Mineral composition of two Shellfishes from the Nun River, Southern Ijaw LGA, Bayelsa State

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Abstract

Recycling agro wastes is paramount in industrialization to optimize the use of every part of some agricultural produce or natural resources in order to increase utilization of resources for income generation and food/material production. The mineral composition of two shellfish species from lower reach of Nun River was investigated. The flesh and the shells of the crustaceans, Macrobrachium vollenhovenii a prawn and Sersama spp a crab, were analyzed on dry weight basis for calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe) and phosphorus (P). The flesh of the prawn yielded the highest value for calcium at 648.52 (mg/100g) followed by the shell of Sersama at 460.75 mg/100g. The shell of the prawn, M. vollenhovenii yielded less than that of the crab at 311.24 mg/100g while the flesh of the crab yielded the lowest value for calcium at 212.57 mg/100g. In general analysis, calcium was recorded as the element with the highest value across the specimen analyzed (flesh and shells). The hierarchy of the mineral elements in shellfishes was recorded as follows; Ca>Na>K>P>Fe>Mg. Magnesium appeared the least element in the tissues of the shell fishes analyzed.

In addition, both the shell and flesh of the prawn stood out to be very rich in mineral elements and even nutrient richer than the crab while the nutrient content of the shell of the crab was more than its flesh. Ironically, the shells of these crustaceans are easily discarded due to their high content of chitin and non-digestible carbohydrate which makes them unpalatable. However, this study has shown that these shells are rich in mineral elements and should be incorporated in fish and animal feed as conventional feed ingredients in order to contribute in reducing feed ingredient cost and waste.

Keywords: Shellfishes, Nun river, Minerals composition, Crab, Prawn.

Introduction

The reports from food and health organizations have shown that about 2 billion of the world's population, majority of which are the third world countries suffer from mineral and vitamin deficiencies.[19] The adequate provision of these elements to the body via dietary intake aids to avoid nutritional and mineral-based deficiency such as osteoporosis, anaemia, impaired growth, underweight and genetic disorders according to Bhandari and Banjara[10] and Fumio et al.[20] Mitigative measures such as food and nutrition-based strategies are considered sustainable and evaluated for enhancing nutrient intake. Minerals are naturally occurring inorganic substances in plants, animals and in the earth crust. And these essential elements are the biochemical elements required for the normal maintenance of the human body.[24]

The elements include Ca, Mg, Na, K, Fe, Zn, Cu, Mn, etc. which are the main components in several biochemical processes. They are majorly divided into major (macro) and trace (micro) elements. They may be required only in small amounts, but play important role in human and animal body in the regulation of major metabolic pathways.

The absence of any of these elements will hamper normal biochemical activities in both human and animal bodies. Deficiencies can lead to metabolic disorders, organ damage, leading to acute and chronic disease and eventual death. Fluoride, iodine, sodium, zinc, iron, phosphorous, magnesium and sulphur are all readily available in seafood such as fish, prawns and crabs. Selenium, another trace element found in seafood, has become a subject of growing interest because of its properties as an antioxidant.[22]

The world's demand for aquatic source of foods is on the rise not only because of its growing population, but also because of a preference for healthier foods for human.[37] Seafood is easily digestible because it has very little connective tissues and for this reason, fish and shrimps are recommended in many special diets.[37] This resource is accessible to poor and vulnerable communities that are prone to nutrient deficiency diseases.[25]

Edible crustaceans such as prawns/shrimps, crayfish, crabs and lobsters are comprised of major sources of nutritious food. The nutritive value of crustaceans depends on their biological constituents.[15] Such are the proximate components as proteins, carbohydrates, lipids (crude fat) and micronutrients (vitamins and minerals).

Prawns and crabs constitute one of the main sources of animal protein most especially, among coastal dwellers in Nigeria. Literature has shown that these crustaceans have high nutritional composition which are usually consumed either wholly (flesh + shell) or partially by sick people and recommended to pregnant women or recuperating patients.[4,7] Shellfish is excellent for growth and development of human body (and animals) and also aids in the prevention

of several nutritional deficiency diseases when compared to red meat.[6]

Apart from being a delicacy, crustacean species including shrimps, lobsters, crabs etc. contain amino acids, peptides, proteins, macro and micro nutrients.[9] Crabs rank third after shrimps and lobsters for their delicacy and value of fishery they support. They also have exceptional and sumptuous taste as compared to fin fish and molluscs.[15] According to Adeyeye[2], carbohydrates components of prawn and crab are relatively small and as a result of this, they are known to be good sources of mineral elements, fat soluble vitamins and a sumptuous provider of some B vitamins with little or no vitamin C. They are low-fat and protein-rich source of food.

