



Mineral contents of tissues and body fluids and heavy metal contaminants of four predominant snail species in the Niger Delta

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Abstract

Mineral contents and heavy metal contaminants of four predominant snail species in the Niger Delta: African giant land snail (*Archachatina marginata*), African land snail (*Achatina fulica*), water snail (*Pila ovata*) and garden snail (*Limicolaria aurora*) were evaluated. Snail tissues and body fluids were harvested having cracked the tail-end of the shell. Triplicate samples of macerated snail tissues and body fluids were separately digested and extracts evaluated for contents of K, Na, Ca, Mg, Zn, Fe and P. The contributions of mineral elements in snail tissues to daily recommended dietary allowances (RDA) for adult males and females were assessed and the results discussed. Contents of Cu, Pb, Cd, Hg and Cr in the tissues as heavy metal contaminants were analysed and compared with Federal Environmental Protection Agency (FEPA) specifications for metals in foods. The ranges of K, Na and Ca contents of snail tissues were 40.4-61.7, 19.3-93.2 and 44.6-530.9 µg/g, respectively. Similarly Mg, Zn and Fe ranges of snail tissues were 45.6-87.5, 0.7-6.6 and 3.5-34.9 µg/g, respectively. Significant (P<0.05) species differences were observed in the mineral contents of the snail tissues and body fluids. Higher concentrations of K were recorded in the tissues of *P. ovata*, *A. fulica* and *L. aurora* than in *A. marginata*. *L. aurora* tissues had significantly (P ≤ 0.05) higher Ca, Mg and Zn than other snail tissues. Mineral contents of body fluids followed the trends of distribution in the snail tissues. *L. aurora* had the highest contribution of Ca (13.3/13.3%), Mg (5.46/7.10%) and Zn (15.0/20.6%) to the RDA for adult males and females, respectively. *A. fulica*, *P. ovata* and *L. aurora* had mean contributions of K 0.3% while *P. ovata* had the highest contribution of Fe 109.1% and Na 4.7% to the RDA for adult males and females. Generally, Cu, Pb, Cd, Hg and Cr were accumulated at levels lower than the World Health Organisation (WHO) and Federal Environmental Protection Agency (FEPA), Nigeria, specifications for metals in foods.

Key words: Snails, minerals, tissues, body fluids, heavy metals.

Introduction

Snails are found in most regions of the humid tropics in fresh water, marine and terrestrial environments. Most of them are herbivores feeding on green vegetation including fruits and vegetables on farms, although a few land species and many marine species may be omnivores or carnivores¹. In Nigeria, land snail habitat ranges from the dense tropical high rainfall forest region of the south to the fringing riparian forests of the derived Guinea savannah². The land snails are non-conventional wildlife protein source in Nigeria and some parts of Africa³. According to Umoh and Bassir⁴ and Mba⁵, the protein contents and chemical score of the molluscs are better than the values for egg and the FAO/WHO⁶ provisional pattern.

Significantly high levels of Na, K, Zn and Cl had been reported⁷ in land snails fed urea while low contents of Mg and Cl were reported in the tissues of snails fed on poultry droppings. Although snail meat (popularly known as 'congo meat') is a delicacy among the Efiks, Itsekiris and Ijaws⁸⁻¹¹, it could possibly be a source of heavy metal poisoning, especially when snails are picked from contaminated environments. Land snails, because of their mode of feeding and unique habitat in the Niger Delta where

the activities of oil prospecting companies result in oil spillages and emission of petroleum hydrocarbons discharged from gas flaring, could be contaminated with heavy metals. The petroleum fractions discharged from gas flaring precipitate with rain and along with oil spill contaminate the environment and eventually enter the food chain¹². Heavy metals such as Cu, Zn, Pb, Hg, Al, Cr and Cd are normal constituents of marine environment, and traces are always found in marine organisms¹³. Thus, people who eat large amounts of fish or shellfish and molluscs from estuarine or coastal areas that are associated with chemical industry or vegetables, fruits and even snails, from oil polluted soils are at risk of heavy metal poisoning¹⁴.

