NUTRITIONAL COMPOSITION OF SELECTED BIVALVE MOLLUSC SHELLFISH CONSUMED IN THE NIGER DELTA, NIGERIA

Ukwo, Sunday Peter*[1], **Ezeama**, Chidi [2] and **Onwuka**, Gregory [2]

[1] Department of Food Science and Technology, University of Uyo, Akwa Ibom state, Nigeria
[2] Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike, Abia State, Nigeria
e-mail: sonipeter75@gmail.com

Abstract
Bivalve molluscs are important delicacies and healthy food items in the Niger delta. Four species of bivalve molluscs: Bloody cockle (Anadara senilis), Donax clam (Donax rugosus), Knife clam (Tagelus adansonaii) and Mangrove oyster (Crassosstra gasar) were assessed for their proximate and mineral content. Percentage recommended daily allowance (RDA) was estimated to determine if their consumption were meeting the nutrition needs of consumers. Standard methods of analysis were employed to determine proximate and mineral content. Results indicated variations in proximate and mineral content. Donax clam had the highest protein content of 18.13%, constituting 33% of RDA for 65kg adult. Bloody cockle had the highest lipid (3.26%), while mangrove oyster had the highest ash (5.31%) and carbohydrate (4.12%) content. Results of trace elements showed mangrove oyster contained 10.47mg/100g of zinc and 2.05mg/100g of manganese which are equivalent to 95% and 89% of RDA for zinc and manganese. Bloody cockle contained 7.26mg/100g of iron and 0.34mg/100g of selenium which are equivalent to 90% and 62% of RDA for iron and selenium. The nutrient burden and RDAs of trace elements in bivalve species indicated that 100g of mangrove oyster can provide 95% of zinc, 89% of manganese, 65% of iron, 60 % of selenium and 14% of copper, while 100g of Donax clam can provide 65% of copper, 53% of iron, 33% of selenium, 23% of zinc and 21% of manganese. Consumption of bivalve molluscs can be a remedy to the problem of hidden hunger in the society.

Key words: proximate composition, mineral content, trace element, bloody cockle, mangrove oyster, Niger delta

Received: 21.06.2019 Reviewed: 24.09.2019 Accepted: 25.09.2019

INTRODUCTION

Molluscs are soft-bodied animals that are protected by hard shells. There are six major classes of molluscs of which bivalves are the most organized and specialized (Gosling, 2003). Bivalve mollusc inhabits fresh and marine waters from the abyssal depths of high intertidal areas in tropical to warm temperate waters. The most important species are the mussels, oysters, clams, cockles and scallops (Gosling, 2003, Gopalsamy *et al*., 2014). The pattern of their distribution is characteristically different from one location to another depending on the sediment types, variations in water salinities as well as the tidal movements (Sarker *et al*., 2008). As the world population is growing, the consumption of seafood is also increasing rapidly due to the health consciousness of modern day consumers who are interested in seafood because of their nutritional superiority and the health benefits (Gopalsamy *et al.*, 2014). According to the reports of FAO (2018), global bivalve production has consistently increased in the last sixty-six years growing from nearly 1 million tonnes in 1950 to about 17.1million tonnes in 2016 contributing to over 10% of the total amount of income in 2016. However according to Pawiro (2010), trade in bivalve species between developing countries and major markets has not developed as well as that for other seafood products. This is because of public health concerns. Importing countries also enforce strict regulations on live, fresh and frozen bivalves which many exporting developing countries are unable to meet. In Nigeria, finfish farming dominates the scanty literature on aquaculture, with much less on bivalve mollusc shellfish. Although there is no statistic on production of bivalve mollusc by species, the Nigeria Bureau of statistic (NBS) reported that Nigeria produced 5.8million

tonnes of fish including bivalve molluscs between 2010 and 2015 (NBS, 2017).

The consumption of bivalves and other seafood is believed to provide an inexpensive source of protein with high biological value, essential minerals such as selenium, calcium, iron, phosphorus as well as vitamins (Astorga-Espana *et al.,* 2007). They are considered as delicious and healthy food items in several dietary regimes in different part of the world. The nutritional characteristics of bivalves vary among species and between individuals of same species. Other factors that affect their nutritional qualities include age, sex, maturation stage, origin, season, seawater, physical/chemical properties of the environment such as temperature and pH as well as feed composition (Orban *et al.,* 2002).

Ecologically, the importance of bivalve mollusc shellfish cannot be underestimated, the filter feeding pattern helps to purify silted marine waters (Picardal *et al.,* 2014), which forms an important links between the primary detritus and consumers and also plays a significant role in nutrient recycling (Long *et al.,*2014).Bivalve mollusc shells have been found important for various commercial purposes like poultry feed, shell lime, cement, lime industries, calcium resources, industrial raw material, fisheries, handicrafts and interior decoration. Other human uses include, food, tools, currency, and ornamentation (Venkatesan, 2010).Bivalves also provide direct benefits to modern cultures as food, building materials, and jewelry and provide indirect benefits by stabilizing shorelines and mitigating nutrient pollution (Voultsiadou *et al.,* 2009).

The Niger Delta coastal waters are exceptional breeding ground for vast variety of fish and shellfish. It provide an excellent habitat for diversity of bivalve mollusc shellfish such as bloody cockle (*Anadara senilis*) mangrove oyster (*Crassosstrea gasar*), razor or knife clam (*Tagelus andansonii*) and others. Bivalve mollusc shellfish are considered as an important delicacies and healthy food items playing a central role in the Niger delta gastronomy. The diversity and abundant of bivalve species in the Niger delta have commercial importance as well as contributes fisheries resources constitute both traditional and primary source of enterprise and livelihood of most communities within the Niger Delta region of Nigeria.

