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Food toxicity assessment of selected canned foods in Nigeria

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Abstract

Food toxicity assessment was made for frequently consumed canned foods in Nigeria in order to estimate potential human health risks associated with their consumption. Levels of heavy metals (Pb, Cd, As, Fe, Mn and Zn), Nitrate and Nitrite, pH and salt were assessed in randomly purchased samples from groceries stores to represent what is readily available on the market. Nitrates and nitrites were assessed using a Perkin-Elmer spectrophotometer while heavy metal levels were determined using Atomic absorption spectrophotometer. Human health risk was estimated using standard indices; estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI) and dietary exposure (DE). Results showed varying concentrations of nitrates, nitrites, heavy metals, in all the canned food categories but the level of salt and pH seemed constant. Nitrate, Fe and Cd in all the canned food categories exceeded recommended limit set by EU. Health risk estimations showed EDI values for Cd in all the canned food categories above the tolerable daily intake, while DE for Fe in canned sweet corn, Fe, Zn and Pb in canned beans/peas had values above recommended limits. THQ values for all the canned foods were above 1 in the canned beans/peas while HI was above 1 in the canned fish category. The study revealed the potential for Cd toxicity and risk of non-carcinogenic health effects from canned beans/peas consumption. Constant monitoring of canned foods is therefore imperative considering the growing demand for canned products due to changing lifestyle.

Keywords Food toxicity · Metals · Nitrate · Nitrite · Canned food · Health risk

Introduction

Canned foods are considered as safe foods due to certain attributes accrued to them; that is, they are easy to prepare at home, have long shelf life and are quite economical. However, varying concentrations of contamination has been reported in these canned foods [1, 2]. The possible contaminants which could be chemical hazards in foods include food additives, environmental contaminants such as mercury, dioxins and residues of heavy metals, pesticides and veterinary drugs. These chemicals may pose long-term adverse effects on public health [3]. Consequently, information about levels of food additives such as nitrates and nitrites compounds in canned foods as it relates to dietary intake is imperative to avert health risks associated with

consumption. Nigeria also falls among the league of Nations who patronize canned foods but there is limited information on the levels of contamination likely present in these canned foods marketed in Nigeria, making the scope of this study a pilot one. More worrisome is the lack of information on health risks associated with consumption. The objectives of the study was therefore to assess the levels of food additives (Nitrite and Nitrate, Na and Cl) heavy metals (Pb, Cd, As, Fe, Mn and Zn), and pH in canned foods frequently consumed in Nigeria, to estimate human health risks associated with consumption.

Materials and methods

Sample collection

A total of 100 samples of canned foods made of different brands and manufacturers were purchased from local supermarkets in Benin City, Nigeria. The canned foods were preserved on the shelf at room temperature (~24 °C) for about 7 days prior to the experiment. They were grouped

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into four categories: fish, meat, beans/peas and sweet corn. Five brands were obtained for each canned category with five replicate per product type. Each can was assigned a sample code and the details on the packaging were recorded as; Brand Name, Date of manufacture, Best before Date, Trade Name, National Agency for Food and Drug Administration and Control (NAFDAC) Reg. No., Country of Origin.

Sample preparation and analysis

All reagents used for analysis were purchased from Sigma Aldrich (Germany). The cans were opened and transferred into the labelled sterile sample containers prior to digestion, the samples were homogenized. The principle is that the quarter taken for analysis should be a representative of the whole [4].

Heavy metal and Na analysis began by wet digestion of food was performed with nitric acid—perchloric acid—sulphuric acid ($\text{HNO}_3\text{--HClO}_4\text{--H}_2\text{SO}_4$). One-fifth of the sample material (0.2 g) was weighed into the beaker and 10 ml of nitric acid was added, followed by 5 ml of perchloric acid and 10 ml of sulphuric acid. A small glass funnel was inserted to act as a reflux condenser and the mixture was heated for 15–30 min at 150 °C until a dense white fume is noticed and a colourless solution was obtained. It was removed from the block and cooled to about 100 °C. The solution was filtered into a 100 ml volumetric flask and diluted to the mark with water. The blank was prepared with same procedure but without samples and the Heavy Metals content was read off using Atomic Absorption Spectrophotometer (AAS) (UNICAM 696, England, UK) [5].