The present study was undertaken to comparatively evaluate the contents of minerals in the tissues and body fluids and heavy metal contaminants in four predominant snail species in the Niger Delta.

Material and Methods

Sample source and preparation: Samples (400 g each) of four species of common snails in the Niger Delta: African giant land

snail (*Archachatina marginata*), African land snail (*Achatina fulica*), water snail (*Pila ovata*) and garden snail (*Limicolaria aurora*) were purchased from farmers that collected them from bushes, farmlands and mangrove swamps near the International Institute of Tropical Agriculture (IITA), High Rainfall Station, Onne, Nigeria (Table 1).

Shells of snails selected for analysis were moistened with soapy water, washed and wiped clean prior to cracking of tails to extract body fluids. The remaining shells were gently cracked to prevent damage to tissues. Extracted tissues were eviscerated, washed in warm water for ease of removal of mucus and weighed. Mean fresh weight of edible tissues of three samples of each of *A. marginata*, *A. fulica*, *P. ovata* and *L. aurora* were 71.63, 34.70, 28.45 and 4.10 g, respectively. Triplicate samples of snail tissues (30.0 g) from each species was cut and chopped into tiny pieces and ground using a laboratory pestle and mortar. Samples of ground snail meat were packed in low-density polyethylene (LDPE) bags and refrigerated for further analysis. Body fluids were filtered through double layers of cheese cloth to remove debris. Triplicate samples (10 ml) from each species were withdrawn into a screw cap bottle and held refrigerated.

Minerals and heavy metal analyses: Potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), zinc (Zn), iron (Fe) and phosphorus (P) in snail tissues and body fluid were the elements analysed in this study. Similarly, presence of heavy metals such as copper (Cu), mercury (Hg), lead (Pb) and chromium (Cr) as contaminants in snail tissues and body fluids were also evaluated. Samples were digested following the procedures described by Onwuka¹⁵. Briefly, samples (1.0 g each) of ground meat were digested with 10 ml concentrated nitric acid (HNO₃) and 2 ml perchloric acid (HClO₄) and heated until white fumes of perchloric acid formed and about 1.5 ml or 2 ml of liquid remained. The flask was cooled, 5 ml deionised distilled water was added and heated to dissolve precipitates. The digested samples were cooled and diluted to 50 ml with deionised distilled water and stored until analysed for mineral contents. Samples (5 ml) of the snail blood were also treated with conc. HNO₃ and HClO₄ as described above and made up to 50 ml mark in a standard flask.

Phosphorus contents of snail tissues and blood were determined by the phosphomolybdate method of Yuen and Pollard¹⁶. Other mineral elements investigated were determined spectrophotometrically on the Buck Scientific Atomic Absorption/Emission Spectrophotometer, Model 205, England.

Daily recommended dietary allowances (RDA) from nutrient minerals determined in snail tissues were estimated with reference tables³⁶.

Statistical analysis: A completely randomised design as described by Wahua¹⁷ was used in the study. Analysis of variance was applied to data and Duncan's New Multiple Range Test used to locate differences among means. Analyses were conducted by a SAS computer programme using Version 9.1 SAS (2003) software package.

Results and Discussion

Data in Table 1 give the common and scientific names as well as the habitat of the snails studied. *Archachatina marginata* and *Achatina fulica* are the common snail species in the bushes/forests of Niger Delta. They inhabit most regions of the humid tropics, especially on farmlands and gardens, where they act as pests on crops and on manure heaps and wetlands. *Pila ovata* prefers aquatic environments where lodges on raffia palms, bark of trees and aquatic plants. Garden snails, *Limicolaria aurora*, act as pests on plants while other land snails migrate on land, inhabit dead woods and climb walls. According to Deekae and Idoniboye-Obu⁹, there are numerous snails in the vast mangrove of the Niger Delta but only a few reports¹⁸ on their ecology and distribution have been made. These workers collected large numbers of *A. fulica* on the floors of humid thick forests and fresh water areas of the Niger Delta. Similarly, they reported huge populations of *A. marginata* and *L. aurora* at dump sites on leaf litter, dead woods, growing trees and on farms at Iwofe, Aluu and Ogbogoro near Port Harcourt and at Dawer Island, Opudakiri and Bonny.

