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Comparative studies on the mineral elemental composition of gamma irradiated smoked shrimps (*Penaeus notialis*) from 3 different water sources in Ghana

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Abstract

Dry and smoked shrimp constitute an important nutrient supplement for the populace in Ghana. Shrimp continues to represent one of the safest forms of muscle protein consumed in the world. Despite this safety record, shrimp have a high tolerance to toxins in polluted areas. The effect of irradiation on the nutrient and mineral elements including heavy metals were examined after storage for 4 months in dense polyethylene bowls. Elemental composition was estimated by Atomic Absorption Spectrometry (AAS). The Flame Photometer (FP) was used in the determination of Sodium and Potassium. There were clear differences in the concentration of heavy metals, and macro nutrients (Mg, K, Na, Zn) due to influence of the type of water body they dwelled in. Irradiation had some or no effect on the concentration of these listed elemental and components, but there were interactions between sources of shrimp, storage time and irradiation dose in some instances. Multivariate analysis of elemental composition showed that, accumulation of Fe, Cu, Zn, and N was generally attended by uptake of Pb, Cr, Na, and K. The order of elemental concentration (in decreasing order) was: Fe > Cu > Zn > N > Mn >Pb> Cr >Na > K > Ni > Cd.

1 Introduction

Fresh and dried shrimp are commercially important products for both national and international market. In Africa about 35 million people depend wholly or partly on the fisheries sector, mostly artisanal fisheries, for their livelihood. According to Mensah *et al.*[1] about 150,000 people are known to be engaged in marine fisheries. It is also estimated that, 1.5-2 million people directly or indirectly rely on or support these fishermen. These include their wives, children, close relatives, canoe carvers, input suppliers and office workers for industrial fleet [2]. The importance of the fishery sector is related to employment, livelihood support, poverty reduction, food security and foreign exchange. In Ghana, the report indicated that fish and fish product accounts for 60% of the population's protein intake. A study by Nketsia-Tabiri [3] revealed that the consumption preference for fish in Ghana is 82% compared to livestock and poultry products. Like the fish counterparts, shrimps are known to concentrate heavy metals in their tissues in varying proportions depending on the species, food habitat and environmental conditions and inhibiting processes [4]. Since the panaeid constitute an important protein source, they are potentially and indirectly source of metals entering the human body when consumed.

Heavy metals are trace metals that are at least five times denser than water [5] and for this reason; are stable, thus cannot be metabolized by the body hence its resultant accumulation. Higher accumulation overtime can reach toxic levels within the individual [6]. Increasing usage of heavy metals by industries and their deposition in marine environment can cause damage to both biodiversity and the ecosystem, due to their toxicity and accumulative tendency in the aquatic biota and pose danger to humans and other wildlife [7]. Although there are preventive measures established to reduce the input of trace metals into oceans, rivers and estuaries, its accumulation in the different aquatic systems have been reported by [7, 8, 9]. Industrial wastes and mining are potential sources of heavy metal pollution in aquatic environment[10]. Metals like iron, copper, zinc and manganese are required for metabolic activities in organisms, others like arsenic, cadmium, chromium, mercury, nickel and lead are toxic because of their long half-life, therefore they have been included in the regulations for hazardous metals [11, 12]. Mineral ratios are of great importance in the diet of all living organisms, though at high levels, they could pose serious risks in the organism.

These are necessary for maintenance of osmotic pressure, acid-base balance, the regulation of pH of blood, haemolymph, urine, and other body fluids [13, 14, 15]. Although minerals may be present in adequate quantities in feedstuffs for shrimp diets mineral deficiencies can occur under intensive culture conditions. The lack of certain specific minerals may be due to the presence of certain compounds that bind the elemental form of the mineral that is used in the feed, and antagonistic or synergistic reactions in the gastro-intestinal tract are factors that sometimes cause dietary mineral imbalances or deficiencies [16, 15]. According to [17], about twenty-two minerals both macro and micro, have been found essential to fish and shrimp. Calcium, phosphorus, potassium, sodium, chloride, magnesium and sulfur are considered macro elements while iron, zinc, copper, manganese, nickel, cobalt, molybdenum, selenium, chromium, iodine, fluorine, tin, silicon, vanadium and arsenium are heavy trace elements. Marine shrimps live in an environment that is hypertonic and continually take up small amounts of water.