Bivalve molluscs are highly exploited by adult female and youth of the coastal communities. The mangrove oyster (*Crassosstrea gasar*) occurs abundantly in the coastal swamp and estuaries of the Niger Delta where they are exploited at subsistence level. Other bivalves harvested include various species of clams, bloody cockle (*Anadara senilis*), *Tagelus adansonaii*, among others (Udotong *et al.*, 2017). At the subsistent level of their production, bivalve are usually sold or marketed either fresh or dried in local markets. Buyers and consumers include individual consumers who buy the products for home consumption, street food vendors, restaurant operators and exporters. Information obtained during the conduct of value chain assessment shows high profitability of the products (Njie and Drammeh, 2011).

There remains no considerable study on some bivalve species consumed in the Niger delta region with regard to their nutritive value for human consumption and despite bivalves being consumed in many part of the world, very limited studies have also been done to estimate the proximate composition of their body tissue, vitamins and minerals content of species endogenous to the Niger Delta coastal area. The objective of this work is to determine the proximate composition and the mineral content of bivalve species consumed in the Niger delta as well as estimate the Recommended Daily Allowance (RDA) for protein and minerals. This will help to increase their utilization and consumption and also help to reduce malnutrition while raising the nutritional status of populations around the coastal communities and beyond.

MATERIALS AND METHODS

Sample collection

Fresh bivalve specimens mostly consumed in the coastal cities of Niger Delta were harvested

manually by fishermen during low tide from intertidal estuarine mudflats of Iko Town in Eastern Obolo in Akwa Ibom State. The bivalve specimens collected were Bloody cockle (*Anadara Senilis*), Donax clam (*Donax rugosus*), Knife or razor clam (*Tagelus Adansonaii*) and Mangrove Oyster (*Crassosstrea gasar*).They were identified at the Department of Fisheries and Aquatic Environmental Management, University of Uyo. At the sampling site, twenty (20) species of each bivalve specimens were collected and transferred to the laboratory within 24hours of collection in plastic containers washed with 5% nitric acid and rinsed with distilled water before use.

Sample preparation

The traditional method of preparing bivalve for consumption in the Niger Delta was used for the study. At the laboratory, the bivalves were promptly cleaned of incrustations, washed in distilled water to remove all dirt, put into a stainless pot and blanched for 5min. at 100°C. After blanching, the samples were poured into a perforated basket to drain and allowed to cool at room temperature (28±2°C). Samples were then shucked with sterile scapel to extract the flesh and intravalvular fluid into sterile container. The extracted tissue was homogenized for 60s in a stomacher (Sewad Laboratory Stomacher 400, England) and stored at -20°C in a scan frost deep freezer for various experimental assays.

Proximate composition

Proximate composition of extracted bivalve samples was determined according to methods outlined by AOAC (2010). Moisture content using the procedure of vacuum oven method, the micro-Kjeldahl method was used to determine protein content, crude fat content was determined by the Soxhlet extraction method, the total ash was determined by incineration of dried sample obtained in muffle furnace at 550^{0}C for 24hours, crude fiber was obtained using trichloroacetic acid method while carbohydrate content was obtained by difference. The percentage recommended daily allowance for protein was calculated according to the method of National academic of Science (2001).The caloric content was determined by the Atwater general factor system as outlined by Onwuka (2008).

Analysis for the mineral content of bivalve: The mineral content includes the composition of macromineral and trace elements present in the bivalve samples. Techniques of ultraviolet – visible spectrophotometry, atomic absorption spectrophotometry and flame photometry were used for analysis. Standard stock solution of the element to be analysed was prepared, diluted to the corresponding working standard solution for recovery experiment according to the methods as outlined by Onwuka (2018). The wet ashing method as outlined by Onwuka (2018) was used to determine the concentration of metallic element in the bivalve samples. The method of preparation and digestion procedure as outlined by AOAC (2010) for biological sample was also employed. Determination of sodium and potassium content was done through the use of Jenway flame photometer at the wavelength of 589nm and 767nm for potassium and sodium respectively, while analysis of Ca, Mg, Zn Cu, Mn, Fe and Se were carried out using a Perkin – Elmer model 3030 Atomic Absorption spectrophotometer (AAS) using their respective lamp and wavelength (Ca, 422.7nm, Mg 285.2nm, Fe 324nm, Zn 213nm, Cu 324nm, Se 196nm). Analysis of phosphorus was done using UV – visible spectrophotometer. The percentage recommended daily allowance for macro mineral and trace elements were also calculated according to the method of National academic of Science (2001).

Data analysis

All the analyses were carried out in triplicate and the experimental data generated were statistically analyzed using one way analysis of variance (ANOVA) using SPSS version 16.0. Duncan multiple range test was used to separate the means at $p<0.05$ significant differences.

RESULTS AND DISCUSSION

Proximate composition and energy value of bivalve samples

The proximate composition and energy value of bivalve samples is shown in Table 1. It showed a moisture content ranging from 69.40% to 75.04%. Mangrove oyster had the highest moisture content of 75.04% followed by knife clam 73.01%, while Donax clam with 69.40% recorded the lowest moisture content. There was significant difference ($P < 0.05$) in the moisture content of bivalve samples analysed. The variations in moisture content could be attributed to species and environmental effects (Osibona *et al*., 2006). Values for moisture content obtained in this study were higher than values reported by Gopalsamy *et al* (2014) on *Donax cuneatus* and Eswar *et al.* (2016) on marine clam (*Gafrarnim divaricatum*) from the cuddalore and mumbai both in India. However, values for moisture content in the present study was in agreement with values of 73.37% for mangrove oyster and 73.72% for clam which was reported by Kin-kabari *et al.* (2017) on selected shellfish (mangrove oyster and clam) from River State, Nigeria. Moisture plays a key role as solvent for organic and inorganic solutes. It is an integral part in most of the reactions having a major impact on the conformation and reactivity of protein. Changes in the amount of water present in the muscle have profound effects on their rheological properties, nutritional value and their sensory properties (Nunes *et al.*, 2008). The protein content of bivalve samples ranged from 14.26-18.13%. Donax clam had the highest protein content (18.38%) followed by bloody cockle (16.38%) while mangrove oyster (14.26%) was the lowest.