Table 2 contains data on the mineral contents of snail tissues and body fluids. Significant ($P \leq 0.05$) species differences were observed in the K, Na, Ca, Mg, Zn and Fe contents of snail tissues and body fluids. The ranges of K, Na and Ca contents of the snail tissues were 40.4-61.7, 19.3-93.2 and 44.6-530.9 $\mu\text{g/g}$, respectively. Similarly, the Mg, Zn and Fe contents of the snail tissues were 45.6-87.5, 0.7-6.6 and 3.5-34.9 $\mu\text{g/g}$, respectively, while the P contents of snail tissues were below detection level (< 0.01). Significantly ($P \leq 0.05$) higher contents of K were recorded in the tissues of *P. ovata* and *A. fulica* than in *A. marginata* and *L. aurora*. *P. ovata* tissues also had significantly ($P \leq 0.05$) higher contents of Na and Fe than *A. marginata*, *A. fulica* and *L. aurora* tissues. *L. aurora* tissues had significantly ($P \leq 0.05$) higher Ca, Mg and Zn contents than other snail tissues. No significant differences ($P > 0.05$) were observed in the Zn contents of *A. fulica* and *L. aurora* tissues. The Zn and Fe contents of the snail tissues were generally low.

Mineral contents of the body fluids followed the trend of distribution in the snail tissues. Significant ($P \leq 0.05$) species differences were observed alongside low contents of Zn and Fe. *L. aurora* body fluid had significantly ($P \leq 0.05$) higher contents of K, Ca, Mg Zn and Fe than other snail body fluids. No significant difference ($P > 0.05$) was observed in the K and Mg contents of *A. marginata*, *A. fulica*, *P. ovata* and *L. aurora* body fluids.

Table 1. Common / scientific names and habitat of snails studied.

Common name	Scientific name	Habitat
African giant land snail	<i>Archachatina marginata</i>	Most regions of the humid tropics, dead wood, leaf litter, clays, mud and gardens
African land snail	<i>Achatina fulica</i>	Most regions of the humid tropics; agricultural areas; natural forest, planted forest; riparian zones; shrub lands; urban areas, wetlands
Water snail	<i>Pila ovata</i>	Fresh water swamp; raffia palms, tree barks and leafy vegetation in streams
Garden snail	<i>Limicolaria aurora</i>	Leafy vegetation, fruits, manure, garden plants

Table 2. Mineral contents ($\mu\text{g/g}$) of snail tissues/ body fluids.

	K	Na	Ca	Mg	Zn	Fe	P
Snail tissues							
<i>A. marginata</i>	40.4 ^a ±0.1	19.3 ^d ±0.1	44.6 ^d ±0.1	52.9 ^e ±0.2	0.7 ^d ±0.1	3.5 ^c ±0.1	<0.01
<i>A. fulica</i>	61.4 ^a ±0.1	47.2 ^b ±0.2	139.6 ^b ±0.1	63.4 ^b ±0.1	3.9 ^b ±0.2	4.2 ^b ±0.1	<0.01
<i>P. ovata</i>	61.7 ^a ±0.2	93.2 ^a ±0.2	102.3 ^c ±0.2	45.6 ^d ±0.2	1.5 ^c ±0.01	34.9 ^a ±0.2	<0.01
<i>L. aurora</i>	59.1 ^b ±0.2	37.9 ^c ±0.2	530.9 ^a ±0.2	87.5 ^a ±0.2	6.6 ^a ±0.1	4.1 ^b ±0.1	<0.01
Body fluids							
<i>A. marginata</i>	23.9 ^b ±0.1	56.5 ^a ±0.1	16.9 ^c ±0.2	12.3 ^b ±0.1	0.4 ^b ±0.01	1.0 ^b ±0.01	<0.01
<i>A. fulica</i>	20.5 ^c ±0.1	42.8 ^c ±0.9	42.2 ^b ±0.2	8.2 ^c ±0.1	0.3 ^b ±0.01	0.3 ^c ±0.01	<0.01
<i>P. ovata</i>	15.6 ^d ±0.1	43.9 ^b ±0.1	4.5 ^d ±0.1	3.5 ^d ±0.1	0.3 ^b ±0.01	0.2 ^c ±0.01	<0.01
<i>L. aurora</i>	40.5 ^a ±0.1	13.3 ^d ±0.1	193.1 ^a ±0.2	439.5 ^a ±0.1	5.3 ^a ±0.1	10.5 ^c ±0.1	<0.02

