African Scientist Vol. 25, No. 1 March 31, 2024
Printed in Nigeria

1595-6881/2023 $80.00 + 0.00

https://africansciientistjournal.org

AFS2024016/25109

Human health risk of cadmium, selenium, and tin concentrations in canned fish from selected markets in Edo State, Nigeria

Iyorah, Ebikere Imelda* and Emerah, Claudia

Department of Environmental Management and Toxicology, University of Benin, P.M.B 1154, Benin City, Nigeria

*Corresponding author Email: imelda.iyorah@uniben.edu, Tel: +234 (0) 706 048 3978

(Received March 5, 2024; Accepted in revised form March 20, 2024)

ABSTRACT: The surge in human exposure to heavy metals, driven by their widespread industrial use, demands a thorough examination of their toxicity. This study focuses on heavy metal contamination in canned fish sold in Benin City, with an emphasis on Atlantic bluefin tuna, Atlantic mackerel, and European pilchard. Six brands of canned fish were purchased from selected markets in Benin City, Nigeria, and the heavy metal levels were assessed using Atomic Absorption Spectrophotometry (AAS) instrumentation. The results revealed notable disparities in copper (Cu), selenium (Se), and tin (Sn) concentrations. Fish brand C (sardine) showed the highest levels of Cu (9.95 ± 2.12 mg/kg), Se (0.54 ± 0.05 mg/kg), and Sn (0.63 ± 0.05 mg/kg) concentrations among all the canned fish brands. Daily Metal Intake (DMI) for adults and children consuming canned fish highlighted fish brand C having the highest values. Health Risk Index (HRI) calculations revealed potential health risks, particularly for children, surpassing recommended levels in Cu, Se, and Sn. This study underscores the need for vigilant monitoring of heavy metal content in canned fish to safeguard consumer health, stressing adherence to safety standards set by approved organizations. These findings advance our understanding of food safety and public health, particularly in canned fish consumption, emphasizing the necessity for robust food safety regulations in Nigeria.

Keywords: Canned food, Health risk index, Heavy metal, Food safety, Benin City

Introduction

The presence of unsafe metals in canned food has triggered research on their toxicological consequences in different regions of the world (Massadeh *et al.,* 2018). Canning food products has the drawback of potentially introducing harmful chemicals into the food during storage and handling (Al-Ghou *et al.*, 2020). When food comes into contact with packaging materials such as glass, ceramics, and plastic, certain chemicals can be released. Human health could be at risk from this chemical migration from packaging and other food contact materials (Ardic *et al.,* 2015). Due to the dual roles that metals play in our diets, it is of great interest to determine the concentration of metals present in our diets, from the nutritional requirements of key elements to the toxicity that can result from excessive metal consumption for an individual (Bassey *et al*., 2014).

Canned fish is extensively consumed in many regions of the world due to its low saturated fat and omega fatty acids that promote excellent health (Aberoumand *et al.,* 2023). Major cities such as Benin City in Southern Nigeria stand as no exception, where canned fish holds a prominent place on the plates of its residents, offering both convenience and affordability (Johnson *et al.,* 2018). Nevertheless, the consumption of canned fish raises concerns about the potential health risks associated with these products. Ensuring the safety of canned fish in the market is paramount to safeguarding the public health. Metal levels in canned food may be elevated due to corrosion and leaching of metals from unlacquered cans or tin foil used in packaging. These canned containers might discharge metals into the food (Shokri *et al.*, 2021). The growing demand for canned fish is reflective of shifting consumer preferences and the need for accessible sources of dietary protein (Menozzi *et al*., 2020). However, from production to distribution, the handling of canned fish can introduce a range of risks, potentially endangering the health of consumers (Roberts, 2017). Thus, it is vital to assess the quality and safety of canned fish available in the local market. This study aimed to assess the potential human health risks in adult and children's populations from Benin City that consume canned fish food.

Materials and methods

Sample collection: Six popular brands of canned fish products (5 units per brand) were purchased from markets, and superstores in Benin City, Nigeria between January to March 2023. All of the fish species were identified, and the producers' information was obtained. The brands were randomly coded as A, B, C, D, E, F and G, with labels A, B, C, and D containing sardine, E, F, mackerel, and G, tuna, respectively, from Morocco and Thailand. The expiration date of samples was between two and four years at the time of study. After collection, combinations of at least five samples of each fish species were prepared and homogenized in a stainless-steel blender cups and 10 g of test portions were stored at -20^{o}c before further analysis.