Values for protein in bivalve molluscs as reported in this study fall within the range of values reported by other researchers (Gopalsamy *et al.*, 2014, Eswar *et al.*, 2016, Kin-kabari *et al*2017). According to Lourenco (2011) seafood contain crude protein ranging from 17-20% corresponding to 2-3% protein nitrogen. Also Nunes *et al*. (2003) stated that though these percentages may be constant, some variations can occur during spawning. Proteins in bivalve have a high biological value and contain all essential amino acids which recognizes its great digestibility. They play a very role in growth and maintenance of vital bodily functions (Nunes *et al.*, 2008). Bivalve shellfish and other seafood are good sources of branched chain amino acids and taurine, which act beneficially on glucose metabolism and also blood pressure (Elmadfa and Meyer 2017). Fermented bivalve shellfish sauces are nutritional condiments, which find uses in cuisines in the Niger Delta, South East Asian and other of world (Grienke *et al*., 2014). In view of the high nutritional value, bivalve shellfish proteins are able to complement the value of plant proteins, which may be deficient in one or more essential amino acids (Kim and Venkatesan 2015; Elmadfa and Meyer 2017). Enzymatic digestion of bivalve proteins, either *in vitro* or in the human digestive system, leads to formation of several peptides besides amino acids. Bivalve peptides especially clam peptides have potent vasoconstrictor which has been considered a therapeutic approach in the treatment of hypertension. Bivalve peptides also possessed an hypocholesterolemic activities, bile acid-binding capacities, and the ability to inhibit solubility of cholesterol, indicative of their cardioprotective role (Lin *et al*., 2010). Peptides having antioxidant, anticoagulant, and antihypertensive properties have also been isolated from bivalve molluscs shellfish (Grienke *et al*., 2014). A novel anticancer peptide from the shellfish *C. gigas* exhibited cytotoxic activity, inducing death of prostate, breast, and lung cancer cells (Cheung *et al*., 2013). In a similar studies, Gopalsamy *et al* (2014) stated that molluscs contain high amount of protein and that sex i.e male or female can be a source of variations to protein content as female usually contain more protein. Bivalve molluscs can therefore be regarded as protein rich food which has the potential of supplying cheap source of protein to the people of Niger Delta.

The lipid content of bivalve samples ranged from 1.02-3.26% with bloody cockle having the highest while mangrove oyster recorded the lowest lipid content. There was a significant difference ($P < 0.05$) in the lipid content of bivalve samples analysed. Belitz *et al* (2004)

reported that lipid content of shellfish can vary between 0.1% - 30%. The author classified shellfish into lean (0.1-0.4% of lipids), fatty (≥ 16%) and semi-fatty 0.4% < lipids < 16%). Despite this classification, bivalve is generally regarded as low fat food. According to Nunes *et al.* (2003), the lipids content of bivalve is strongly influenced by season, geographical area and age.

Ash content of bivalve samples ranged from 3.68-5.31%. Mangrove oyster had the highest ash content. Values for ash content in this present study are similar to values reported by Kiin-kabari *et al* (2017). High ash content of the bivalve species is an indication that they are rich in mineral content. Bivalve molluscs and other seafood products are not fiber rich food. Values obtained in analysis for fiber indicate a ranged of 0.24-1.73%. The fibre content of seafood is dependent on the age and environmental factors.

Carbohydrate content of bivalve molluscs shellfish ranged from 3.10%- 4.12% with mangrove oyster with highest while bloody cockle was the lowest. Values for carbohydrate in the present study were similar to values reported by researchers in various part of the world (Louranco *et al.*, 2011, Obande *et al.*, 2013, Gopalsamy *et al.* 2014 and Eswar *et al.*, 2016). According to Belitz *et al.* (2004), shellfish especially bivalve molluscs stored their energy reserves as glycogen which contributes to the characteristic sweet taste of the product. Also several authors have also indicated that carbohydrate content of some bivalve molluscs are as much as 3-10% in species such as pacific oyster 6.5 ±3 % reported by Dridi *et al* (2007). Asian clam 7.9% reported by Karnjana pratum *et al.*, (2013). These values are high when compared to some shell fish like lobsters which have around 1.0% of carbohydrate. Generally carbohydrate content in sea foods is known to be very small, low carbohydrate content indicates that high consumption of bivalve must be supplemented with energy rich foods to balance the energy protein intake requirement (Kiin-kabasi *et al.*, 2017).The energy value of bivalve samples analysed ranged from350.20-481.53 KJ per 100g. Bloody cockle had the highest energy value followed by Donax clam while mangrove oyster had the least.

Table 1: Proximate composition of bivalve samples

Parameters	Bloody cockle	Donax clam	Knife clam	Mangrove oyster
Moisture (%)	72.54^{c} ±0.27	69.40^{d} ±0.27	73.01^{b} ±0.17	75.04^{a} ±0.11
Protein(%)	16.38^{b} ±0.14	18.13^{a} ±0.60	15.74^{c}±0.11	14.26^{d} ±0.10
Lipid (%)	3.26^{a} ±0.13	2.18^{c}±0.22	2.32^{b}±0.08	1.02^{d}±0.12
Ash (%)	4.18^{b} ±0.14	5.09^{ab}±0.32	3.68^{c}±0.08	5.31^{a}±0.11
CHO(%)	3.10^{d}±0.05	3.46^{c}±0.17	4.09^{b}±0.03	4.12^{a}±0.06
Fiber (%)	0.53^{c} ±0.11	1.73^{a} ±0.27	1.15^{b} ±0.09	0.24^{d}±0.35
Energy (KJ per 100g)	481.53^{a}±0.28	452.41^{b}±0.17	422.95^{c}±0.25	350.20^{d}±0.30