Information is lacking on the elemental composition of shrimp farmed from the different water sources in Ghana. The profile of heavy metals in *P. notialis* harvested from Ghana waters need to be investigated due to their possible bio-concentration and consequent bioaccumulation in human beings who occupy the top level on the food chain. This work therefore seeks to ascertain the accumulation of heavy metals (iron, manganese, copper, zinc, nickel, calcium, cadmium, lead, cobalt and chromium) in *P. notialis* species collected at the different water sources ; Sea, Lagoon and River using Atomic Absorption Spectrophotometer, in order to evaluate their hazard level in relation to the maximum residual limit for human consumption.

2 Materials and Methods

2.1 Shrimp sample

Dehydrated-smoked shrimps from the sea, lagoon, and river, were purchased from three different areas, "Faana", "Tsokome" and "Bortiano" respectively; all located at the coastal areas of Ghana. The samples were dominated mainly by *P. notialis* although there were other few varieties found in the population, which were identified as *P. monodom* and *P. kerathucus.* The samples were them carefully sorted to ensure a homogenous population of *P. notialis*. They were then wrapped in a brown paper and then placed in a black polyethylene bag, (main mode of packaging by the local producers) and then transported to the Department of Botany laboratory of the University of Ghana. The shrimps were poured into dense polypropylene containers and kept at a temperature (6-8°C) appropriate for storage. These were considered the population from which the samples were collected for further analysis.

2.2 Irradiation of shrimp samples and dosimetry method

Irradiation was done according to Varanyanond *et al* [18] and Wang *et al.*[19] with modifications. The samples were packaged in dense polypropylene bowls which was able to satisfy this condition (packaging material which is strong enough to resist piercing/ puncture by the antenna of the shrimp was considered) in accordance to the East African Standard (EAS, CD/K/512:2010: ICS 67.120.30) for dried shrimp packaging**.** The samples were treated with gamma irradiation (cobalt-60 irradiator) in a Category Four (4) Wet Storage Irradiator at the Radiation Technology Centre at the Ghana Atomic Energy Commission. Doses applied were 0 kGy (control), 4 kGy, 8 kGy and 10 kGy within the range used by for dried shrimp in East Asia. The dosimeter used was the Ethanolchlorobenzene (ECB) Dosimetry system, which comprise of the Ethanolchlorobenzene Dosimeter and the High Frequency Dosimeter Reader (HFDR). The dosimeter was calibrated against an International standard set by the International Atomic Energy Agency and read using the HFDR. To minimize variations in radiation dose absorption, the bags were turned at different angles halfway through the procedure. Samples were analysed in triplicates for each source. The dose rate used was 2.17 kGy / hour in air.

2.3 Mineral element determination

This was done according to Obodai *et al*. [20] with modifications. The Atomic Absorption Spectrometer (AAS), model (AA24OFS Varian) was used in the determination of elemental composition of both irradiated and control samples. The Milestone Acid Digestion was used. Each sample from the different sources was blended into smooth powder. 0.5 g of each powdered sample was weighed into tephron beakers. 6mls of Nitric Acid (65 % Purity Level) and 1ml Hydrogen Peroxide (30 % Purity Level) was added. The samples in the beaker was mounted on a Rotor and placed into ETHOS 900 microwave digester.

The Rotor was then removed and samples were cooled in a water bath. The samples were unscrewed from the tephron casket and diluted with distilled water to a final volume of 20ml. The digested solution was then transferred into test tubes and assayed for Iron, Manganese, Copper, and Zinc. Some heavy metals such as Lead, Nickel, Cadmium, Cobalt and Chromium were also identified.

