 90% in the wet season [27].

2.2 Collection and Identification of Specimens

All specimens used in this study including *Thais coronata* (Plate 1), *Typanosomas fuscatus* (Plate 2), *Callinectes amnicola* (Plate 3) and *Egeria radiata* (Plate 4), and were bought from fishermen at Nsidung beach, Calabar river, Cross River State, between October 2016 and May 2017. A total of fifty (50) samples collected for each species were identified based on species identification sheets given by Food and Agriculture Organization (FAO).

Plate 1. Rock snail (*Thais coronata*)

Plate 2. Mud-flat periwinkle (*Typanosomas fuscatus*)

Plate 3. Blue crab (*Callinectes amnicola*)

Plate 4. Clam (*Egeria radiata)*

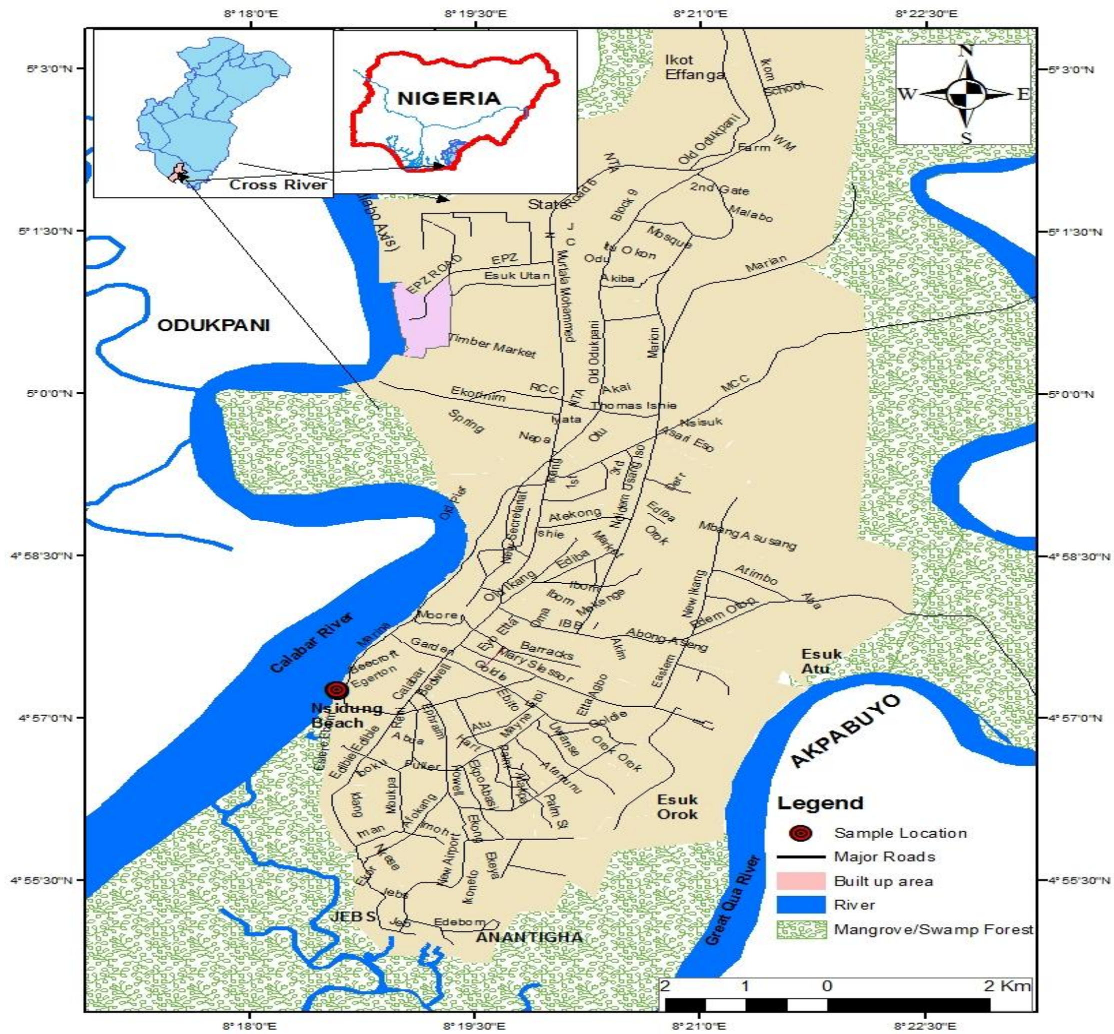

Fig. 1. Map of Calabar River showing Nsidung beach where specimens were collected