*Values are Means ± SD of triplicate determination. Means in the same row with different superscript are significantly different at(P <0.05)KEY: CHO – Carbohydrate

Table 2: Percentage* RDA of protein consumed in 100g of bivalve

Samples	Protein (%)	RDA (%)
Bloody cockle	16.38	29.25
Donax clam	18.13	32.38
Knife clam	15.74	28.11
Mangrove oyster	14.26	25.46

*Based on 56g protein per day for 65kg adult male
Key: RDA – Recommended Daily Allowance

Percentage Recommended Daily Allowance (RDA) for protein

The RDA is the average daily intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98 percent) healthy individuals in a particular life stage and gender group. As presented in Table 2, consumption of 100g of any of the analyzed bivalve samples by a 65kg adult male as the only source of protein in the diet, would provide 29.25% RDA in Bloody cockle, 32.38% RDA from Donax clam, 28.11% RDA from Knife clam and 25.46% from Mangrove oyster. This result showed that the bivalves samples are good source of protein. Protein is the major functional and structural component of every cell in the body. All enzymes, membrane carriers, blood transport molecules, the intracellular matrices, hair, fingernails, serum albumin, keratin, and collagen are proteins, as are many hormones and a large part of membranes (Elmadfa and Meyer 2017).The requirements for protein are based on careful analyses of available nitrogen balance studies.

Mineral content of bivalve samples

The macro mineral content of bivalve mollusc shellfish is presented in Table 3.The results revealed that bivalve shellfish are rich sources of micronutrients: calcium, magnesium, potassium, sodium, phosphorus. Significant difference ($p<0.05$) existed in values obtained for all macro mineral content of bivalve samples analysed. Mangrove oyster contained the highest concentration of sodium (111.37mg/100g) and potassium (44.23mg/100g). Bloody cockle had the highest calcium content (120mg/100g) while Donax clam recorded the highest content of magnesium (37.24mg/100g) and phosphorus (65.32mg/100g). The macro mineral content of bivalve mollusc shellfish vary considerably within species with age, size, sex, season, diet, state of health and geographical locations (Lourenco, 2011). Macro minerals such as Na, K, Mg and P were detected in significant level in this study which is in agreement with reports from several authors that the edible portions of bivalve shellfish are rich in macro minerals (Karnjanatum *et al* 2013: Gopalsamy *et al.*, 2004; Venugopal and Gopakum 2017 and Kiin-kabri *et al.*, 2017).

Lourenco *et al.* (2009) reported that sodium and potassium are usually higher in bivalve shellfish when compared to other shellfish. Sodium content of bivalve sample obtained in this present study was in agreement with values of 66.7mg/100g reported by Akinjogunla *et al.* (2017), on mangrove oyster from Lagos lagoon, but higher when compare to the value of 0.66mg/100g reported by Gopalsamy *et al.* (2014) for a Donax clam at cuddalore coastal waters in India. However, values from this present study were lower when compared with 263.24mg/100g, 344.56mg/100g for sodium in mangrove oyster and clam respectively reported by Kiin-kabari *et al.* (2017) in River State, Nigeria. Also value for potassium in the study was in agreement with values reported by Gospalsamy *et al.* (2014). The variations in sodium and potassium may be attributed to diet, sex and environmental factors. Sodium and potassium are the main monovalent electrolytes which are necessary for intercellular ion balance. They are important in osmo-regulation, balance and membrane potential of cells as well as transport across membranes. Sodium and potassium are also needed to activate amylase, an enzyme which is important in glucose metabolism in human body (Belilz *et al.*, 2004, Lourence 2011).

Calcium is a major component in bones and constitutes over 95% of bivalve shell in the form calcium carbonate. Calcium is involved in structure of muscle system and controls essential processes like muscle contraction, blood clothing and actively involves in brain cells and their growth (Beutz *et al.*, 2004). Calcium deficiency provokes kidney stones and poor bone growth. Calcium content of bivalve molluscs in the study was similar to values 138.20mg/100g reported by Ehigiator and Akisc (2016) on fresh water clam (*Egeria radiata*) and 99.3–120.2mg/100g reported by Akinjogunla *et al.* (2017) on mangrove oyster in Lagos lagoons. Also values obtained in the study for calcium was higher when compared to values (60.14mg/100g) reported by Davis and Jamabo (2016) on Mangrove oyster from

Okpoka creeks and 52.53mg/100g and 40.27mg/100g reported by Kiin-kabri *et al* (2017) on mangrove oyster and clam respectively both in River State, Nigeria, 85.42mg/100g reported by Carvallo *et al.* (2005) in Portugal and 59.70mg/100g reported by Gopalsamy *et al.* (2014) in India.

Bivalve mollusc shellfish is reported not to be a good source of magnesium (Lourenco *et al.*, 2009), but in this study significant level of magnesium was detected up to 37.24mg/100g in Donax clam and 34.62 mg/100g in mangrove oyster and this value is lower when compare to 55.76mg/100g and 71.85mg/100g for Mg reported by Kiin-kabari *et al* (2017) for mangrove oyster and clam in River State, Nigeria. For this study it is believed that variations in magnesium within species in the location could be attributed to feeding habit, sex and other factors. Magnesium just as calcium formed a greater part of human bones as well as prosthetic group in enzyme that hydrolyses and transfer phosphate groups, consequently, Mg is essential in energy requiring biological functions such as membrane transport, generation and transmission of impulses, contraction of muscles and oxidative phosphorylation (Lourenco 2011). Magnesium deficiency can cause neuromuscular irritability, muscle spasm, while excesses can cause diarrhea, anesthesia and depression of central and peripheral nervous system (Belitz *et al.*, 2004).