The final concentration is calculated using the following equation:

$$\text{Final concentration (mg/kg)} = \frac{Conc.(d.f) \times 20.0ml}{0.5g}$$

2.4 Determination of Sodium and Potassium

The Flame Photometer method was used in the determination of sodium and potassium in both irradiated and control samples. Shrimp from different water sources (river, lagoon and sea) were blended into powder and 0.2 g of each was measured into a clean dry 125ml 'Pyrex' conical flask. 4ml of concentrated H_2SO_4 was added and the flask was swirled carefully to ensure that entire sample was wetted. The samples in the flask were heated in a fume hood on an electric hot plate (with medium heating). 4-5 drops of H_2O_2 was added slowly at a time (in order to avoid vigorous reaction of the contents) to clear the solution. The solution was allowed to cool and transferred quantitatively into a 100ml volumetric flask. The contents were brought to a mark by adding distilled water. Two blanks digest were prepared from the same amount of reagents (H_2SO_4 and H_2O_2). Data was corrected against the blank value. Na and K values were read from the same solution using the Flame Photometer. The percentage sodium and potassium content were calculated as follows.

$$\% \text{ Na} = \frac{(Flame\ reading)}{1000} \times \frac{100}{1000} \times \frac{100}{0.2g}$$

$$\% \text{ K} = \frac{(Flame\ reading)}{1000} \times \frac{100}{1000} \times \frac{100}{0.2g}$$

2.5 Statistics analysis

The data was analyzed using Microsoft excel and analysis of variance (two way ANOVA) using Statgraphics software (centurion XVI.I) to assess whether the 2 independent variables thus radiation dose at the different levels and sources of shrimps had any effect on the variable been measured (various parameters). Differences among mean values were processed by Fisher's Least Significant Difference (LSD) procedure. Mean difference values were reported and significance was defined at $P<0.05$. Each analysis was subjected to its own unique experimental design in a randomized complete block.

3 Results

Multivariate analysis of the elemental composition showed that, accumulation of Fe, Cu, Zn, N was generally attended by Pb, Cr, Na, K (Table 1). Comparatively, higher concentrations of heavy metals accumulated in shrimp from the lagoon and sea followed by the riverine shrimp. The order of the heavy metals concentration was as follows, (in decreasing order) Fe>Cu>Zn>N>Mn>Pb>Cr>Na>K>Ni>Cd (Table 1).

The mineral levels of shrimp from the various sources have been summarized in Table 1. The iron content in shrimp from the various sources ranged between 34.54 – 68.14 mg/kg in both irradiated and control shrimp. The average Fe content recorded were 45.30 mg/kg, 67.43 mg/kg and 56.34 mg/kg in shrimp from sea, river and lagoon respectively, at 0 kGy (Table 1). After irradiation at the various doses its Fe content decreased to 57.85 mg/kg, 40.25 mg/kg and 64.10 mg/kg in shrimps from sea, river and lagoon respectively. Fe content in shrimps from river was highest but decreased significantly (P<0.05) after irradiation, nonetheless Iron content in shrimp from the sea and lagoon was directly proportional to the radiation doses.

Sodium and potassium in shrimp were in the range of 0.64 mg/kg – 1.22 mg/kg and 0.78 mg/kg – 1.17 mg/kg respectively (Table 1). Shrimp from lagoon contained 1.08 mg/kg and that from the sea was 1.04 before irradiation. Sodium content in river was 0.63mg/kg before irradiation (Table 1). Potassium content in shrimp from river was highest (1.03 mg/kg) followed by shrimp from the lagoon (1.02 mg/kg).

Nitrogen content was in the range of 3.18 – 8.02 mg/kg. Nitrogen content in river was highest (7.47 mg/kg) followed by nitrogen content in lagoon (5.66 mg/kg) (Table 1).

Magnesium content was within the range of 1.58 mg/kg- 9.88 mg/kg (Table 1). Shrimp from lagoon contained the highest amount of magnesium with range of 6.97 mg/kg – 9.88 mg/kg

Manganese content in shrimp from the sea was within the range of 1.58 mg/kg – 2.13 mg/kg whereas that from the river was within the range of 2.04 mg/kg – 2.92 mg/kg.