Metal analyses: All the brands of oil or sauce were drained off after opening each can, at least five samples of each fish species were prepared and homogenized in a stainless-steel blender (Boadi *et al.*, 2011). For each canned fish sample, 4 g of fish muscle (wet weight) was weighed and placed in a Teflon digestion vessel with 15 mL of pure nitric acid and microwave-assisted digestion as reported by Mindak and Cheng (2010). The digested samples were analyzed for Cu, Se and Sn using the scientific equipment Atomic Absorption Spectrometer, model (Model AA 500L, England)

Human health risk assessment: The potential health risks associated with heavy metal contamination for imported canned fish, the average DIM, the HRI, and the total health risk index were estimated in this study.

Daily intake of metal: The average DIM was calculated using the equation reported by Guo *et al.* (2016).

$$DIM = Cmetal \times Cfactor \times Dfood\ intake/weight$$

where Cmetal is the metal content (mg/kg),
Cfactor is the conversion factor (0.085),
Dfood intake is the daily consumption of canned fish (3.5 E0-3 kg/person/day), and
Average body weight is 70.0 kg for adults and 15.0 kg for children (Tang *et al.*, 2015).

Health risk index (HRI): The health risk index (HRI) for the local population through the consumption of canned fish was assessed using the equation reported by Guo *et al*. (2016).

$$HRI = DIM/RFD$$

where DIM is the daily metal intake, while
RfD is the metal reference dose.
The oral reference dosages of Cu, Se, and Sn were 0.04, 0.005, and 0.20 mg/kg/day, respectively. An HRI < 1 indicates that the population is safe.

Total health risk index (HRI): The total HRI (THRI) of heavy metals in canned fish was computed by the sum of HRI values for each metal.

$$THRI = HRI\ (toxicant\ 1) + HRI\ (toxicant\ 2) + HRI\ (toxicant\ 3)$$

Statistical analysis: The mean and standard errors for metal levels in several canned fish species were computed. The significance of metal levels between distinct fish species was investigated using one-way variance analysis (ANOVA). Multivariate post hoc Duncan test was used to compare the mean levels of each metal ($p < 0.05$) among fish species. All statistical analyses were carried out using the SPSS 16 statistical software.

Results

Concentration of heavy metals in canned fish: Figures 1a - c depict a violin box showing basic statistics for concentrations of heavy metals in different canned fish samples sold in the Benin City market. Figure 1a shows that the Cu concentration was highest in fish brands C (sardine) and G (tuna), while the lowest concentration was observed in fish brands E and F (mackerel). Cu exhibited the highest variation in concentration for all the metals quantified in the different brands. In Figure 1b, fish brands C and A (sardine) and E (mackerel) showed the highest Se concentration, while fish brands D (sardine) and E (mackerel) had the lowest Se concentration. In Figure 1c, the highest Sn concentration was observed in fish species brand C (sardine), while the lowest concentration was observed in fish species brands B and E (sardine). The concentrations of metals in different canned fish varied significantly between brands ($p<0.05$).

Human health risk: The calculated DIM values for heavy metals in canned fish species in adults and children are presented in Table 1. The DIM for adults is in the range of Cu (0.02-0.05), Se (0.00170-0.00268), Sn (0.00102-0.00310) and children Cu (0.01-0.19), Se (0.006148-0.010710) and Sn (0.004086-0.012396).