Phosphorus, the main structural element found in shellfish is usually found equal amount with sulphur. In this study, phosphorus detected in these species were lower when compared with values of 286.22mg/100g and 90.70mg/100g reported by Kiin-kabari (2017) on mangrove oyster and clam respectively but it was within the range of values reported by Akinjuogunla *et al.*, (2017). Shellfish especially bivalve molluscs have been reported to be very rich in phosphorus up to 200mg/kg. Several authors have reported that variations could be attributed to habitat, season, feeding pattern, species and gametogenesis and sprawing cycle have proven to affect protein and phosphorus in bivalve molluscs (Ozogul *et al.*, 2008 and Li *et al.*, 2010).

Trace elements or micro minerals are group of mineral elements that play an essential role in human health and nutrition. The trace elements content of bivalve samples is presented in Table 4. Values for micro mineral as obtained in this study showed significant difference ($P < 0.05$) among bivalve samples analysed. Copper with 5.85mg/100g in Donax clam was the highest, followed 4.26mg/100g in knife clam. Mangrove oyster had the highest concentration of zinc and manganese (10.47mg/100g and 2.05mg/100g), followed by bloody cockle (5.38mg/100g and 1.48mg/100g respectively). Bloody cockle was the richest in iron (7.26mg/100g) and selenium (0.34mg/100g) followed by mangrove oyster (5.23mg/100g) and (0.33mg/100g) while Donax with (4.21mg/100g) and (0.18mg/100g) respectively had the least concentrations.

Trace elements play an important role of functional elements in various metalloenzymes, which have particular catalytic functions in living organisms. As observed, bivalve mollusc shellfish in this study are rich sources of trace element when consumed. Variations in trace element content within species could be attributed to factors such as habitat of the organisms, dietary pattern, other ecological interactions and overall body size of the bivalve species (Davis and Jamabo, 2016). Copper is a component of a number of enzymes involve in glucose metabolism, synthesis of haemoglobin, connective tissue and phospholipid (Lourenco, 2011). Several authors have reported higher concentration of Copper in shellfish from Niger Delta (Edoghotu *et al.*, 2015 and Davis and Jamabo, 2016) and these have been attributed to the environmental pollution occasioned by anthropogenic activities in this area. Consumption of higher concentration of Copper in shellfish can have detrimental effects to human body. Such effects include Wilson's disease, hepatic necrosis, cirrhosis and haemolytic crisis (Celik and Oehlenchläger, 2004).

Zinc is an essential element for human and its presence in bivalve corroborates the hypothesis that zinc is always presence in shellfish and that the concentration presents in bivalve is usually higher (Celik and Oehlenschläger, 2004). The important function of zinc is based on its role as an integral part of a number of metalloenzymes and as a catalyst in regulating the activity of specific zinc- dependent enzyme. Among the bivalve species analysed, mangrove oyster recorded the highest concentration of zinc (10.47mg/100g) followed by bloody cockle (5.38mg/100g). The higher concentration of zinc in mangrove oyster have been attributed to the reason why therapists recommend eating of oyster for men with sexual disorder since the high content of zinc can be helpful in raising libido in men. Manganese functions as a cofactor in activating a number of enzymes such as aginase, amino petidase, alkaline phosphatase and enolase (Belitz *et al*., 2004). Manganese can also be on integral part of metalloenzymes necessary in lipid and carbohydrate metabolism and brain functions. Manganese is relatively non toxic, however, an excess intake and lead to mental disorder while its deficiency can cause bone deformation, sterility and ataxia (Belitz *et al*., 2004, Lourenco, 2011). The result from this study confirmed the report that seafood is not a good source of Manganese, nonetheless, bivalve can provide up to 2.05mg/100g. Also values from this study is similar to values reported by Davis and Jomaba (2016) in mangrove oyster at the Niger Delta but lower when compared to values reported by Akinjogunda *et al.* (2017) in mangrove oyster in Lagos lagoon.

Iron is present in cells of living organism and plays a vital role in several biochemical reactions. Most of iron is present in the haemoglobin (blood) and myoglobin (muscle tissue), pigments, cytochromes and other proteins participating in transport, storage and utilization of oxygen. It is also in a number of enzymes thereby making iron essential elements since its deficiency cause anemia (Belitz *et al*., 2004). The total iron in bivalve varies greatly, and from the result of this study, bloody cockle contain the highest concentration of iron followed by Knife clam. Bloody cockle as the name implies is the only bivalve among the species analysed that contain haemglobin in the internal fluid.

This may account for an elevated concentration of iron compare to other species of bivalve in this present study. However, values for iron reported in this study was lower compared to values reported by Edoghotu (2015), Kiin-kabari *et al.* (2017) and Akinjogule *et al.* (2017). This could be attributed to some intrinsic and extrinsic factors. Selenium is recognized both as an essential trace elements and a toxic agent. It is an integral component of enzyme, glutathione peroxidase (selenoprotein) in human and animal tissue, which together with vitamin E and enzyme catalase superoxide dismutase acts as an antioxidant, thereby protecting cells against oxidative damage. It is also involved in thyroid metabolism and proper functioning of immune system (Sirichakwal *et al.*, 2005). The presence of Selenium reduces the availability of mercury and cadmium ions thereby reducing their toxicity. Selenium was found in all the bivalve samples studied with concentration ranging from 0.17–0.34mg/100g and the values were similar to those reported by Carvalho *et al.* (2005), Sirichakwal *et al.* (2005) and Garg and Ramakrishna (2006). The dietary reference intake for Selenium can be made when bivalve is incorporated in daily meals.