Copper content was found between 7.06 mg/kg to 13.56 mg/kg (Table 1). Cu content in shrimp recorded before irradiation was 7.74 mg/kg, 8.55 mg/kg and 7.34 mg/kg in shrimp from sea, river and lagoon respectively. After radiation at different levels of doses, there were changes in Cu content. The average Cu content recorded after irradiation is 9.06 mg/kg, 8.38 mg/kg and 11.37 mg/kg in shrimp from the sea, river and lagoon respectively.

Zinc content in shrimp was in the range of 4.2 mg/kg – 9.83 mg/kg, Lead in shrimp was in the range of 0 – 7.96 mg/kg, Cadmium was in the range of 0 – 0.96 mg/kg and nickel was in the range of 0 – 5.28 mg/kg (Table 1). Chromium content in shrimp was in the range of 0.57mg/kg – 2.12mg/kg (Table 1).

Calculation of the Pearson correlation showed that most metals were correlated. The values of the correlation matrix are shown in Table 2. Strong correlations were recorded at 99 % confidence level ($p \leq 0.001$) and significant correlations were recorded at 95 % confidence level ($p \leq 0.05$). Association between elements of strong correlation was Cd-Zn, whereas associations between elements of significant correlations were Fe-Na, Zn-Na, Cd-Na, Ni-N and K-N (Table 2).

Table 2 shows the means of the heavy metals and other mineral elements before and after irradiation of shrimp from different water sources with 0-10 kG.

Table 1: Mean±S.D of heavy metals concentration, mg/kg and other macronutrient in the irradiated samples from sea and river water sources