Nitrates and Nitrites were analysed using a Perkin-Elmer spectrophotometer (LAMBDA 25, CT, USA). Ten millimetre of the filtrate was pipetted into a 50 ml flask; 2 ml of Brucine was added followed immediately by 10 ml of conc. H_2SO_4 . The beaker was stirred gently to allow for thorough mixing and it was allowed to stand for 10 min. The standard was treated similarly and the samples were read spectrophotometrically.

Determination of pH

This is done using HANNA pH Meter (HI 9813-6, Woonsocket, RI, USA). The meter is switched on and allowed to stabilise for 10 min. Then calibrate the pH meter by immersing the Probe in the Buffers solutions 4, 7 and 10. Rinse the probe and immerse in the sample solution and the pH is read.

Determination of chloride

Ten millimetre of the filtrate was pipetted into a 250 ml conical flask, 1 ml or 3 drops of K_2CrO_4 was added and titrated with standard 0.05 M HCl until a slight red precipitate

occurs. The blank, 9 ml of the K_2CrO_4 indicator and 10 ml of 20 ppm Cl^- were treated similarly.

Determination of nitrate

Ten millimetre of the filtrate was pipetted into a 50 ml flask; 2 ml of Brucine was added followed immediately by 10 ml of conc. H_2SO_4 . The beaker was stirred gently to allow for thorough mixing and it was allowed to stand for 10 min. The standard was treated similarly and the samples were read spectrophotometrically at 470 nm.

Determination of nitrite

Ten millimetre of the filtrate was pipetted into a 50 ml flask, 2 ml of 2 M HCl was added and diluted with water to 30 ml. 2 ml of sulphanilic acid was then added and stirred and allowed to stand for 5 min. The standards were treated in a similar manner as the samples. Colour development occurred after a few minutes, and the absorbance were read spectrophotometrically at 520 nm after 20 min.

Health risk assessment

Average estimated daily intake (EDI)

EDI was calculated using the following equation, which is recommended by the US EPA [6].

$$\text{EDI} = \frac{C \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}$$

where EDI is the average daily intake or dose through ingestion ($\text{mg kg}^{-1} \text{bw day}^{-1}$); C is the heavy metal concentration in the exposure medium (mg l^{-1} or mg kg^{-1}); IR is the ingestion rate (l day^{-1} , or kg day^{-1}); EF is the exposure frequency (365 days/year); ED is the exposure duration (54 years, equivalent to the average lifespan); BW is the body weight (kg) and AT is the time period over which the dose is averaged ($365 \text{ days/year} \times \text{number of exposure years}$, assumed to be 54 years in this study).

Target hazard quotient

The human health risk posed by contaminant exposure are usually characterized by the target hazard quotient (THQ) [6], the ratio of the average estimated daily intake (EDI) resulting from exposure compared to the reference dose (RfD) for an individual pathway and chemical. Oral reference dose obtained from the Integrated Risk Information System [7] is an estimation of maximum permissible risk to a human population through daily exposure when taking into consideration a sensitive group during a lifetime. The applied RfD for Cd, Pb, Cu and Zn was 1.0, 4.0, 40,

300 mg kg⁻¹ day⁻¹, respectively. The THQ based on non-cancer toxic risk was determined by;

$$THQ = \frac{EDI}{RfD}$$

If the value of THQ is less than 1, the risk of non-carcinogenic toxic effects is assumed to be low. When it exceeds 1, there may be concerns for potential health risks associated with overexposure.

To assess the overall potential risk of adverse health effects posed by more than one metal, the THQs can be summed across contaminants to generate a hazard index (HI) to estimate the risk of a mixture of contaminants. The HI refers to the sum of more than one THQ for multiple substances and/or multiple exposure pathways.

$$HI = \sum THQ_1 + THQ_2 + THQ_{n...}$$

In the present study, the HI was used as a screening value to identify whether there is significant risk caused by heavy metals through average dietary consumption of canned foods.

Dietary exposure

A dietary exposure assessment was calculated by multiplying consumption data with data on the concentration of chemicals in food [8]. It is expressed as;

$$DE = \sum (FCC \times FCR)$$

where FCC = food chemical concentration, FCR = Food consumption rate [7].

Statistical analysis

All data were subjected to one-way analysis of variance (ANOVA) using XL Stat program for windows. The level of significance was chosen at $p < 0.05$ and the results are presented as mean $\pm$ standard error. Graphs were plotted using GraphPad Prism7.04.