Table 3: Macro mineral content in the bivalve samples

Mineral element (mg/100g)	Bloody cockle	Donax clam	Knife clam	Mangrove oyster
Sodium	62.70^{d} ±0.46	80.87^{c} ±0.42	82.33^{b}±11.92	111.37^{a} ±0.29
Potassium	31.24^{d} ±0.16	39.22^{b} ±0.61	37.40^{c} ±0.77	44.23^{a} ±0.18
Calcium	120.15^{a} ±0.16	83.43^{d} ±0.29	113.86^{b} ±0.40	102.22^{c} ±0.21
Magnesium	28.45^{c} ±0.12	37.24^{a} ±0.36	28.20^{c} ±0.23	34.62^{b} ±0.19

Phosphorous	60.41^{b} ±0.24	65.32^{a} ±0.64	58.72^{c} ±0.46	54.26^{d} ±0.97

*Values are Means ± SD of triplicate determination. Means in the same row with different superscript are significantly different at (P <0.05)

Table 4: Micro minerals or trace elements content in the bivalve sample

Mineral element (mg/100g)	Bloody cockle	Donax clam	Knife clam	Mangrove oyster
Copper	2.56^{c} ±0.27	5.83^{a} ±0.63	4.26^{b} ±0.80	1.24^{d} ±0.27
Zinc	5.38^{b} ±0.56	2.62^{d} ±0.11	3.82^{c} ±0.13	10.47^{a} ±0.46
Manganese	1.48^{b} ±0.92	0.49^{d} ±0.04	1.26^{c} ±0.14	2.05^{a} ±0.87
Iron	7.26^{a} ±0.17	4.21^{d} ±0.10	5.08^{c} ±0.51	5.23^{b} ±0.50
Selenium	0.34^{a} ±0.15	0.18^{b} ±0.01	0.17^{b} ±0.00	0.33^{a} ±0.45

*Values are Means ± SD of triplicate determination. Means in the same row with different superscript are significantly different at (P <0.05)

Recommended daily allowance for mineral elements

The percentage recommended daily allowance for macro minerals and trace elements are presented in table 5 and 6 respectively. The results indicated that consumption of 100g of bivalve samples can provide 12.54-22.65% of sodium, 1.56-2.21% of potassium 7.01-8.52% of calcium, 7.05-9.31% of magnesium and 7.75-9.33% of phosphorus. Mangrove oyster provided the highest percentage of sodium, potassium and calcium while Donax clam supplied the highest percentage of magnesium and phosphorus. The estimated percentage recommended allowance for trace elements indicated that values for copper ranged from 13.78-64.78% which implies that 100g of Donax clam can provide up to 65% of daily recommended allowance of copper for an adult male of 65kg body weight. The percentage RDA for zinc ranged from 23.82-95.18%. Mangrove oyster has been noted to contain higher zinc content when compare to other bivalve species a position that is in agreement with this study. Therefore, 100g of mangrove oyster can provide 95% and 89% of the daily requirement of zinc and manganese respectively for an adult male. The estimated RDA for iron ranged from 52.63-90.75%. Consumption of 100g of bivalve shellfish can provide over 50% of daily requirement of iron for adult man of 65kg body weight. Particularly, 100g of bloody cockle is able to provide 91% and 62% of adult man daily requirement for iron and selenium respectively. The nutrient burden of trace elements for individual bivalve species indicated that 100g of mangrove oyster can provide 95% of zinc, 89% of manganese, 65% of iron 60 % of selenium and 14% of copper, making it the richest. This is followed by bloody cockle with 92% of iron, 64% of manganese, 62%of selenium and 28% of copper while Donax clam was the least with 65% of copper 53% of iron, 33% of selenium, 23% of zinc and 21% of manganese. The importance of estimating nutrients recommended daily allowance is to determine if the consumption bivalve mollusc shellfish are meeting the nutrient and health needs of the people of the Niger delta who depend on the bivalve shellfish as a replacement for meat and as a major ingredient in their diet. According to Jennifer *et al*., (2006), determination of percentage recommended allowance can also help to recommend specie(s) that provides adequate, but not excessive, levels of nutrients during the planning stage.

Table 5: Percentage Recommended Daily Allowance (RDA) for macro minerals as provided by 100g/portion

Mineral element	RDA (mg)	%*RDA per 100g molluscs			
		Bloody cockle	Donax clam	Knife clam	Mangrove oyster
Sodium	500	12.54	16.17	16.47	22.67
Potassium	2000	1.56	1.96	1.87	2.21
Calcium	1000	12.02	8.34	11.39	10.22
Magnesium	400	7.11	9.31	7.05	8.66
Phosphorous	700	8.63	9.33	8.39	7.75

*Dietary Reference Intake, National Academy of Sciences (2001)

Table 6: Percentage Recommended Daily Allowance (RDA) for micro minerals as provided by 100g/portion

Mineral element	RDA	%*RDA per 100g molluscs			
		Bloody cockle	Donax clam	Knife clam	Mangrove oyster
Copper	900(µg)	28.44	64.78	47.33	13.78
Zinc	11(mg)	48.91	23.82	34.73	95.19
Manganese	2.3(mg)	64.35	20.87	54.78	89.13
Iron	8.0(mg)	90.75	52.63	63.50	65.38
Selenium	55(µg)	61.81	32.73	32.73	60.00

*Dietary Reference Intake, National Academy of Sciences

CONCLUSION

The findings from this work showed that bivalve contain considerable amount of protein and minerals. High protein values were noted in all the bivalve samples analysed. Donax clam had the highest protein content of 18.13%, bloody cockle had the highest lipid 3.26% and energy content 481.53 KJ per 100g, while mangrove oyster had the highest ash 5.31% and carbohydrate content of 4.12%, therefore with increased consumption the serious problem of protein deficiency can be mitigated in Nigeria and the world at large. Bivalve mollusc shellfish are veritable sources of macro minerals although constituting a meager percentage of the daily recommended allowances. Analysis for trace elements showed that mangrove oyster contained 10.47mg/100g of zinc and 2.05mg/100g of manganese which are equivalent to 95% and 89% of the daily recommended allowance for zinc and manganese respectively. The result also indicated that bloody cockle contained 7.26mg/100g of iron and 0.34mg/100g of selenium which is also equivalent to 90% and 62% of daily recommended allowance for iron and selenium respectively. The nutrient burden of trace elements for individual bivalve species indicated that 100g of mangrove oyster can provide 95% of zinc, 89% of manganese, 65% of iron 60 % of selenium and 14% of copper, making it the richest. This was followed by bloody cockle with 92% of iron, 64% of manganese, 62% of selenium and 28% of copper while Donax clam was the least with 65% of copper 53% of iron, 33% of selenium, 23% of zinc and 21% of manganese. With the result obtained in this study consumption of bivalve mollusc shellfish can be a remedy to the problem of hidden hunger that is prevalent in the society.