Based on fresh weight of samples. Values are means \pm S.D of triplicate analysis estimated by Duncan's New Multiple Range Test (DNMRT). Means in the same column with different superscripts for tissues or body fluids differ significantly ($P \leq 0.05$).

Fagbua *et al.*³ similarly reported that the Na, K, Ca and Mg contents of land snails (*Archachatina marginata* (ovum) Pfeiffer and *Archachatina marginata* (saturalis) Philippi) in Nigeria were consistently high while the Zn, Fe, P and S contents were generally low. Thus, for all species the Zn and Fe contents ranged from 1.2-4.0 $\mu\text{g/g}$, while $< 0.1 \mu\text{g/g}$ of P and S were detected. The distribution of any element in snail tissue or body fluid will depend on the availability or deficiency of such mineral elements in the soil and therefore fruits and vegetables in localities where the snails were picked¹⁹. Additionally, Ozogul *et al.*¹⁹ investigating the free fatty acid and mineral contents of the flesh of wild snails (*Helix pomati*) in Turkey reported that the major minerals analysed were Ca, K, Mg, P and Na while the Fe, Mn and Zn contents of snail meat were less than 2 mg/100 g. They concluded that snails were good sources of protein and minerals.

In a feeding trial⁷ with caged African giant snail (*A. marginata*), snails fed on paw-paw leaves had highest feed intake with high contents of Na, K, Zn and Cl whereas snails fed on poultry droppings had least contents of Mg and Cl in their flesh. Similarly, snails fed on soya bean had higher levels of Ca, Mg and Fe in their meat than snails on other test diets. These studies^{3,7} suggest that the accumulation of trace elements and minerals can be manipulated through dietary intake of selected feeds that are good sources of these nutrients. Powell¹ reported that most snails, especially the African giant land snail, are macrophytophagous herbivores, i.e. eat a wide range of plant materials (fruit and vegetables). Sometimes they eat sand, very small stones and even concrete as calcium source for their shell and in rare instances they consume each other. Deekae and Indoniboye-Obu⁹ had reported that the large proportions of organic matter (90-95%) in the gut of snails collected were not unrelated to their feeding habits. They concluded that snails are foragers or grazers and garden pests taking in a lot of debris and other vegetation. This could explain the significantly higher contents of minerals in their tissues and body fluids.

Our results (Table 2) show that with the exception of phosphorus among the five major elements, K, Na, Ca and Mg occur in high concentrations in snail tissues and body fluids. The results strongly recommend consumption of snails as important sources of the major mineral elements. The importance of this observation stems from the fact that deficiency diseases associated with these minerals are known to be common, especially among the infants, pregnant and lactating mothers and the aged²⁰. The physiological roles of minerals in human diet are well-documented^{21,22}. K for instance is a primary electrolyte and major cation inside the cell and low blood K is a life-threatening problem²³. Fruits, vegetables

and animal products are important sources of K in human diets. Therefore, snails being herbivores as well as carnivores contribute significantly to the K requirements of humans.

Similarly, Na is a primary cation in the extra-cellular medium. Na intake of less than 2 g daily increases Ca loss in urine and high intakes can contribute to hypertension in some people²². Natural plant foods are low in Na except for some species of vegetables such as spingils, but fruits are generally low in Na²⁴. The Na contents of the snails were considerably higher compared with vegetables²⁵. This could be attributed to their mode of nutrition and movement on land^{1,9}. This does not, however, portend a danger of hypertension from consumption of snails as elimination of Na or K salts is almost entirely urinary²⁰.