Sodium is required in the body for proper fluid balance, nerve transmission, and muscle contraction. Potassium helps in blood pressure regulation and also functions in acid-base balance, nerve transmission and muscle contraction. Calcium is very important for ensuring healthy teeth and bones, and also functions in muscles toning as well as plays major role in nerve functioning, blood clotting and balanced immune system.

Sulphur is useful in protein synthesis as it is found in the protein molecules. Iron is a major part of hemoglobin found in red blood cells for oxygen transportation in the body and for energy metabolism while manganese is a part of enzymes and also a metal antioxidant that helps in mopping up free radicals to prevent cellular damage.[22]

Therefore, the animal feed should be fortified with good and nutritious feed ingredients such as fish/shellfish meals. Fish meal is known for its richness as protein source. On the other hands, shell fishes which are basically crustaceans and molluscs have hard and calcified exoskeleton which makes them good source of mineral nutrients apart from their primary protein sources.

In addition, the high rate of food wastages, postharvest losses and poor waste recycling should necessitate the need to recycle some of these recyclable agricultural produce such as shells of shellfishes. Fish offal contains beneficial enzymes and the wastes including shells are usually discarded during processing.

This information is important for the animal feed industry owing to their applications in feed formulation and production. Shells of molluscs such as oysters are slightly roasted and used in water treatment to balance pH (treat acidity). Also, the shells of crustaceans such as crabs and prawns can also be collected and processed into meals as mineral sources in feed formulation.

This study therefore aimed to analyze the mineral composition of the Crab, *Sersama spp* and the freshwater prawn *Macrobrachium vollenhovenii* in a comparative analysis to assess the more nutritious species as well as the nutrition status of their shells in order to buttress recommendations for their incorporation in animal feed formulation.

Material and Methods

Study area: The geographic position of the study area was within Ekowe and Ayama communities of the eastern part of Southern Ijaw LGA in Bayelsa State. The coordinates are as follows:

Ayama: N 04^0 52.321'; E 006^0 12.543' with elevation of 4m above sea level
Ekowe: N 04' 42.464'; E 006^0.05.590' with elevation of 4m above sea level
The study was carried out at the Nun River ecosystem within the Local Government Area.

Materials used: Fish scoop nets, fish box, ice block, hand gloves, knives, plastic packs to collect samples, etc. were used during the field work.

Sample collection: Shellfish samples were collected with the help of the fishermen in the fishing camp. They fish using various techniques such as trapping, hooking using baited lines, casting, drift netting, gill netting, and so on. However, trapping is mostly used for these shellfishes. Samples were randomly taken from catches which were submitted to the liaison officers for identification and proper recording.

The prawns and crabs samples were collected directly from fishermen at the landing site located in the Okoungbene fishing camp. Samples were weighed, lengths were taken and specimen collected in duplicate. The carapace of the crustacean samples were extracted while the muscle fillets were taken and transported in cold chain to keep fresh in transit to the Food Science and Technology laboratory of the Rivers State University of Science and Technology.

Mineralogical test: The shellfish tissue samples were analyzed for calcium, magnesium, potassium, sodium, iron and phosphorous (Ca, Mg, K, Na, P and Fe mineral elements) using method recommended by AOAC[8]. Atomic absorption spectrometer was used for the metals while the ultraviolet spectrophotometric method was used for the phosphorous. The concentrations of the mineral elements were interpreted using the World Health Organization[40] and American National Institute of Health (NIH) Recommended Dietary Intake Model.

Data analysis: The raw data obtained after the mineral analysis on wet weight were analyzed statistically using SPSS to determine the significant differences among the flesh and shells of the shellfish species. Duncan multiple range test was used to separate the means. Values with the same superscript within the same row showed no significant differences while those with different superscript within the same row are significantly different.

Results

The flesh and the shells of *Macrobrachium vollenhovenii* and *Sersama spp* were analyzed for calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe) and phosphorus (P). There were significant differences among the means. The flesh of the prawn yielded the highest value for calcium at 648.52 (mg/100g) followed by the shell of *Sersama* at 460.75 mg/100g. The shell of the prawn *M. vollenhovenii* yielded 311.24 mg/100g while flesh of the crab was 212.57 mg/100g.

For potassium, the value for the flesh of the prawn was 95.17 mg/100g which was the highest followed by the shell at 72.33 mg/100g. 67.99 mg/100g was recorded for the flesh of the crab and 22.10 mg/100g for the shell.