2.3 Sample Preparation

After collection, edible parts (soft tissues) of all the specimens were separated very carefully from the shells before washing in distilled water to remove dirt and debris. The edible parts (soft tissues) of *Thais coronata* and *Typanosomas fuscatus* was separated from their shell with the aid of drilling pin. For *E. radiata,* the two valves of their shells were opened and the soft tissue removed with the help of a sharp knife. For *C. amnicola*, the shell was cracked before opening to remove the meat (soft tissue).

Thereafter, the specimens were preserved in an ice-chest before transporting them to the laboratory for proximate composition and mineral contents analysis.

2.4 Proximate Composition

Proximate composition of the samples evaluated in this study were crude protein content, moisture content, fat content, carbohydrate content, ash and fibre content. Crude protein content was determined according to Kjeldahl's method (6.25 x N) following procedures given by AOAC [28] and calculated by converting the nitrogen content. Moisture content was determined by drying the collected edible parts of the specimens in an oven at 105ºC until a constant weight was obtained according to AOAC [28] and AOAC [29]. Fat content was also determined following standard method given by AOAC [28] and AOAC [29] by the acid hydrolysis Soxhlet system. Carbohydrate content was estimated by subtracting the sum of the weight of protein, ash and fiber from the total dry matter. Ash content was determined by furnace ashing in a furnace oven at 600ºC for 12 hours [28] and [29]. Determination of proximate composition was done in triplicates.

2.5 Mineral Analysis

The mineral contents of the dry matter specimens were determined according to standard procedures given by AOAC [29]. The analysis for each sample was done in triplicates. The ash samples for each specimen were leached with 10mls of 20% hydrochloric acid (HCl), thereafter the solutions were diluted to 50 ml with deionized water. The solutions were analyzed with the aid of Atomic Absorption Spectrophotometer (model GBC Scientific ASS GF 3000) for sodium (Na), calcium (Ca), copper (Cu), iron (Fe) and Manganese (Mn).

2.6 Statistical Analysis

Results obtained for the proximate and mineral composition of the specimens were subjected to one-way analysis of variance (ANOVA) to test for significance using PASW windows software (predictive analytical software) program (version 19.0). Effects with a probability of $P < 0.05$ were considered significant whereas the probability of $P > 0.05$ was not considered significant. Duncan's multiple range tests was used to compare the mean values of the samples.

3. RESULTS

3.1 Proximate Composition

Results obtained for the proximate composition of the dry matter (g/100 g) of the edible part of some economical shellfishes (Table 1) from the Calabar river showed that ash content was highest in *E. radiata* (3.80 ± 0.01 g/100 g), followed by *C. amnicola* (3.30 ± 0.01 g/100 g), followed by *T. fuscatus* (2.66 ± 0.01 g/100 g) and least in *T. coronata* (2.57 ± 0.01 g/100 g). Fat content was highest in *T. coronata* (1.50 ± 0.01 g/100 g), followed by *E. radiata* (1.36 ± 0.02 g/100 g), followed by *C. amnicola* (1.23 ± 0.01 g/100 g) and least in *T. fuscatus* (1.18 ± 0.01 g/100 g). Fibre content was highest in *T. coronata* (0.06 ± 0.01 g/100 g), followed by *C. amnicola* (0.05 ± 0.02 g/100 g), followed by *T. fuscatus* (0.05 ± 0.01 g/100 g) and least in *E. radiata* (0.04 ± 0.01 g/100 g). Moisture content was highest in *T. coronata* (76.35 ± 0.01 g/100 g), followed by *T. fuscatus* (71.22 ± 0.01 g/100 g), followed by *C. amnicola* (65.50 ± 0.29 g/100 g) and least in *E. radiata* (61.20 ± 0.11 g/100 g). Protein content was highest in *E. radiata* (32.10 ± 0.06 g/100 g), followed by *C. amnicola* (23.50 ± 0.06 g/100 g), followed by *T. fuscatus* (22.52 ± 0.01 g/100 g) and least in *T. coronata* (14.88 ± 0.01 g/100 g). Nitrogen free extract (NFE) was highest in *C. amnicola* (6.42 ± 0.25 g/100 g), followed by *T. coronata* (4.64 ± 0.02 g/100 g), followed by *T. fuscatus* (2.37 ± 0.02 g/100 g) and least in *E. radiata* (1.50 ± 0.10 g/100 g).