Results

The mean and standard error (mean $\pm$ SE) for canned fish showed variation across the different canned food sampled as showed in Table 1. The pH values ranged from 5.48 ± 0.12 to 5.66 ± 0.05 . Na ranged from 3.88 ± 2.1 to 445.08 ± 41.54 mg kg⁻¹, nitrite and nitrate ranged from 21.1 ± 3.69 to 31.04 ± 2.95 mg kg⁻¹ and 54.22 ± 9.52 to 79.8 ± 7.58 mg kg⁻¹ respectively. These values were not found to be significant at $p > 0.05$. Fe, Zn and Pb

Table 1 Summary of data from the analysis of canned fish

Parameters mg/kg	Product type A			Product type B			Product type C			Product type D			Product type E			p value	Standard	References
	Mean $\pm$ SE	Min	Max	Mean $\pm$ SE	Min	Max	Mean $\pm$ SE	Min	Max	Mean $\pm$ SE	Min	Max	Mean $\pm$ SE	Min	Max			
pH	5.66 ± 0.05	5.5	5.8	5.64 ± 0.09	5.3	5.8	5.48 ± 0.12	5.2	5.8	5.5 ± 0.05	5.4	5.6	5.58 ± 0.12	5.3	5.9	> 0.05	5.70–6.60	[9]
Na	416.4 ± 8.08	393.4	442	399.98 ± 14.18	358.4	439.2	388.3 ± 2.1	358.8	448.9	428.3 ± 41.58	324.9	568.8	445.08 ± 41.54	348.2	598.5	> 0.05		
NO ₂	29.98 ± 2.98	21.1	37	31.04 ± 2.95	21.6	38.6	30.22 ± 2.1	25	35.2	21.1 ± 3.69	9.7	30.9	30.82 ± 3.76	18.9	39.1	> 0.05	50 mg/kg	[10]
NO ₃	77.2 ± 7.59	54.8	95.2	79.8 ± 7.58	55.6	99.2	77.74 ± 5.39	64.3	90.5	54.22 ± 9.52	24.8	79.6	79.04 ± 9.67	48.7	100.6	> 0.05	50 mg/kg	[10]
Fe	228.2 ± 17.93	172.2	282.5	161.78 ± 16.44	124.7	216.7	245.7 ± 3.09	235.6	252.5	170.4 ± 27.34	112.9	262.3	216.1 ± 9.42	184.3	233.1	< 0.01		
Mn	1.97 ± 0.80	0	4.7	1.44 ± 0.34	0.7	2.41	2.03 ± 0.54	0.89	4.05	2.02 ± 0.53	0.73	3.79	2.66 ± 0.38	1.76	3.82	> 0.05		
Zn	48.14 ± 9.45	21	73.1	60.2 ± 12.61	35.6	100.8	39.8 ± 11.29	13.4	76.4	15.72 ± 3.49	10.2	29.4	34.36 ± 7.92	10.6	56.4	< 0.05		
Cd	0.18 ± 0.05	0.05	0.35	0.084 ± 0.02	0.04	0.15	0.06 ± 0.06	0	0.3	0.13 ± 0.08	0	0.4	0.13 ± 0.08	0	0.34	> 0.05	0.1 µg/g	[11]
Pb	0.17 ± 0.08	0.05	0.45	0.09 ± 0.04	0	0.2	0	0	0	0	0	0	0	0	0	< 0.05	0.30 mg/kg	[11]
As	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	–		
Cl	93.7 ± 1.83	88.5	99.5	89.98 ± 3.19	80.6	98.8	87.38 ± 3.51	80.7	101	96.36 ± 9.34	73.1	127.9	100.16 ± 9.36	78.3	134.7	> 0.05		

Na, Fe, Mn, Zn standards are available as Recommended Maximum daily intake. $p < 0.001$, Highly significant, $p > 0.05$, no significance

ND below detected limit

were found to be significant ($p < 0.05$) and the values ranged from 161.78 ± 16.44 to 245.7 ± 3.09 mg kg⁻¹, 15.72 ± 3.49 to 60.2 ± 12.61 mg kg⁻¹ and 0.09 ± 0.04 to 0.17 ± 0.08 mg kg⁻¹ respectively. Mn and Cd were found to be non-significant. Arsenic was not detected all through the canned groups.