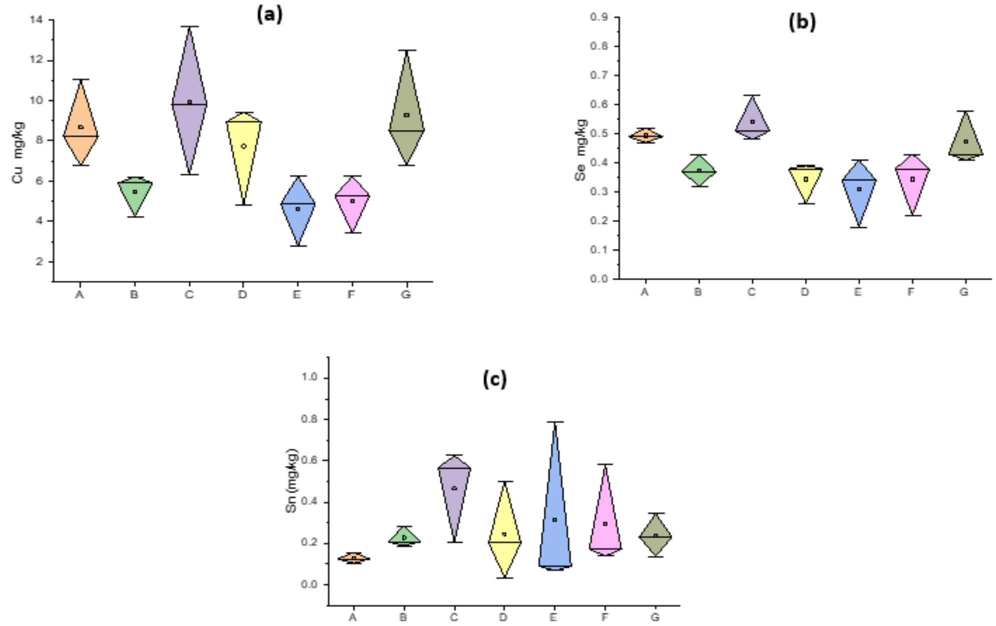

Figure 1: Violin plot for the concentration of heavy metals in different canned fish species brands sold in the market

Fish Brand	Adults			Children		
	Cu	Se	Sn	Cu	Se	Sn
A	0.04	0.00245	0.00233	0.17	0.009784	0.009302
B	0.03	0.00185	0.00130	0.11	0.007404	0.005216
C	0.05	0.00268	0.0031	0.19	0.010710	0.012396
D	0.04	0.00170	0.00302	0.15	0.006809	0.012396
E	0.02	0.00154	0.00102	0.09	0.006148	0.012098
F	0.03	0.00170	0.00255	0.10	0.006809	0.004086
G	0.05	0.00235	0.00204	0.18	0.009388	0.010214

Table 1: Daily intake of metals (DIM, mg) in adults and children consuming canned fish

HRI values of heavy metals for adults and children were not all within the limits (HRI<1) (Table 2). Furthermore, the THRI values, which varied from 0.08 to 6.29 for adults and from 0.31 to 25.14 for children, were above the limit (THRI<1).

Table 2: Daily intake of metals (DIM, mg) in adults and children consuming canned fish

Fish Brand	Adults			Children		
	Cu	Se	Sn	Cu	Se	Sn
A	1.07431	0.48922	0.01163	4.29722	1.95689	0.04651
B	0.67681	0.37022	0.00652	2.70725	1.48089	0.02608
C	1.23339	0.5355	0.01549	4.93354	2.142	0.06198
D	0.95861	0.34047	0.01549	3.83444	1.36189	0.06049
E	0.57475	0.30742	0.00511	2.29901	1.22967	0.02043
F	0.61814	0.34047	0.01277	2.47256	1.36189	0.05107
G	1.14951	0.46939	0.01021	4.59803	1.87756	0.04086
THRI	6.28551	2.85269	0.07685	25.1421	11.41078	0.30742

Discussion

Concentration of metals in canned fish: Trace metals present in the human diet are vital for human survival in low quantities but can be hazardous at excessive levels (Hosseini *et al.,* 2013). Thus, both the scientific community and consumers are beginning to gain a greater awareness of how processed foods can benefit their health and the potential hazards that may arise from them. Canned foods, which are widely consumed, could pose a serious threat to consumers if they contain high levels of contaminants. Comparing the heavy metal concentration in canned fish in this study with the highest permissible limits according to FAO/WHO in mg/kg (0.50 for Cu, 2.0 for Se, and 250 for Sn), the canned fish's contribution to the total body burden of these metals may be regarded negligibly as miniature. According to Salama and Radwan (2005), copper plays an important role in bone development, skeleton mineralization, cell structure protection, and the scavenging of free radicals. However, when consumed in excess, copper is highly toxic (Mol, 2011). As a result, high Cu consumption has been recognised as being connected with detrimental health consequences such as kidney and liver damage in humans (Hussein and Khaled, 2014). Previous studies on copper levels reported from the literature range from 0.91 – 3.01 mg/kg in canned fish from Iran (Isam and Mustaf, 2023), 1.37 mg/kg in canned fish from Serbia (Popovic *et al.,* 2018), and 1.10 – 2.50 mg/kg in canned fish from Turkey (Tuzen and Soylak, 2007). In this study, copper levels were within the recommended limits of 0.50 mg/kg.