3.2 Mineral Contents

Mineral contents (g/100 g) of the edible part of some economical shell fishes (Table 2) from the Calabar River showed that sodium content (Na) was highest in *C. amnicola* (108.34 ± 0.08 g/100 g), followed by *E. radiata* (38.60 ± 0.06 g/100 g), followed by *T. coronata* (16.43 ± 0.01 g/100 g) and least in *T. fuscatus* (16.33 ± 0.01 g/100 g). Calcium content (Ca) was highest in *T. coronata* (188.42 ± 0.09 g/100 g), followed by *C. amnicola* (182.46 ± 0.09 g/100g), followed by *E. radiata* (66.72 ± 0.01 g/100g) and least in *T. fuscatus* (49.86 ± 0.01 g/100g). Copper content (Cu) was highest in *T. coronata* (10.03 ± 0.02 g/100 g), followed by *E. radiata* (3.16 ± 0.01 g/100 g), followed by *T. fuscatus* (2.01 ± 0.01 g/100 g) and least in *C. amnicola* (0.49 ± 0.01 g/100 g). Iron content (Fe) was highest in *T. coronata* (14.83 ± 0.01 g/100 g), followed by *T. fuscatus* (10.42 ± 0.02 g/100 g), followed by *C. amnicola* (9.33 ± 0.01 g/100 g) and least in *E. radiata* (8.76 ± 0.01 g/100 g). Manganese content (Mn) was highest in *T. coronata* (1.65 ± 0.01 g/100 g), followed by *C. amnicola* (0.69 ± 0.02 g/100 g), followed by *E. radiata* (0.54 ± 0.01 g/100 g) and least in *T. fuscatus* (0.21 ± 0.01 g/100 g).

Table 1. Mean (± SE) of proximate composition of four shellfish species from the Calabar River, Nigeria (g/100 g)

Species	Ash	Fat	Fibre	Moisture	Protein	NFE
Typanosomas fuscatus	2.66 ± 0.01^a	1.18 ± 0.01^a	0.05 ± 0.01^a	71.22 ± 0.01^a	22.52 ± 0.01^a	2.37 ± 0.02^a
Egeria radiata	3.80 ± 0.01^b	1.36 ± 0.02^b	0.04 ± 0.01^a	61.20 ± 0.11^b	32.10 ± 0.06^b	1.50 ± 0.10^b
Callinectes amnicola	3.30 ± 0.01^c	1.23 ± 0.01^c	0.05 ± 0.02^a	65.50 ± 0.29^c	23.50 ± 0.06^c	6.42 ± 0.25^c
Thais coronata	2.57 ± 0.02^d	1.50 ± 0.01^d	0.06 ± 0.01^a	76.35 ± 0.01^d	14.88 ± 0.01^d	4.64 ± 0.02^d

**Column values with different superscript are significantly different (P<0.05)*

Table 2. Mean (± SE) of mineral contents of four shellfish species from the Calabar river, Nigeria (mg/100 g)

Species	Sodium	Calcium	Copper	Iron	Manganese
Typanosomas fuscatus	16.33 ± 0.01[a]	49.86 ± 0.01[a]	2.01 ± 0.01[a]	10.42 ± 0.02[a]	0.21 ± 0.01[a]
Egeria radiata	38.60 ± 0.06[b]	66.72 ± 0.01[b]	3.16 ± 0.01[b]	8.76 ± 0.01[b]	0.54 ± 0.01[b]
Callinectes amnicola	108.34 ±0.08[c]	182.46 ± 0.01[c]	0.49 ± 0.01[c]	9.33 ± 0.01[c]	0.69 ± 0.02[c]
Thais coronata	16.43 ± 0.01[d]	188.42 ± 0.09[d]	10.03 ± 0.02[d]	14.83 ± 0.01[d]	1.65 ± 0.01[d]