REFERENCES

[1] Akankali, J. A. and Nwafili, S. A. (2017). An Assessment of the Socioeconomic Impact of Crude oil pollution an aquaculture in Gokana Local Government Area Rivers State, Nigeria. Nigerian Journal of Fisheries and Aquaculture 5 (1), 87 – 94.

[2] Akinjogunla, V. F., Lawal-Are, A. O., and Soyinka,O. O., (2017) Proximate Composition and Mineral Content of Mangrove Oyster (*Crassosstrea gasar*) from Lagos Lagoon, Lagos. *Nigerian Journal of Fisheries and Aquaculture*, 5(2), 36-49.

[3] AOAC (2010) Official methods of analysis of Association of Official Analytical Chemist. Washington DC. USA

[4] Astorga Espana, M.S., Rodriguez, E. M and Diaz, R.C. (2007). Comparison of Mineral and Trace Element Concentrations in Two Mollusks Form The Srait of Magellan (Chile). *Journal Food Composition and Analysis*, 20(3-4), 273-279.

[5] .Belitz, H., Grosh, W., Schieberle, P., (2004). *Food Chemistry*, Springer-Verlag, Berlin, 1070p

[6] Carvalho, M. L., Santiago, S., and Nunes, M. L., (2005). Assessment of the essential element and heavy metal content of edible fish muscle. *Analytical and Bioanalytical Chemistry*, 382, 426-432.

[7] Çelik, U. and Oehlenschläger, J., (2004). Determination of zinc and copper in fish samples collected from Northeast Atlantic by DPSAV. *Food Chemistry*, 87, 343-347.

[8] Cheung S-H, Kim E-K, Hwang J-W, Kim Y-S, Lee JS, Moon S-H, Jeon B-T, Park P-J. (2013). Purification of a novel peptide derived from a shellfish Crassostrea gigas and evaluation of its anticancer property. J Agric Food Chem 61, 11442–11446

[9] Davies I.C and Jamabo N.A (2016). Determination of Mineral Contents of Edible Parts of Shellfishes from Okpoka Creeks in Rivers State, Nigeria. *International Journal of Fisheries and Aquaculture Research*, 2(2), 10-18

[10] Dridi S, Romdhane M. S, Elcafsi M. (2007). Seasonal variation in weight and biochemical composition of the Pacific oyster (*Crassostrea gigas*) in relation to the gametogenic cycle and environmental conditions of the Bizert lagoon Tunisia. *Aquaculture* 263, 238–248.

[11] Edoghotu A. J., Onwuteaka J., Friday U., A. O. F. Wokoma and F. G. Bob-Manuel. (2015) Heavy metals contamination of the sessile bivalve, *Crassostrea gasar* (mangrove oyster) in post oil spilled brackish water creek of the NigerDelta, Nigeria. *Annals of Biological Research*,6 (11), 72-77

[12] Ehigiator F. A. R. and Akise, O. G.(2016) Proximate, Amino acid and Mineral composition of wild and cultured Fresh water clam(*Egeria radiata) Nigerian Journal of Agriculture, Food and Environment*. 12(2), 103-108

[13] Elmadfa, I., and Meyer, A.L. (2017). Animal Proteins as Important Contributors to a Healthy Human Diet.pp 13-22

[14] Eswar. A., Nanda, R. K., Ramamoorthy, K., Isha, Z.,and Gokulakrishnan, S., (2016) Biochemical Composition and Preliminary Qualitative Analysis of Marine Clam *Gafrarium divaricatum* (Gmelin) From Mumbai, West Coast of India. *Asian Journal of Biomedical and Pharmaceutical Sciences*, 6(55), 1-06.

[15] FAO (2018). Global aquaculture updates. In: FAO aquaculture Newsletter No. 58. Fisheries and aquaculture Department. Rome. Italy 19200EN. (accessed July 6,2018).

[16] Garg, A. N. and Ramakrishna, V. V. S., (2006). Fish as an indicator of aquatic environment: Multielemental neutron activation analysis of nutrient and pollutant elements in fish from Indian coastal areas. *Toxicological and Environmental Chemistry*, 88(19), 125-140.

[17] Gopalsamy, I., Arumagam, M., Saravanan, K. and Thangavel, B. (2014). Nutritional value of Marine Bivalve, *Donax cuneatus* from cuddalore coastal waters, southeast coast of India, *Inventi Impact*1, 15-19.

[18] Gosling, E. (2003). Bivalve Molluscs; Biology, Ecology, and Culture. Black well Publishing Ltd, Grasington Road, Oxford U.K.

[19] Grienke U, Silke J, Tasdemir D. (2014). Bioactive compounds from marine mussels and their effects on human health. *Food Chem* 142, 48–60.

[20] Jennifer, J. O., Jennifer, P.H., and Linda, D. M. (2006). Dietary Reference Intake; The Essential Guide to Nutrient Requirement; *Institute of medicineofNational Academy*, Washington D.C.