Code	Fe	Mn	Cu	Zn	Pb	Cd	Ni	Cr	Na	K	N
S0	45.30±0.50 (45.30–45.80)	2±0.02 (1.98–2.01)	7.74±0.26 (7.45–7.96)	9.37±0.08 (9.28–9.43)	<0.001 (0)	0.82±0.16 (0.64–0.94)	5.15±0.13 (5.02–5.28)	1.29±0.18 (1.12–1.47)	1.04±0.03 (1.01–1.07)	0.83±0.02 (0.81–0.85)	3.35±0.18 (3.18–3.53)
S4	51.48±0.37 (51.07-51.80)	1.62±0.04 (1.58–1.65)	8.64±0.34 (8.32–8.99)	8.52±0.32 (8.15–8.72)	3.24±0.19 (3.04–3.41)	0.87±0.09 (0.78–0.96)	0.17±0.06 (0.12–0.23)	1.55±0.07 (1.48–1.62)	1.15±0.04 (1.11–1.19)	0.81±0.03 (0.78–0.83)	4.52±0.27 (4.23–4.77)
S8	54.85±0.54 (54.30–55.37)	1.78±0.04 (1.75–1.83)	9.07±0.09 (8.99–9.17)	8.23±0.18 (8.09–8.43)	5.33±0.06 (5.27–5.39)	0.64±0.07 (0.59–0.72)	< 0.001 (0)	1.43±0.13 (1.32–1.57)	1.13±0.03 (1.09–1.15)	0.81±0.02 (0.79–0.83)	4.90±0.23 (4.63–5.05)
S10	67.21±0.85 (66.49–68.14)	2.04±0.08 (2–2.13)	9.48±0.44 (9.02–9.89)	8.83±0.13 (8.74–8.98)	7.23±0.24 (7.08–7.54)	0.62±0.22 (0.43–0.86)	0.76±0.11 (0.68–0.88)	1.13±0.06 (1.08–1.19)	1.15±0.04 (1.11–1.19)	0.83±0.03 (0.80–0.85)	4.28±0.07 (4.21–4.34)
R0	67.43±0.53 (66.89–67.95)	2.84±0.08 (2.76–2.92)	8.55±0.77 (7.98–9.43)	5.51±0.07 (5.43–5.57)	7.51±0.33 (7.23–7.87)	0.42±0.09 (0.34–0.51)	0.34±0.07 (0.28–0.41)	1.58±0.10 (1.48–1.68)	1.07±0.02 (1.05–1.08)	1.03±0.02 (1.02–1.05)	7.47±0.48 (7.11–8.02)
R4	40.65±0.40 (40.22–41.01)	2.08±0.04 (2.04–2.12)	7.61±0.49 (7.06–7.98)	4.54±0.26 (4.27–4.78)	7.85±0.16 (7.67–7.96)	0.56±0.05 (0.52–0.61)	0.56±0.05 (0.51–0.6)	1.82±0.13 (1.68–1.91)	0.92±0.10 (0.81–0.98)	1.05±0.13 (0.91–1.17)	4.96±0.29 (4.65–5.01)
R8	44.83±0.52 (44.30–44.85)	2.48±0.04 (2.44–2.51)	8.96±0.38 (8.54–9.29)	4.73±0.34 (4.34–4.98)	4.66±0.37 (4.28–5.01)	0.20±0.03 (0.18–0.23)	< 0.001 (0)	1.14±0.08 (1.08–1.23)	0.74±0.03 (0.71–0.77)	0.88±0.03 (0.86–0.91)	5.21±0.07 (5.14–5.27)
R10	35.26±0.8 (34.54–36.21)	2.38±0.05 (2.35–2.44)	8.57±0.35 (8.31–8.97)	5.49±0.42 (5.19–5.97)	<0.001 (0)	<0.002 (0)	< 0.001 (0)	1.51±0.08 (1.43–1.58)	0.74±0.04 (0.75–0.78)	0.86±0.03 (0.84–0.9)	5.17±0.14 (5.01–5.28)
L0	56.34±0.50 (55.56–56.34)	9.82±0.06 (9.76–9.88)	7.34±0.22 (7.11–7.54)	4.80±0.21 (4.57–4.96)	<0.001 (0)	0.15±0.03 (0.12–0.17)	< 0.001 (0)	0.66±0.08 (0.57–0.72)	0.66±0.02 (0.64–0.67)	1.02±0.02 (1.01–1.04)	5.66±0.52 (5.11–6.15)
L4	62.56±0.37 (62.15–62.87)	8.59±0.25 (8.3–8.76)	11.58±0.40 (11.22–12.01)	4.71±0.07 (4.64–4.78)	<0.001 (0)	<0.002 (0)	< 0.001 (0)	1.48±0.04 (1.45–1.52)	1.06±0.04 (1.02–1.09)	0.93±0.03 (0.91–0.96)	5.57±0.32 (5.24–5.88)
L8	64.74±0.68 (64.13–65.47)	7.67±0.61 (6.97–8.04)	9.33±0.40 (8.96–9.76)	4.26±0.06 (4.2–4.31)	3.35±0.26 (3.16–3.64)	0.33±0.10 (0.24–0.43)	0.6±0.04 (0.56–0.64)	2.10±0.02 (2.08–2.12)	1.12±0.06 (1.06–1.18)	0.91±0.02 (0.89–0.92)	4.98±0.79 (4.36–5.87)
L10	65±0.30 (64.66–65.19)	9.58±0.30 (9.23–9.76)	13.21±0.35 (12.87–13.56)	9.76±0.08 (9.68–9.83)	4.26±0.26 (4.01–4.53)	0.73±0.06 (0.68–0.8)	1.52±0.09 (1.43–1.6)	1.76±0.15 (1.64–1.92)	1.18±0.04 (1.14–1.22)	0.92±0.04 (0.88–0.95)	4.44±0.18 (4.23–4.57)

Key: S0 – Sea shrimp, 0 kGy, S4 – Sea shrimp, 4 kGy, S8 – Sea shrimp, 8 kGy, S10- Sea shrimp, 10 kGy, L0 – River shrimp, 0 kGy, L4 – River shrimp, 4 kGy, L8 – River shrimp, 8 kGy, L10- River shrimp, 10 kGy, L0 – Lagoon shrimp, 0 kGy, L4 – Lagoon shrimp, 4 kGy, L8 – Lagoon shrimp, 8 kGy, L10- Lagoon shrimp, 10 kGy. The highlighted figures represent the least and highest range

Table 2: Pearson correlation coefficient between the mineral compositions of shrimps from three different sources