The calcium contents of the snail tissues are lower than what has been reported²⁶ in crayfish (*Macrobrachium* sp.). Calcium is quantitatively most abundant mineral in the body, and in ionic form it regulates transport across the cell wall²². Its high concentration in all the snail species investigated could be attributed to their consumption of soil and stones^{1,9} and suggests that consumption of snail will increase calcium level in the body. This is important because the cells need calcium and more than 99% of calcium in the body is used in structural component of bone and teeth²².

Green leafy vegetables, whole grain seeds and nuts, which are the major foods for snails, are the richest sources of Mg²². Mg has a vital role in a varying range of biochemical and physiological process including binding to ATP to form active ATP, contributing to DNA and RNA synthesis, nerve and heart function, insulin action on cells and decreasing blood pressure by dilating arteries and preventing heart rhythm abnormalities²². The recommended dietary allowance (RDA) for Mg of 400 mg/day for men 19 to 30 years of age and 310 mg/day for women of the same age bracket²⁷ indicates variability in requirements of men and women and suggest that the four species of snails studied were good sources of Mg.

L. aurora would be an excellent source of dietary zinc when the results obtained in this study are viewed against a recommended daily allowance (RDA) of 11 mg/day for men and 8 mg/day for women²⁷. The concentration determined in the study, however, fell below the toxic level of 1000 mg/kg²⁸ stated by World Health Organization (WHO). Thus *L. aurora* does not have potential hazardous effects. Many enzymes require Zn as a cofactor for optimal activity, and adequate intake is important for nucleic acid synthesis, protein metabolism, immune, insulin and cell membrane functions, sexual organ development and mineralization of bone matrix²².

The Fe level was lower than that reported²⁹ for shellfish from

the Niger Delta area of Nigeria. However, with a recommended dietary allowance (RDA) of Fe 8 mg/day for men 19 years and older and 18 mg/day for girls and women 11 to 50 years old³⁰, the species of snails analysed were good sources of Fe. The low iron content is attributed to the absence of haemoglobin in snail body fluids as they derive their iron from vegetable sources.

Information on the food applications of snail body fluids is scant in literature. It is, however, believed that some pharmacologically active substances such as acetylcholinesterase, dopamine and histamine are associated with snail body fluid¹. Traditional medicine practitioners in Africa use snail body fluids for treatment of various ailments ranging from conjunctivitis, whooping cough to asthma⁸.

Daily recommended dietary allowances from nutrient trace elements found in snail tissues were estimated (Table 3). The results show that K, Ca, Mg and Zn contributions to RDA were 0.22-0.33, 1.1-13.3, 2.85-7.10 and 1.6-20.6%, respectively, while the contributions of Fe and Na were 4.9-48.5 and 0.97-4.7%, respectively, in both adult males and females if 250 g of snail tissue were eaten daily. Significant species differences were observed in their contents of minerals, presumably due to their habitat, movement and mode of nutrition. Wegwu and Wigwe³⁰ reported Fe concentrations ranging from 18.2 to 19.0 mg/kg and Zn concentrations ranging from 13.0 to 13.5 mg/kg in *A. marginata* picked at different locations in Southern Nigeria. They attributed this high level of Fe and Zn in snail tissues to the discharge of industrial wastes into terrestrial environment. Besides, fresh fruits and vegetables are the most nutrient-dense sources of K and Mg while stones and soil make significant contributions to Ca in snail meat. We conclude that the variations in mineral accumulation in snail tissues and their contribution to human nutrition are location dependent. *L. aurora* had the highest contribution of Ca (13.3/13.3%), Mg (5.46/7.10%) and Zn (15.0/20.6%) to the RDA for adult males and females, respectively. *A. fulica*, *P. ovata* and *L. aurora* contributed K an average of 0.30% each to the RDA of adult males and females while *P. ovata* had the highest contribution of Fe (109.1%) and Na (4.7%), respectively.