**Column values with different superscript are significantly different (P<0.05)*

4. DISCUSSION

Increase in global population has resulted to increase in per capita consumption of aquatic food including shellfishes. According to Samya and Mohamed [30] shellfishes have long been included as an important part of the diet of human populations especially in coastal areas. Due to the nutritional benefits of shellfishes, the current dietary guidelines have recommended increased consumption of seafood [31]. The four species of shellfishes evaluated in this study are important commercial species that are consumed by inhabitants of the Calabar River and other coastal areas in other parts of the world due to its nutritional benefits such as protein, fat, fibre content etc. Results obtained for the proximate composition of four economical shellfishes (*E. radiata*, *C. amnicola*, *T. coronata*, and *T. fuscatus*) in this study showed that these shellfishes were rich in nutritional qualities. In this study, the following trends were observed in this study: Protein (*E. radiata* > *C. amnicola* > *T. fuscatus* > *T. coronate*), fat (*T. coronata* > *E. radiata* > *C. amnicola* > *T. fuscatus*), fibre (*T. coronate* > *C. amnicola* > *T. fuscatus* > *E. radiata*), moisture (*T. coronata* > *T. fuscatus* > *C. amnicola* > *E. radiata*). Results of this study showed that there was a significant difference (P<0.05) in all the proximate indices including protein, fat, moisture, lipid and NFE except fiber content among the four species. Comparing results obtained in this study with findings of other studies, variations in these indices were obtained. Apart from protein content and NFE, results of all other proximate indices were lower than values reported by [13]. Protein obtained from molluscs are known to be rich in essential amino acids which are required for growth, reproduction and vitamins synthesis in living systems [32]. According to Okuzumi and Fujii [33] protein is an essential substrate for the sustenance of life and exists in the largest quantity of all the nutrients as a component of the human body. The protein content of *C. amnicola* obtained in this study was higher than 19.82% reported by Moronkola et al. [20] for the same species. For *E. radiata*, protein content was lower than 47% reported by Ehigiator and Akise [22] for the same species in Okwagbe waterside along the right bank of Forcados River, Nigeria. The protein content of *T. fuscatus* and *T. coronata* were lower than values reported by [13] for the same species sampled from Okpoka Creeks in Rivers State, Nigeria. Job and Ekanem [9] reported a crude protein level of 41.04% for *T. fuscatus* from a tropical creek in Nigeria which is far higher than 22.52% obtained in this study. Knowledge of the moisture content in an organism important since it provides useful information that helps in the preservation of the qualities and susceptibility to fungi infection [34]. Moisture content was found to be high in all the shellfishes analyzed in this study with highest levels obtained in *T. coronata* and least in *E. radiata*. Variation in proximate composition of shellfishes has been linked with reproduction cycles. Etim [35] observed high moisture content in tissues of shellfishes during spawning period and attributed it to the fact that the organism absorbs more water to fill the lumen created after gametes are released for reproduction. Davies and Jamabo [13] attributed high moisture content in the flesh of shellfish to the quantity of water they absorb into their cells from the external environment which is high in concentration to help balance the osmotic pressure between the surrounding water and in their cells. This finding is similar to findings of Job and Ekanem [9] and Omotoso [36] for *T. fuscatus* from similar water bodies. According to Zhu and Bai [37], high moisture content in an organism is advantageous since it helps movement stabilization of the organisms. Fat plays a vital role in the structural and biological function of the cells and transporting fat soluble vitamin in the body and also as food reserve along with protein. In this study, fat content was significantly (P<0.05) highest in *T. coronata* and least in *T. fuscatus*. However, fat content in *C. amnicola* was higher than that reported by Moronkola et al. [20] and Kucukglumez et al. [38] but was found to be lower than the fat content reported by Davies and Jamabo [13] and Nalan et al. [39]. Findings of this study agree with findings of other authors shellfishes belong to the low fat class of organisms [13] and [38]. Davies and Jamabo [13] explained that the percentage storage of fat in crabs is dependent on periodic change which is influenced by environmental factors such as temperature. According to Suzanne [40] lipids are high sources of energy containing twice the energy of obtained in carbohydrates and proteins. The concentration of nitrogen free extract observed in this study was low with *C. amnicola* recording the highest (6.42 ± 0.25%) and *E. radiata* recording the lowest (1.50 ± 0.10%). These findings agrees with findings of Bassey et al. [41] on *E. radiata* (clams) and *Pomecia palludosa*. Also, the low nitrogen free extract content observed in this study is justified by findings of Suzanne [40] and Eddy et al. [42] that in most sea foods, nitrogen free extract constitute only a minor percentage