[21] Karnjanapratum, S., Benjakul, S., Kishimura, H., and Tsar,V.H. (2013). ChemicalComposition and Nutritional Value of Asian Hard Clam *Meretrix lusoria* from. The Coast of Andaman Sea. *Food Chemistry* 141, 4138–4145

[22] Kiin-kabari, D.B., Hart, A.D., and Nyeche, P.T. (2017). Nutritional Composition of Selected Shellfish Consumed in River State, Nigeria. *American Journal of Food and Nutrition*, 5(4), 142-146.

[23] Kim S-K, Venkatesan J. (2015). Introduction to seafood science. In: Kim SK, editor. *Seafood science*: *Advances in chemistry technology and applications*. Boca Raton, Fla.: CRC Press. p 1–13

[24] Lin, Y-H. Tsai, J-H. Hung, L-B. and Pan, B.S., (2010). Hypocholesterolemic effect of compounded freshwater clam protein hydrolysate and Gracilaria. *Food Chem* 123 (2), 395–399.

[25] Long, S. M, Azizil, F.A., Abdullah, G., and Syahidatul, A. R.(2014). Marine Gastropod and Bivalves of Sampadi Island, Lundu, Sarawak. *Monograph Aquatic Science Colloquium*, pp 75-87.

[26] Lourenço, H.M., Anacleto, P., Afonso, C., Ferraria, V., Martins, M.F., Carvalho, M.L., Lino, A.R., Nunes, M.L. (2009) Elemental composition of cephalopods from Portuguese continental waters.*Food Chemistry*, 113, 1146-1153.

[27] Lourenço, H. M. G., (2011). Essential and Toxic Elements inFish Productsconsumed in Portugal.Doctoral dissertation in Biology presented to the University of Lisboa

[28] Lushenko, M. A., (2010) A Risk Assessment for Ingestion of Toxic Chemicals in Fish from Imperial Beach, California. Master Thesis on Public Health, San Diego State University.

[29] National Academy of Science (2001). Dietary Reference Intake. Retrieved from http://www.nationalacademies.org. 13th June, 2018.

[30] NBS (2017) Nigeria's Fish Production 2010-2015 National Bureau of Statistics. Abuja, Nigeria. Accessed 27 July 2018.

[31] Njie, M. and Drammah, O. (2011). Valve chain of the artisanal oyster harvesting fishery of the Gam Gia, Costal resource centre. University of Rhode Island pp. 74.

[32] Nunes, M. L., Bandarra, N. M., Batista**, I.**, (2003). Fish products: contribution for a healthy food. *Electronic Journal of Environmental Agriculture Food Chemistry*. 1579-4377, 453-457.

[33] Nunes, M. L., Batista, I., Bandarra, N. M., Morais, M. G., Rodrigues**,** P. O., (2008). Produtos da Pesca: Valor nutricional e importância para a saúde e bem-estar dos consumidores. *Publicações Avulsas do IPIMAR*. 18, 1-77.

[34] Onwuka G. I. (2018). *Food Analysis and Instrumentation- Theory and Practice*. 2nd Edition. Naphtali Prints, Somolu Lagos, Nigeria.

[35] Orban, E., Di Lena, G., Nevigato, T., Casini, I., Marzetti, A., Caproni, R.(2002). Seasonal changes in meat content, condition index and chemical composition of mussels (*Mytilus galloprovincialis*) cultured in two different Italian sites. *Food Chemistry*,77(1), 57–65.

[36] Osibona A.O, Kusemiju K and Akande G.R (2006). Proximate Composition and Fatty Acid Profile of African Catfish *Clarias gariepinus. Journal Acta SATECH*. 3, 85-89.

[37] Ozogul F, Kuley E, Ozogul Y. (2015). Sterol content of fish, crustacea and mollusk: effects of cooking methods. *Intl J Food Prop* 18, 2026–2041.

[38] Pawiro, S. (2010). Bivalves: Global production and trade trends. In safe management of shell fish and harvest waters. Edited by G. Recs, K. Ponds, D. Kay, J. Bartram and J. Santo Domingo. World Health Organization (WHO). Published by IWA publishing London, UK.

[39] Picardal, D., Rafael, M., and Roger,G. D. (2014). The Molluscan Fauna (Gastropods and Bivalves) and Notes on Environmental Conditions of Two Adjoining Protected Bays in Puerto Princesa City, Palawan, Philippines. India *Journal of Entomology and Zoology Studies*, 2(5), 72-90.

[40] Sarkar, S. K., Cabral, H. Chatterjee, M. Cardoso, I. Bhattacharya, A., Satpathy, K. K., Alam, and M. A. (2008). Biomonitoring of heavy metals using the bivalve mollusks in Sunderban Mangrove Wetland, Northeast Coast of Bay of Bengal. (India): Possible Risks to Human health.*Clean* 36 (2), 187-194.

[41] Sirichakwal, P. P., Puwastien, P., Polngam, J., Kongkachuichai, R**.**, (2005). Selenium content of Thai foods. *Journal of Food Composition and Analysis*, 18, 47-59.

[42] Venugopal, V. and Gopakumar, K., (2017). Shellfish: Nutritional Value, Health Benefits and Consumer Safety. *Comprehensive Reviews in Food Sc. and Food Safety*. 16:1219-1242.

[43] Venkatesan,V.(2010). Marine Ornamental Molluscs. Procedureof National Training Programme on Marine Ornamental Fish Culture, Mandapam, CMFRI, pp27-32.

[44] Voultsiadou, E., Drosos, K.,and Maria A. (2009). Bivalve Mollusc Exploitation in Mediterranean Coastal Communities: an Historical Approach. *Journal of Biology Research.* 12, 1-11.

[45] Udotong, J. I. R., Udoudo, U. P. and Udotong, I. R. (2017). Effects of oil and gas exploration and production activities on production and management of seafood in Akwa Ibom State, Nigeria. *J of Environmental Chemistry and Ecotoxicology*. 9(3), 20 – 42.