The concentrations of heavy metal contaminants in snail tissue and body fluids are given in Table 4. Ranges of Cu, Pb and Cd

contents of *A. marginata*, *A. fulica*, *P. ovata* and *L. aurora* tissues and body fluids were 0.28-1.10, 0.3-0.5, 0.1-0.36 and 1.0-1.6, 0.06-0.25, 0.1-0.2 µg/g, respectively. Generally the Hg and Cr contents were <0.01. The levels of Cu found in snail tissues and body fluids in this study are much lower than the values (3.20-9.6 mg/kg) reported³⁰ for *A. marginata* collected in different locations in Bayelsa, Edo, Akwa Ibom, Cross River, Abia, Anambra and Ondo States of Nigeria. On the contrary, Idowu *et al.*⁷ reported Cu levels of 0.16-0.18 mg/kg in the tissues of *A. marginata* reared in confinement and fed different nitrogen sources. Cu like Fe and Zn are nutrient trace elements that are associated with many enzymes, especially those involved in oxidative processes. Although copper is quite widely found, especially in animal foods, the level of need seems to lie between 1 and 3 mg/day²². The levels of Cu determined in this study fell below the WHO specifications of 30 mg/kg³¹.

The interference of Pb with haem biosynthesis is one of the best-reported effects of Pb on blood³². Pb inhibits the activities of δ-aminolaevulinic acid dehydratase and ferrochelatase and as such interference with the insertion of Fe into protoporphyrin has been shown to result in accumulation of protoporphyrin in human erythrocytes²⁰. The levels of Pb in the tissues and body fluids of snail species collected at Onne were lower than the values reported³⁰ for *A. marginata* collected at certain location at Akpor, Ogoni and Aluu (1.0 mg/kg), Bayelsa (0.86-5.0 mg/kg) and Anambra State (2.0-2.2 mg/kg). The levels of Pb determined in this study fell below the FEPA and WHO specifications of 1.0 and 2.0 mg/kg, respectively³². The low levels of Pb in the experimental samples can be attributed to the considerably low oil exploration activities and the highly forested landscape of Onne. Mean Pb levels lying close to or above the WHO specification (2.0 mg/kg) were reported in *A. marginata* picked from bushes in oil-producing communities where oil-spillage is frequent and in areas where vehicle traffic is heavy³⁰. Wegwu and Wigwe³⁰ have noted that substantial levels of Pb emitted in vehicle exhaust gases are deposited directly on the road surface, and according to Kakulu and Osibanjo³³, Nigerian crude gasoline is highly leaded.

The concentration of Cd in the four snail species did not vary significantly (P>0.05). The Cd levels were considerably low when compared with mean values ranging from 0.66 to 1.70 µg/g for *A.*

Table 3. Mineral contributions of snail tissues to the daily recommended dietary allowance (RDA), % minerals from daily consumption of 250 g snail tissue by adult male/female.

Snail species	K	Na	Ca	Mg	Zn	Fe
<i>A. marginata</i>	0.22/0.22	0.97/0.97	1.1/1.1	3.31/4.27	1.60/2.20	10.94/4.90
<i>A. fulica</i>	0.33/0.33	2.4/2.4	3.5/3.5	3.96/5.11	8.9/12.2	13.12/5.83
<i>P. ovata</i>	0.33/0.33	4.7/4.7	2.6/2.6	2.85/3.67	3.47/4.70	109.1/48.9
<i>L. aurora</i>	0.31/0.31	1.9/1.9	13.3/13.3	5.46/7.10	15.0/20.6	12.8/5.70

RDA for adult males and females are 4.7 g K each, 500 mg Na each, 1000 mg Ca each, 400 mg and 310 mg Mg respectively, 11 mg and 8 mg Zn, respectively and 8 mg and 18 mg Fe respectively. Institute of Medicine, National Academy of Science; 2002. Estimated values were from data on mineral composition of snail tissue in Table 2.

Table 4. Some heavy metal contaminants (µg/g) of snail tissue and body fluids.