Table 1
Mineral Composition of two Shellfish Species on dry weight basis

PARAMETER	FISH SPECIES					
	Macrobrachium vollenhovenii shell	*Macrobrachium vollenhovenii* flesh	*Sesarma spp* shell	*Sesarma spp* flesh	SEM	LOS
Ca (mg/100g)	311.24^{c}	648.52^{a}	460.75^{b}	212.57^{d}	62.16	*
K (mg/100g)	95.17^{a}	72.33^{b}	67.99^{b}	22.10^{c}	10.02	*
Mg (mg/100g)	6.94^{b}	8.07^{a}	6.22^{b}	1.83^{c}	0.90	*
Na (mg/100g)	134.38^{a}	121.55^{a}	79.69^{b}	4.85^{c}	19.11	*
Fe (mg/100g)	13.95^{a}	12.87^{a}	11.87^{a}	3.43^{b}	1.57	*
P (mg/100g)	49.00^{a}	49.60^{a}	43.27^{a}	13.75^{b}	5.57	*

LOS= Level of Significance
SEM= Standard Error Mean
*= significant
abcd= significant difference among the species means

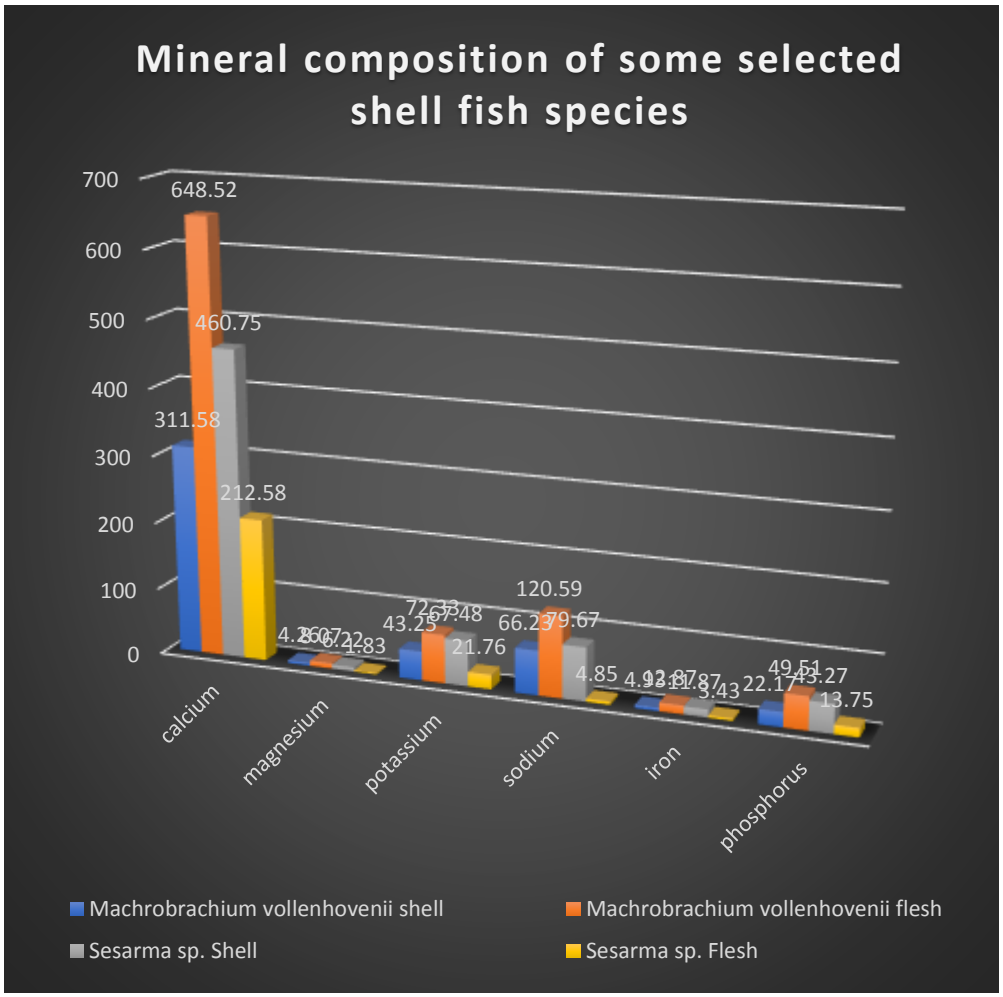

Figure 1: Graphical representation of two shell fishes analyzed for some micro-nutrients

Magnesium had the lowest value of all the mineral elements analyzed (Fig. 2). 8.07 mg/100g was recorded for the prawn shell which came out the highest value. The flesh of the prawn yielded 6.94 mg/100g while the crab flesh and shell yielded 6.22 mg/100g and 1.83 mg/100g respectively which are lower than the values recorded for the freshwater prawn analyzed.