Selenium, a micronutrient, is essential for the formation of many selenium-dependent enzymes in humans and animals. However, excessive amounts could have negative health effects on humans (Sobhanardakan, 2018). The maximum limit for Se set by the FAO (2021) is 2.0 mg/kg for fish. Se concentrations of all samples in canned fish species were below the permissible limits. Our observed Se mean value of 0.54 mg/kg were lower than those reported in the literature (Miklavcic *et al.,* 2011). Tin is an essential trace element that is required for growth and development (Wu *et al.,* 2019). Elevated tin levels in food pose a risk to human health and could have an adverse effect on the metabolism of an organism. A study conducted by Kowalska *et al.* (2020) found that mean Sn concentrations in canned fish were 0.018 - 1.362 mg/kg, which was similar to this study. Tin contents in canned fish have been reported in the literature to be in the range of 8.05 – 8.13 mg/kg from Nigeria and 0.000 - 0.385 mg/kg in sardines from Turkey (Mol, 2011; Markmanuel *et al.,* 2022).

Human health risk: DIM (Table 1) and HRI (Table 2) values were calculated to estimate consumer health hazards related to the intake of canned fish samples from various brands in the Benin City metropolitan area. The current estimations assume that people of two ages (children and adults) consume canned fish. The study's findings revealed that the average daily intake metal (DIM) values for all metals detected in various canned brands of fish were below the maximum permitted limits (MPI) set by the relevant authorities (Table 1). The calculations showed that DIM levels were greater in children than in adults. Based on the DIM values, consumption of canned fish samples was deemed unsafe in terms of the examined metals. Sobhanardakani *et al.* (2018) observed acceptable DIM values for Cr, Cu, Fe, Mn, and Ni in 124 different canned fish, unlike the present study. There have been few investigations on the DIM levels in canned fish. Furthermore, the majority of these studies indicated that DIM values for metals were below the DIM thresholds set by regulatory bodies. HRI values of Cu, Se, and Sn for children and adults are > 1 in most of the canned fish brands. The average HRI value was 6.29 for adults and 25.14 for children. As a result, we conclude that consuming canned fish from Benin City can pose a significant risk to the target population's health, especially to children

Conclusion

The study's findings revealed that certain canned fish products contain substantial amounts of heavy metals, which might pose health hazards to the consumers who consume them, particularly children. To safeguard customers and assure the safety of canned fish available to the public sector, authorities in Nigeria should establish maximum allowed limits for heavy metal concentrations in these goods. Furthermore, constant monitoring of canned fish in the markets should be conducted to ensure compliance with these standards and avoid associated health risks from the consumption of contaminated canned foods.

References

Aberoumand A, Baesi F: The nutritional quality and contents of heavy elements due to thermal processing and storage in canned (*Thunnus tonggol*) fish change compared to fresh fish. Food Sci Nutr, 11(6):3588-600. 2023.

Al Ghoul L, Abiad MG, Jammoul A, Matta J, El Darra N: Zinc, aluminium, tin and bis-phenol a in canned tuna fish commercialized in Lebanon and its human health risk assessment. Heliyon, 23:6(9) e04995. 2020.

Ardic M, Kahve HI, Duran A: Chemical migration in food technology. Acad J Sci, 04:163–168. 2015.

Bassey FI, Oguntunde FC, Iwegbue CM: Effects of processing on the proximate and metal contents in three fish species from Nigerian coastal waters. Food Sci Nutr, 2: 272–281.2014.

Boadi NO, Twumasi SK, Badu M, Osei I: Heavy metal contamination in canned fish marketed in Ghana. Am J Sci Ind Res, 2:887–882.2011.

FAO: The State of World Fishery and Aquaculture.2021, Available from: http://www.fao.org/fishery/en/statistics

Guo J, Yue T, Li X, Yuan Y: Heavy metal levels in kiwifruit orchard soils and trees and its potential health risk assessment in Shaanxi, China. Environ Sci Pollut Res, 23:14560-14566. 2016.