of the total biochemical composition. Values obtained for nitrogen free extract in this study varied slightly with results of other studies in similar water bodies [9,13,20] and [38]. Such variations may be attributed to the difference in the geological location of the aquatic environment because according to Bassey et al. [41] and Fagbuaro et al. [43] variation of the water quality influences the physiological processes and physico-chemical compositions of the aquatic ecosystem. Results obtained for the mineral composition revealed that all the evaluated species contained sodium, calcium, copper, iron and manganese in different amounts which varied significantly ($P<0.05$) among these shellfishes. In the living system, sodium is a very important mineral since it helps in regulating the pH, nerve impulse transmission, water balance, osmotic pressure and transportation of glucose/amino acid [44]. According to Turhan et al. [45] and Gokoglu and Yerlikaya [46] the concentration of minerals in tissue and other parts of shell fishes can be influenced by various factors such as food source, season, environmental parameters (water chemistry, salinity, temperature and contaminants), and biological attributes (species, age, sexual maturity size, and sex). Sodium concentration obtained in this study is similar to finding Udo and Arazu [2] on the same species from the Cross river. The trend observed for sodium in this study was as follows: *C. amnicola* > *E. radiata* > *T. coronata* > *T. fuscatus*. This trend is similar to trend reported by Davies and Jamabo [13] for the same species sampled from Okpoka Creeks in Rivers State, Nigeria. Hughes et al. [47] attributed the differences in sodium concentration among shellfishes to the type of food they eat and the different types of minerals they absorb directly from their aquatic environment through their gills and body surfaces. Calcium content was also high in the flesh of all the four shell fish species with the trend *T. coronata* > *C. amnicola* > *E. radiata* > *T. fuscatus*. Calcium is an important minerals that help in bone and shell formation. Also, it plays a major role in blood clotting, muscles contraction and in metabolic processes [48]. Calcium content in the flesh of *C. amnicola* obtained in this study was slightly lower compared to the earlier work obtained on *C. amnicola* by Davies and Jamabo [13] from Okpoka Creeks. However, Calcium content in the flesh of *T. coronata* and *T. fuscatus* were higher compared to findings of Davies and Jamabo [13]. For *E. radiata*, calcium content obtained in this study was higher than values obtained for wild and cultured *E. radiata* reported by Ehigiator and Akise [22]. Davies and Jamabo [13] attributed variation in calcium content of shellfishes in different locations to the feeding habit of the shellfish on rich mineral source from the aquatic environment. Copper is another important mineral that is essential for good health. In this study, copper was found to be present in the four shellfishes with the trend: *T. coronata* >*E. radiata* > *T. fuscatus* > *C. amnicola*. This trend was also similar to findings of Davies and Jamabo [13] from Okpoka Creeks although values obtained in this study for all the four shellfishes were slightly lower than values obtained by the above mention authors. These variation in copper content of shellfishes in different locations may be attributed to the nature of food and the type of mineral source available in their environments. The iron content in this study was highest in *T. coronata* and least in *E. radiata*. Values obtained for iron in this study for *T. coronata*, *T. fuscatus*, and *C. amnicola* were all higher than values reported by Davies and Jamabo [13] in a similar water body. This may be attributed to the type of food they eat and the types of minerals they absorbs directly from environment [47]. Manganese is a trace elements that helps in the normal functioning of the body and a required co-factor for an enzyme called prolidase, which is used in making collagen as a structural component of the skin [43]. In this study, Manganese was highest in *T. coronata*, followed by *C. amnicola* and least in *T. fuscatus*. Values obtained for manganese in the flesh of the shellfishes in this study were lower than findings of other authors such as Davies and Jamabo [13] for the same shellfishes in Okpoka Creeks. Again, these variations may be due to the type of food these shellfishes eat from their environment and the different types of minerals they absorb.

5. SUMMARY AND CONCLUSION

Based on findings of our study, the meat of *T. coronata*, *E. radiata*, *T. fuscatus*, and *C. amnicola* are high in nutritional quality and are suitable for human consumption. Apart from high protein, low fat and carbohydrate content, these shellfishes are also rich in minerals such as sodium, calcium, iron, copper and manganese which are necessary for good health, growth and other vital cellular functions. The nutritional values of the four species of shellfishes studied are suitable for human consumption, and the species could have potential alternative for animal feed industries. Therefore, aquaculture activities related to shellfishes should be encouraged to reduce pressure and total dependence on wild stock.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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