Sodium emerged the second mineral element with the highest value recorded in this research. *M. vollenhovenii* had the highest Na value at 134.38 and 121.55 for flesh and shell respectively followed by *Sersama* flesh at 79.69 and the shell had the least yield at 4.85 mg/100g. Iron was 13.95, 12.87, 11.87 and 3.43 mg/100g for the prawn flesh (which is the highest), prawn shell, crab flesh and shell respectively. In the same vein, the result for phosphorus is as follows: 49.60 which is the highest value for phosphorous recorded for prawn shell, 49.00 for prawn flesh, 43.27 and 13.75 mg/100g for crab shell and flesh respectively.

Discussion

In general analysis, calcium had the highest value in mg/100g recorded in this study while magnesium values were very low for the shell fishes assessed. It was observed that the prawn recorded higher mineral values among the elements analyzed than the crab. Again, the shell of these shellfishes presented high values of the elements even better than the flesh in some elements.

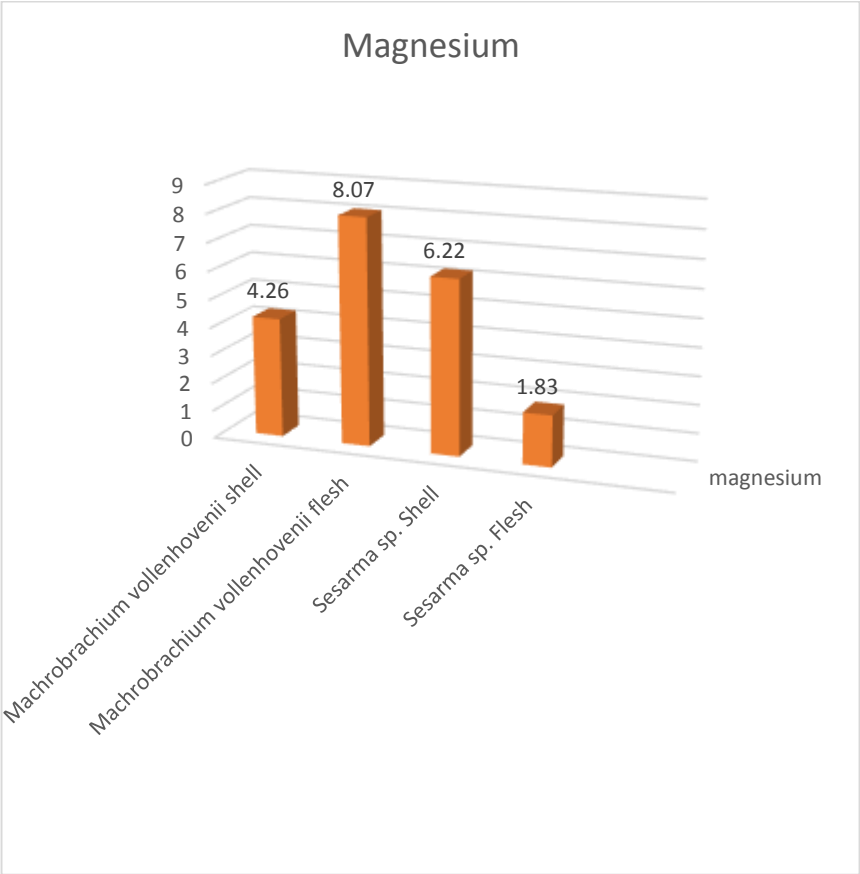

Figure 2: Concentration of magnesium in the two shellfishes

Table 2
Comparative analysis of values of some macronutrients determined in the shellfishes with the recommended daily intake ranging from children to adult[26,28,40]

S.N.	Mineral Element	Range value In the Prawn (mg/100g)	Range value In the Crab (mg/100g)	Recommended Daily Intake (RDI)
1.	Calcium (Ca)	311.24 - 648.52	212.57 - 460.75	200 – 1300 mg
2.	Potassium (K)	72.33 - 95.7	22.10 - 67.99	3500 – 4700 mg
3.	Magnesium (Mg)	6.94 - 8.07	1.83 - 6.22	80 – 420 mg
4.	Sodium (Na)	121.55 - 134.38	4.85 - 79.69	< 2300 mg
5.	Iron (Fe)	12.87 - 13.95	3.43 - 11.87	13.7 – 20.5 mg
6.	Phosphorous (P)	49.00 - 49.60	13.75 - 43.27	1189 – 1596 mg

This shows that the shells of these shellfishes should not be discarded after processing, but should be recycled in production processes to create values for them and improve utilization for possible product development from them.

Generally, the flesh of fish (and shellfish) is rich in both macro and micro elements such as calcium, magnesium, potassium, sodium, phosphorus, zinc, iron, iodine and manganese.[14,25] This agrees with this study that assessed and confirmed the presence of some of these nutrients in the flesh and shells of the shell fishes (crab and prawn).