Snail species	Cu	Pb	Cd	Hg	Cr	
<i>A. marginata</i>	A _t	0.28 (0.29-0.30)	0.47 (0.46-0.48)	0.36 (0.38 - 0.40)	0.01 (<0.01 - 0.01)	0.04 (0.03 - 0.05)
	A _r	1.6 (1.5-1.7)	0.25 (0.24 - 0.26)	0.20 (0.19 - 0.21)	<0.01	<0.01
<i>A. fulica</i>	B _t	0.75 (0.74-0.76)	0.50 (0.48 - 0.51)	0.32 (0.30 - 0.34)	0.01 (<0.01-0.01)	0.02 (0.02 - 0.03)
	B _r	1.2 (1.0 - 1.3)	0.19 (0.18 - 0.20)	0.18 (0.17 - 0.20)	<0.01	<0.01
<i>P. ovata</i>	C _t	1.10 (0.9 - 1.2)	0.38 (0.37 - 0.39)	0.1 (0.08 - 0.12)	0.01 (<0.01 - 0.01)	0.02 (0.01 - 0.03)
	C _r	1.0 (0.9 - 1.2)	0.12 (0.9 - 0.13)	<0.01	<0.01	<0.01
<i>L. aurora</i>	D _t	0.80 (0.7 - 0.9)	0.30 (0.28 - 0.31)	0.2 (0.18 - 0.21)	0.01 (<0.01 - 0.01)	0.01 (<0.01 - 0.01)
	D _r	1.4 (1.3 - 1.5)	0.06 (0.05 - 0.07)	<0.01	<0.01	<0.01
FEPA limit	<1.0	<1.0	<1.0	0.05	<1.0	

A_t, A_r = *A. marginata* (tissues, body fluid), B_t, B_r = *A. fulica* (tissues, body fluid), C_t, C_r = *P. ovata* (tissues, body fluid), D_t, D_r = *L. aurora* (tissues, body fluid). Data in parenthesis are range of values obtained for four samples. FEPA = Federal Environmental Protection Agency, Nigeria.

marginata samples collected from different locations in southern Nigeria³⁰. Cd like Pb and Hg are non-nutrient trace elements that have no known function in humans but are toxic at very low levels of intake and present no identified deficiency symptoms²⁰. The toxicological activity of Cd is attributed to its chemical similarity to Zn, as Cd may conveniently replace Zn in some enzymes, thus altering the three-dimensional structure and impairing catalytic activity³⁴. Among the enzymes inhibited by Cd are adenosine triphosphatase, alcohol dehydrogenase, amylase, carbonic anhydrase and peptidases (in carboxypeptidase and aspartate aminotransferase)³⁵. Fortunately, the experimental Cd concentration for all the snail tissue and body fluid samples were far below the Federal Environmental Protection Agency (FEPA), Nigeria, (1.0 mg/kg) and WHO (2.0 mg/kg)³².

Levels of Hg in the experimental samples were generally low (<0.01) and below the FEPA limit (0.05). Hg is a neurotoxin, which inhibits foetal and child development and cause irreversible deficits in brain function²⁰. All foods contain minute amount of Hg but some foods, especially some species of fish, have considerable power to accumulate distinctly high levels of Hg²². When the level of industrial contamination is excessive due to industrial pollution then carnivorous snails and other animals can be a source of Hg poisoning to people.

The nutrient trace element Cr fell within 0.01-0.04 µg/g. This value fell below 0.72-4.28 µg/g reported in catfish obtained from New Calabar River¹⁰. Chromium is an essential trace metal that plays significant role in maintaining proper carbohydrate and lipid metabolism.

Snails may come in contact with microorganisms and poisonous substances by way of movement over land surface^{1,9}. Most organisms have capacity for concentrating certain trace metals due to their requirement in life processes. This capacity is enhanced by specific feeding and metabolic processes, which could result in an enormously high concentration factor. In the tissues, trace metals have the ability to form complexes with organic substances and this property enhances chances of the trace metals to be fixed rather than excreted from the body of the animal. Fortunately, the concentration of heavy metal contaminants in the snail tissues studied was low.

Conclusions

The four snail species were good sources of K, Na, Ca, and Mg. Ca plays a significant role in blood clotting in the human body, and its high concentration in the snail species is beneficial to humans in the development of bones, teeth and the clotting of blood. The heavy metal contaminants in the snail tissues were generally low and below the WHO and Federal Environmental Protection Agency (FEPA) limit in foods. The results strongly recommend consumption of snails as important sources of major mineral elements.

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