Main effects	Fe mg/kg	Mn mg/kg	Cu mg/kg	Zn mg/kg	Pbmg/kg	Cd mg/kg	Ni mg/kg	Cr mg/kg	Na mg/kg	K mg/kg	N mg/kg
Fe mg/kg	-										
Mn mg/kg	0.484	-									
Cu mg/kg	0.514	0.515	-								
Zn mg/kg	0.160	-0.226	0.291	-							
Pbmg/kg	0.269	-0.406	-0.005	0.073	-						
Cd mg/kg	0.113	-0.369	0.005	**0.799****	0.394	-					
Ni mg/kg	-0.116	-0.123	-0.078	0.534	-0.233	0.519	-				
Cr mg/kg	0.092	-0.007	0.336	-0.063	0.289	0.193	0.004	-			
Na mg/kg	**0.603***	-0.054	0.497	**0.590***	0.364	**0.655***	0.237	0.536	-		
K mg/kg	0.125	0.403	-0.135	**-0.615***	0.208	-0.347	-0.234	0.059	-0.339	-	
N mg/kg	0.284	0.156	-0.072	**-0.615***	0.228	-0.529	**-0.605***	0.002	-0.236	**0.642***	-

Correlation matrix (significant figures in bold text)

4 Discussions

Iron is an essential trace element since it forms a significant part of heamoglobin, and allows oxygen to be carried from the lungs to the tissues. Results obtained in this study agreed with published findings of [21] who recorded 4.83 ± 0.02 mg/100 g (~4830 mg/kg). Adeyeye *et al* [22] also recorded 16.4 g/100g for *P.notabilis*.

Adeyeye and Adubiaro[23] reported values of 23030 mg/kg for *P.notialis*. Ozden[24] recorded 3018.98 mg/kg for *Parapenaeus longirostris*. Sodium is the principal caution of the extra cellular fluid, aids acid-base balance and is essential for nervous system [25]. The level of Na in flesh of *L. vannamei* was found as 67.7 mg.

Adeyeye and Adubiaro[23] reported 31772 mg/kg for *P. notalias*. In another study, Ozden[24] recorded 4479.64g/kg for *Parapenaeus longirostris.* Potassium assists in maintaining fluid, electrolyte balance and cell integrity. During nerve transmission and muscle contraction, potassium and calcium briefly exchange places across the cell membrane. Potassium requirement for human is about 2 g day^{-1}.

The average K contents of *L. vannamei* were found to be 56.7 mg, which is lesser compared to that reported by [26] for green tiger shrimp and [27] recorded 459.7 mg/100g (sea bass) and 393.8 mg/100g (sea bream).

The body utilizes Nitrogen for promoting protein synthesis, the creation of compounds and amino acids influence growth, hormones, brain functions and the immune system. About 0.83 gram of protein per kilogram per day is considered sufficient to cover nitrogen requirements [28]. Recently, [29] suggested a maximum intake of 2 to 2.5 g/kg of body weight per day.

Results obtained agreed with published works of some researchers such as [30] recorded values of 382±21.5 mg/kg and 579±84.8 mg/kg (*P. longirostris* and *P. martia* respectively). In another study, Adeyeye and Adubiaro[23] recorded 670 mg/kg (*P.notalias*). Whithney[25] and Kortei et al [15] underscored that Magnesium toxicity is rare, but could be fatal when it occurs. Magnesium is required for the body's enzyme system, bone health; it is a major part of protein synthesis in soft tissues and energy metabolism.

Results agreed with[30] who recorded 0.729 mg/kg (*P. Longirostris*) and 0.145 mg/kg (*P.martis*) respectively.

Copper concentration was lower as compared with copper concentrations reported in other species of shrimp by [31]. Adeyeye *et al* [22] reported values of 4.3 mg/100g for *P.notabilis*.

Results of Zinc concentrations obtained in this studies were higher as compared to similar studies carried out by [31]. Baboli and Velayatzadeh [32] reported lower than 13.8±0.7 µg/g in *Fenneropenaeus merguiensis*. Nonetheless, the zinc concentrations were lower than FAO recommended standard (1000mg/kg) in fish and fishery products[32]. According to Oguzie *et al.* [31] the recommended daily allowance for zinc intake is 10mg/day for growing children while for adults it is 15mg/day. A deficiency of Zinc is marked by loss of taste, retarded growth and hypogonadism leading to decreased fertility. Zinc has a protective effect against toxicities of both cadmium [33] and lead [34]. Shrimp from the sea contained high amounts of zinc followed by that from the river. The Food and Agricultural Organization [32] suggests limits for Cu and Zn of 30 mg/kg.