Meeting up with calcium requirement according to WHO[40] is majorly from dairy products, however, the findings in this study have shown that calcium consumption is highly accessible by the consumption of these shell fishes; both muscle and shell for humans and animals. The benefits of these nutrients in the proper functioning of human and animal body cannot be overemphasized. Since the deficiencies of these elements could lead to high incidence of disease infections due to poor immune system, anaemia, poor fetal development, retarded growth and poor body development in farm animals[39], there is the need to access cheaper and more available feed ingredients to ensure high quality feed for animals and food for man. Note that the quality of a food product is a reflection of the presence of essential mineral in that food product.[23]

Ehigiator and Oterai[17] reported mineral composition of *M. vollenhovenii* in Ovia river, Edo State for calcium, magnesium and phosphorous to be 47.64, 20.80 and 106.71 mg/100 g for flesh and 52.00, 20.48 and 100.81 mg/100 g respectively for the shell. This reveals higher content of phosphorous than calcium and magnesium. On the contrary, this study in Nun River, Bayelsa State revealed higher calcium than phosphorous with magnesium as low as 1.83 – 8.04 mg/100g and also, higher calcium values for Nun River than in Ovia River. Another analysis revealed that iron and magnesium recorded higher amounts than calcium, potassium and sodium[17] which is the reverse case of the Nun River study which recorded iron and magnesium as the lowest.

However, the high iron content in *M. vollenhovenii* from Ovia River at 40.44 in shell and 22.91 mg/100g exceeds the RDI for humans (Table 2) which means the river could be iron polluted and may pose risk to consumers. For Nun River, no iron toxicity was recorded in the reports making it a healthier ecosystem. This shows that these elements are environmentally dependent as well as nutritionally based.[33]

For the crabs, Udo and Arazu[39] confirmed that crabs are the prominent sources of essential macro and micro elements. The investigation of mineral composition of the freshwater crab *Paratelphusa lamellifrons* from the river Padma near Rajshahi city of Bangladesh was conducted by Islam et al.[23] Report showed that phosphorous was highest at a range of 6539.21-7729.15 mg/kg (equivalent to 653.921 – 772.915 mg/100g) followed by calcium at 5385.87-5640.81 mg/kg, potassium at 1037.03-1192.79 mg/kg and Iron at 423.22-487.03 mg/kg.

Iron came out the least in this study by Islam et al[23] in Bangledash, so also, iron was recorded very low in this study in both prawn and crab from Nun River Ekowe, Nigeria. This shows that iron occurs low in natural organisms although highly required in blood formation and transportation in the animal system. Excess concentration of this trace element could lead to iron toxicity. Iron content of 423.22 – 487.03 (= 42.32 – 48.70 mg/100g) already exceeded RDI of 13.7 – 20.5 mg per day (Table 2).

Soundarapandian et al[36] also reported about minerals which occurred in the order Na>K>Mg>Ca>Fe. Iron was also the minimum in the study at average value of 4.95 mg/day making it safe for consumption. Fagbuaro et al[18] also reported mineral analysis in crab, *S. africanus* in Ifaki-Ekiti, Ekiti State. The nutrient composition occurred in the order, P>Ca>Mg>K>Na>Fe in the crab shell at 237.03, 22.15, 21.65, 20.33, 18.10 and 8.36 respectively all in mg/100g. The flesh recorded the values for P>K>Mg>Na>Ca>Fe at 170.11, 35.21, 30.20, 30.14, 23.52 and 12.30 mg/100g respectively. Iron was also the least in both flesh and shell and at healthy rates, however, magnesium was higher than calcium in the flesh and also higher than sodium and potassium in the shell.

This means that magnesium may be more abundant in the Oniyo River, Ifaki-Ekiti than in the Nun River, Bayelsa State. It has been established that the environmental factors such as soil/sediment and water quality and also feed composition determine the concentration or composition of these elements in the fish body. In other words, changes in the dietary composition and/or mineral concentration of culture water could impact on the mineral balance in fish[33]. From these authors, varying reports on composition have been confirmed. However, the values will be compared in the light of the standard legal limits for these shell fishes for the safety of consumers.

Iron is a trace element required in smaller quantities. From Table 2, the values from this study showed that the shells of the two crustaceans contain more iron than the flesh. The shell of the prawn from the table exceeded the lower limit of the RDI. That means, the consumption of these shell fishes should be moderate to avoid iron toxicity especially in children. The other mineral elements fell below the legal limits; however, the nutrient requirements for healthy body development can be obtained from other food/feed ingredients.

Hence, the place of feed formulation and balanced diets is high even in humans. In addition, the Nun river shell fish species is close to getting contaminated by the iron in the environment. Studies by Okogbue et al[29] revealed that the lower reach of the Nun River exceeds the legal limits of 1

mg/L (WHO) for iron content in surface waters where values as high as 6.5 mg/L was recorded during the rains.