Hosseini SV, Aflaki F, Sobhanardakani S, Tayebi L, Lashkan A, Regenstein JM: Analysis of mercury, selenium and tin concentrations in canned fish marketed in Iran. Environ Monit Assess, 185(8):6407-6412.

Hussein A, Khaled A: Determination of metals in tuna species and bivalves from Alexandria, Egypt. Egypt J Aquat Res, 40: 9-17. 2014.

Islam MDS, Mustafa RA: Assessment of trace elements in canned fish and health risk appraisal. Food Raw Mat, 1:43–56.2023.

JECFA/WHO: Safely Evaluation of Certain Food Additives and Contaminants. WHO Food Additive Series. No.55. Joint FAO/WHO Expert Committee on Food Additives. 543p. 2006

Johnson A: Canned fish: A dietary staple in Benin City. Nutr Rev, 28: 87-98 2018.

Kowalska G, Pankiewicz U, Kowalski R: Determination of the level of selected elements in canned meat and fish and risk assessment for consumer health. J Anal Methods Chem, 2020:2148794, 2020.

Markmanuel DP, Amos-Tautau BMW, Songca SP: Tin Concentrations and human health risk assessment for children and adults in seafood and canned fish commonly consumed in Bayelsa State, Nigeria. J Appl Sci Environ Manage, 26:1263-1269. 2022.

Massadeh AM, Al-Massaedh AA: Determination of heavy metals in canned fruits and vegetables sold in Jordan market. Environ Sci Pollut Res, 25:1914-20. 2018.

Menozzi D, Nguyen TT, Sogari G, Taskov D, Lucas S, Castro-Rial JLS, Mora C: Consumers' preferences and willingness to pay for Fish products with health and environmental labels: Evidence from five European countries. Nutrients, 12(9): 2650. 2020

Miklavcic A, Stibilj V, Heath E, Polak T, Tratnik JS, Klavz J, Mazej D, Horvat M: Mercury, selenium, PCBs and fatty acids in fresh and canned fish available on the Slovenian market. Food Chem, 124:711–720. 2011.

Mindak WR, Cheng J: Graphite furnace atomic absorption spectrometric determination of cadmium and lead in food using microwave assisted digestion in: Elemental analysis manual. Section 4.3. 2010, [cited 2017 June 12]. Available from: https://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm2006954.htm.

Mol S: Levels of heavy metals in canned bonito, sardines, and mackerel produced in Turkey. Biol Trace Elem Res, 143: 974-982. 2011.

Popović AR, Relić DJ, Vranić DV, Babić-Milijašević JA, Pezo LL, Đinović-Stojanović JM: Canned Sea fish marketed in Serbia: their zinc, copper, and iron levels and contribution to the dietary intake. Arh Hig Rada Toksikol, 69: 55–60. 2018.

Roberts M: Microbial contamination in canned fish: An assessment of health risks. J Food Hyg Saf, 20:32-48.2017.

Salama AK, Radwan MA: Heavy metals Cd and Pb and trace metals Cu, Zn contents in some foodstuffs from the Egyptian market. Emir J Food Agric 17: 34-42. 2005.

Shokri S, Shokri E, Sadighara P, Pirhadi M: Heavy metals contamination in fresh fish and canned fish distributed in local market of Tehran. Hum Health Halal Metrics, 2:12-7. 2021.

Sobhanardakani S, Hosseini SV, Tayebi L: Heavy metals contamination of canned fish and related health implications in Iran. Turk J Fish Aquat Sci, 18: 951-957. 2018.

Tang W, Cheng J, Zhao W, Wang W: Mercury levels and estimated total daily intakes for children and adults from an electronic waste recycling area in Taizhou, China: Key role of rice and fish consumption. J Environ Sci, 34:107-115. 2015.

Tuzen M, Soylak M: Determination of trace metals in canned fish marketed in Turkey. Food Chem, 101:1378-1382. 2007.

World Health Organization: Heavy metals environmental aspects," Tech. Rep., Environmental Health criteria No. 85, Geneva, Switzerland 1995.

Wu B: Effects of trace elements - tin or tin compounds on animals. Austin J Vet Sci Anim Husb, 6(2): 1055. 2019.