Shrimp from the various sources contained low amounts of Lead, Cadmium and Nickel, though after irradiation they increased. Shrimp from the river recorded the highest amounts of Lead, nonetheless, Pb content in shrimp from sea and lagoon were in traces but increased considerably after irradiation. The range of Pb concentrations found in this thesis were higher than those recorded by [31] and was above the recommended limit (2mg/kg) in fish and fishery products as prescribed by[32]. Shrimp from sea recorded the highest amounts of cadmium followed closely by shrimp from the river (Table 1). The Cd values recorded were below permitted limits (2.0 mg/kg) in fish and fishery products. According to Calabrese *et al.*[33], humans are exposed to Cd through food intake; and so the average daily intake for adults was put at approximately 50mg. The threshold for acute cadmium toxicity is a total ingestion of 3-15 mg, and severe toxicity symptoms occur at ingesting 10-326 mg [5, 35]. Fatal ingestion produces shocks and acute renal failure when ingestion exceeds 350mg. Shrimp from lagoon contained low amounts of Cd. There were high amounts of nickel content in shrimp from the sea, but reduced considerable after irradiation at 4 kGy (Table 1). Nickel content in river was considerably low. The average concentrations of nickel recorded were comparatively higher than those reported by [31] in similar studies.

Chromium content in shrimp from river was highest before irradiation, followed by shrimp from the sea. Oguzie and Achegbulu[36] found the following heavy elements in *P. notialis* from Ovia river in Edo State, Nigeria: Cd (Not detected-0.010 mg/kg, Cr (Not detected-0.035 mg/kg), Cu (20.185-26.172 mg/kg), Pb (0.351-3.810 mg/kg), Ni (Not detected-0.382 mg/kg) and zinc (0.280-0.335 mg/kg). The concentrations of Cu and Pb were higher than values recommended in fish and fishery products by the FAO.

Chromium is an essential metal whose useable form plays an important role in glucose metabolism. An average human requires about 1μg/daily of Cr. Cr deficiency causes impaired growth, disturbances in glucose, lipid and protein metabolism [33] but is known as one of the notified hazardous metals[12]. Lead in shellfish can cause renal failure and liver damage in humans if taken in concentrations above 0.4 mg/kg recommended by [37]. Nickel was found in *P. notialis* at concentrations up to 0.536 mg/kg in Nigeria [36]. The maximum residue level for Ni is 70-80 mg/kg. The major source of nickel for human is food, as well as uptake from natural sources. The normal range of oral intake for nickel for humans is 300-600 μg/day [12].

Higher concentrations of heavy metals accumulated in shrimp from lagoon and sea with the least in the riverine shrimp (Table 1). This is not surprising because they serve as damping sites of most waste and antropogenic contaminants from urban dwellings and industrial emissions [38]. The order of heavy metal concentration was as follows (in decreasing order); Fe $>$ Cu $>$ Zn $>$ N $>$ Mn $>$Pb$>$ Cr $>$ Na $>$ K $>$ Ni $>$ Cd (Table 1). A similar work was carried out by [39], on (*Panaeus monodom*) with accumulated heavy metals in the order of Cu $>$ Zn $>$Pb$>$ Cd.

5 Conclusion

Data obtained from this study showed that shrimp is a good source of minerals, and other essential elements, although it also contained some levels of toxic heavy metals. The estimated mean concentrations for Cu, Zn in the present was lower than the International Standards (WHO, 1996; Tuzen, 2009) which makes it safe for consumption. Although irradiation had some significant effect on the mineral content, they were within safe limits for consumption.

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7 Conflicts of Interests

The authors hereby declare that there are no conflicts of interests

8 Author’s contributions

FA, GTO and NKK carried out data analysis/interpretation and manuscript preparation. AAA and NKK worked on the final document approval. FA and GTO carried out research conception/design and data acquisition.

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