In other words, the iron content in the shellfishes could exceed the legal limits since they have great capacity to bio-accumulate and concentrate metals in their system. Hence, this report. On the other hand, Calcium is highly recommended for both young and old especially, growing children, the aged, pregnant and lactating mothers. From the table, it is clear that a serving of 200g of prawn will supply the maximum limit (1300 mg/day) required for that category of humans. Also, in farm animals, this is also required during gestation and lactating periods.

In aquatic organisms, this element is also required for fish and shellfishes for proper growth and body development especially, during molting in prawns. Therefore, prawns in diets can actually displace dairy products for healthier living since it has been established that calcium consumption will be difficult without the dairy products[12]. This study on shellfish has shown that they are rich in mineral elements while other authors emphasized their richness in diverse nutrients such as protein, omega 3 fafty acids, antioxidants, etc. Freshwater crabs have been reported to be consumed for evidence-based medicinal properties, such as for treatment of stomach ailments and physical injuries[8].

Faguaro et al[18] established that crabs contain Omega 3-polyunsaturated fatty acids and other valuable essential foods such as protein, carbohydrate, ash, and energy[12] possessing less calories than other meat sources such as beef, pork and poultry. Prawns are also healthy category of seafood because they are low in fat and calories but rich in protein, antioxidants (astaxanthin, selenium element, Vit. E), micronutrients (phosphorous, calcium, potassium, vitamin B12) and healthy omega-3 fatty acids[35]. The astaxanthin is a carotenoid antioxidant (that gives prawn its red colouration when boiled) richly abundant in the head, fillet and shell of prawns[21]. This study supports the assertion that they are rich in micro and macro elements.

Accessing seafood such as prawns and crabs will help less privileged fishing communities attain their protein and nutrient daily requirements[13], Adeyeye et al[1] and Adeyeye[2], emphasized that studies like this will help create awareness concerning the nutritional value of shellfish for human consumption as food supplement and also suitable alternative for fish meal in animal production[18].

Since the shells of these aquatic organisms are not ususally consumed by humans due to its chitin content, they are used in the formulation of animal feed. Roasting enhances the digestibility of these chitin rich ingredients to make the elements available for body utilization.

These crustaceans are in abundance and so should be optimally utilized with their wastes recycled in order to make most use of these natural resources.

Conclusion

The flesh of *M. vollenhoveli* yielded relatively higher values for analyzed mineral elements than that of the *Seserma sp*. The shell of the crab recorded higher calcium than that of the prawn while all other mineral elements occurred at higher concentrations in the prawn shell. Prawn has been reported to be the most nutritious of the shell fishes followed by lobster and thirdly, the crab. This comparative study with the crab has buttressed this assertion. This research is aimed to help promote the nutritive value of shellfish generally to make it gain enormous relevance.

This will contribute to database development for nutrition education and awareness. These shellfishes will supply the daily nutrient intake for both humans and animals and so should be optimally used with little or no wastes generated since the offal and shells could be processed and incorporated into animal feed as mineral sources.

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References

1. Adeyeye E.I., Olanlokun J.O. and Falodun T.O., Proximate and mineral composition of wholebody, flesh and exoskeleton of male and female common West African freshwater crab *Sudananautes africanus africanus*, *Polish J. Food Nutr. Sci.*, **60(3)**, 213-216 **(2010)**

2. Adeyeye E.I., Determination of the chemical composition of the nutritionally valuable parts of male and female common West African fresh water crab *Sudananautes africanus africanus*, *Int. J. Food* Sci. *Nutr*., **53**, 189-196 **(2002)**

3. Adeyeye E.I., Adubiaro H.O. and Awodola J.O., Comparability of chemical composition and functional properties of shell and flesh of Penaeus *notabilis*, *Pak. J. Nutr*., **7**, 741- 747 **(2008)**

4. Adeyeye E.I. and Kenni A.M., The Relationship in the Amino Acid of the Whole Body, Flesh and Exoskeleton of Common West African Fresh Water Male Crab Sudananautes *africanus africanus*, *Pakistan Journal of Nutrition*, **7**, 748-752 **(2008)**

5. Awate Annapurna, Pawar Ashok, Ramchandra B. and Girish M.H., Age Related Estimation of Physical and Chemical Properties of Pelvic Long Bones in Kenguri Sheep, *International Journal of Agricultural Sciences and Veterinary Medicine*, **8(2)**, 6-8 **(2020)**

6. Agusa T., Kunito T., Sudaryanto A., Monirith I., KanAtireklap S., Iwata H., Ismail A., Sanguansin J., Muchtar M., Tana T.S. and Tanabe S., Exposure assessment for trace elements from consumption of marine fish in Southeast Asia, *Environmental Pollution*, **145**, 766-777 **(2007)**

7. Akin-Oriola A., Anetekhai M.A. and Olowonirejuaro K., Morphometric and Meristic Studies in Two Crabs: Cardiosoma armatum and Callinectes pallidus, *Turkish Journal of Fisheries and Aquatic Sciences*, **5**, 85-89 **(2005)**

8. AOAC, Official methods of analysis of the association of official's analytical chemists, 17th ed., Association of official analytical chemists, Arlington, Virginia **(2003)**

9. Binsan W., Benjakul S., Visessanguan W., Roytrakul S., Tanaka M. and Kishimura H., Antioxidative activity of Mungoong, an extract paste, from the cephalothorax of white shrimp (Litopenaeus vannamei), *Food Chem.*, **106**, 185–193 **(2008)**

10. Bhandari S. and Banjara M.R., Micronutrients Deficiency, a Hidden Hunger in Nepal: Prevalence, Causes, Consequences and Solutions, *Int. Sch. Res. Notices*, Doi:10.1155/2015/276469 **(2015)**

11. Bothwell T.H., Charlton R.W., Cook J.D. and Finch C.A., Iron metabolism in man, Oxford, Blackwell Scientific **(1979)**

12. Broughton K., Johnson C.S., Peace B.K., Liebman M. and Kleppinger K.M., Reduced asthma symptoms with n-3 fatty acid ingestion are related to 5-series Leukotriene production, *Am. J. Clin. Nutri*., **65**, 1011-1017 **(1997)**

13. Carter A. and Chung H.Y., Volatile components in crab meals of Charybdis feriatus, *J. Agric. Food Chem.*, **4**, 2280- 2288 **(1999)**

14. Dana J.D., Hurlbut C.S. and Klein C., Manual of Mineralogy, 2nd ed., New York, US, John Wiley and Sons Inc. **(1985)**

15. Dubois M., Giller K.A., Hamilton J.K., Roberts R.A. and Smith F., Colorimetric method for determination of sugars and related substances, *Analyt. Chem*., **28**, 350-356 **(1956)**

16. Ehigiator F.A.R. and Oterai E.A., Chemical Composition and Amino Acid Profile of a Caridean Prawn (*Macrobrachium vollenhovenii*) from Ovia River and Tropical Periwinkle (*Tympanotonus Fuscatus*) from Benin River, Edo State, Nigeria, *IJRRAS*, **11(1)**, 1-18 **(2012)**

17. Ehigiator F.A.R. and Akise O.G., Proximate Composition, Macro and Trace Mineral Compositions of Different Body Parts of *Macrobrachium vollenhovenii* from Ovia River in Edo State, Nigeria, *Tropical Freshwater Biology*, **22**, 1-11 **(2013)**

18. Fagbuaro O., Majolagbe F.A. and Oso J.A., Proximate Composition and Mineral Content of the Land Crab *Sudanonautes africanus*, *Journal of Scientific Research & Reports*, **3(2)**, 349-355 **(2014)**

19. FAO/WHO, Human Vitamin and Mineral Requirements, Rome: FAO, Report of joint Food and Agricultural Organizations of the United Nations, World Health Organization **(2001)**

20. Fumio K., Yasuo K., Terue K., Yoshimori K., Hideki K., Baatar P., Judger O. and Ulziburen C., Influence of essential trace minerals and micronutrient insufficiencies on harmful metal overload in a Mongolian patient with multiple sclerosis, *Curr. Aging Sci.*, **5**, 115-125 **(2012)**

21. Giselda M.L. Ana M.Q.L., Guilherme O.F., Santos S.D. and Ranilson de Souza B., Total Caroteinoids and anti-oxidant activity of fillets and shells (in natura or cooked) of "Vila Franca" (*Litopnaeus schmitti*) in different intervals of storage under freezing, *Ciencia e Agrotecnologia*, **41(1)**, 94 – 103 **(2017)**

22. Husney A., Anti-oxidants, Michigan medicine retrieved from www.uofmhealth.org **(2019)**

23. Islam Badrul, Md. Bokul Mia, Md. Abdur Razzaque, Md. Moniruzzaman Sarker, Md. Redwanur Rahman, Md. Abdul Jalil, Md. Abdur Rahim and Dalim Kumar Roy, Investigation on mineral composition of freshwater crab (*Paratelphusa lamellifrons*) of Padma River near Rajshahi City, *Bangladesh International Journal of Fisheries and Aquatic Studies*, **4(6)**, 236-240 **(2016)**

24. Jiang J., Lu S., Zhang H., Liu G., Lin K., Huang W., Luo R., Zhang X., Tang C. and Yu Y., Dietary intake of human essential elements from a Total Diet Study in Shenzhen, Guangdong Province, China, *J Food Compos Anal.*, **39**, 1-7 **(2015)**

25. Mogobe O., Mosepele K. and Masamba W.R.L., Essential mineral content of common fish species in Chanoga, Okavango Delta, Botswana, *African Journal of. Food Science*, **9(9)**, 480-486, DOI: 10.5897/AJFS2015.1307 **(2015)**

26. NAS, Dietary reference intake for vitamin A Vitamin K, As, B, Cr, Cu, I. Fe, Mn, Mo, Ni, Si, Va and Zn: A Report of the Panel on Micronutrients. National Institute of Medicine, Food and Nutrition Board, Washington DC, National Academies Press (US), Iron **(2001)**

27. NIH, Dietary Supplement Fact Sheet on Phosphorous, National Institute of Health, Office of Dietary Supplement, Bethesda, MD, USA, www.ods.od.nih.gov **(2020)**

28. NIH, Dietary reference intake for Calcium, Phosphorous, Magnesium, Vitamin D and Floride, Institute of Medicine, Food and Nutrition Board, Washington DC, National Academies Press (US) **(2007)**

29. Okogbue B.C., Seiyaboh E.I., Ansa E.J., Ofunama P., Okocha B.I. and Omovwohwovie E.E., Heavy Metal Analysis of Nun River, Ekowe, Bayelsa State. Paper presented at the 32nd National Conference of the Fisheries Society of Nigeria (FISON) at Nnamdi Aizkiwe Univ., Awka, Anambra State in October **(2017)**

30. Okogbue B.C., Ansa E.J. and Hart A.I., Impact of Calcium Carbonate on the Juveniles of the Brackish River Prawn, *Macrobrachium Macrobrachion* (Herklot, 1851) under laboratory conditions, *Journal of Fisheries and Aquatic Sciences*, **9(4)**, 281 – 284 **(2014)**

31. Okogbue B.C., Morphology of some body organs of juvenile river prawns *macrobrachium macrobrachion*) exposed to hydrated lime under laboratory condition, *Journal of Aquatic Sciences*, **30(1A)**, 17-2 **(2015)**

32. Okogbue B.C., Afolabi J.T. and Tarfa L.S., Post-Harvest Technology, Chapter twenty-five, In Integrated Culture Fisheries: Agrosilviaqua culture Manual & Workbook, University of Port Harcourt Press, Port Harcourt Rivers State, 254 – 260 **(2020)**

33. Prabhu A.J., Minerals in fish: does the source matter? A Thesis submitted in fulfilment of the requirements for the degree of doctor at Wageningen University by the authority of the Rector Magnificus Prof. Dr A.P.J. Mol, in the presence of the Thesis Committee appointed by the Academic Board on the 12th of October 2015, 1-267 **(2015)**

34. Romitto Kathleen and O'Brien Rhonda, Minerals: Their Functions and Sources, University of Michigan Health System, Michigan Medicine, Retrieved from https://www.uofmhealth.org/health-library/ta3912 **(2019)**

35. Siddhi C.L., Do prawns make a health meal, Livestrong.com **(2019)**

36. Soundarapandian P., Varadharajan D. and Sivasubramanian C., Mineral Composition of Edible Crab, *Charybdis Natator* Herbst (Crustacea: Decapoda), *Journal of Bioanalysis and Biomedicine*, **5**, 099-101, doi:10.4172/1948-593X.1000088 **(2013)**

37. Ssyed Raffic Ali, Ramachandran M., Satyo Kumar Chakma and Asrar Sheriff M., Proximate composition of commercially important marine fishes and shrimps from the Chennai coast, India, *International Journal of Fisheries and Aquatic Studies*, **5(5)**, 113-119 **(2017)**

38. Tsegay Teame, Natarajan P. and Tesfay Zelealem, Proximate and mineral composition of some commercially important fish species of tekeze reservoir and lake Hashenge, Ethiopia, *International Journal of Fisheries and Aquatic Studies*, **4(1)**, 160-164 **(2016)**

39. Udo P.J. and Arazu V.N., The Proximate and Mineral Composition of Two Edible Crabs *Callinectes amnicolaand* Uca tangeri (Crustecea: Decapoda) of The Cross River, Nigeria, *Pak J Nutr*., **11(1)**, 78-82 **(2012)**

40. WHO, Guideline: Potassium intake for adults and children, Geneva, World Health Organization (WHO) **(2012)**

41. WHO, Vitamins and mineral requirements in human nutrition, Second edition, FAO/WHO Expert Joint Consultation on Human Vitamin and Mineral Requirements, Bangkok, Thailand, World Health Organization and Food & Agriculture Organization of the United Nations **(2004)**.

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