Canned meat had pH values ranging from 5.24 ± 0.11 to 5.7 ± 0.13 . Na ranged from 432.4 ± 41.32 to 478.48 ± 43.25 mg kg⁻¹, NO₂ and NO₃ ranged from 27.04 ± 3.94 to 33.26 ± 1.71 mg kg⁻¹ and 69.58 ± 10.14 to 86.1 ± 4.49 mg kg⁻¹ respectively. These parameters were not significantly different at $p > 0.05$ across the product types. Similar significance occurred for Zn, Pb and Cl with values ranging from 36.12 ± 11.51 to 68.94 ± 17.09 mg kg⁻¹, 0 to 0.16 ± 0.04 mg kg⁻¹ and 97.4 ± 8.63 to 107.66 ± 9.73 mg kg⁻¹. However, the values of Fe, Mn, and Cd showed significant level of difference when assessed across the canned beef products samples which ranged from 205.28 ± 8.13 to 303.08 ± 11.57 mg kg⁻¹, 2.46 ± 0.43 to 4.64 ± 0.47 mg kg⁻¹ and 0 to 0.22 ± 0.07 mg kg⁻¹ respectively. This is shown in Table 2.

The results from canned beans/peas as shown in Table 3 revealed that pH values ranged from 5.02 ± 0.02 to 5.72 ± 0.05 . This range in pH values were found to be highly significant ($p < 0.001$). Na ranged from 332.6 ± 45.08 to 458.72 ± 22.14 mg kg⁻¹ with no significant difference ($p > 0.05$). Same trend of significance was observed for Mn (3.43 ± 0.31 to 4.84 ± 0.4 mg kg⁻¹), Zn (50.74 ± 4.79 to 87.26 ± 22.31 mg kg⁻¹) and Pb (0 to 0.15 ± 0.04 mg kg⁻¹). NO₃ was highly significant ($p < 0.001$) in the canned beef products (69.46 ± 4.08 to 93.92 mg kg⁻¹) but NO₂ was significant ($p < 0.01$) with ranged values of 27.02 ± 1.89 to 36.54 ± 1.45 mg kg⁻¹. The ANOVA analyses for Fe and Cd in the canned products was found to be significant ($p < 0.05$) with ranged values of 130.68 ± 1.74 to 191.02 ± 22.25 mg kg⁻¹ and 0 to 0.29 ± 0.05 mg kg⁻¹.

Canned sweet corn recorded most of the highest values when assessed as shown in Table 4. The pH ranged from 5.84 ± 0.03 to 6.16 ± 0.07 and was highly significant across the products sampled ($p < 0.001$). Na, Fe and Cl values ranged from 378.56 ± 15 to 497.58 ± 42.35 , 140.28 ± 31.89 to 194.06 ± 5.71 and 85.16 ± 3.38 to 111.96 ± 9.53 respectively but showed no significant difference ($p > 0.05$). Cd (0 to 0.05 ± 0.04) was found to be highly significant ($p < 0.001$) across the products sampled. Other parameters sampled showed significant difference ($p < 0.05$) across the products with NO₂ ranging from 27.34 ± 1.79 to 35.2 ± 2.27 , NO₃ (70.34 ± 4.6 to 90.78 ± 5.73), Mn (3.89 ± 0.53 to 6.3 ± 0.35), Zn (51.76 ± 10.54 to 91.88 ± 3.95), and Pb ranged from 0 to 0.14 ± 0.03 .

Table 2 Summary of data from the analysis of canned meat

Parameters mg/kg	Product type A				Product type B				Product type C				Product type D				Product type E				p value	Standard	References
	Mean $\pm$ SE		Min	Max	Mean $\pm$ SE		Min	Max	Mean $\pm$ SE		Min	Max	Mean $\pm$ SE		Min	Max	Mean $\pm$ SE		Min	Max			
	Mean $\pm$ SE	Max	Min	Max	Mean $\pm$ SE	Max	Min	Max	Mean $\pm$ SE	Max	Min	Max	Mean $\pm$ SE	Max	Min	Max	Mean $\pm$ SE	Max	Min	Max			
Ph	5.24 ± 0.11	5.5	4.9	5.5	5.26 ± 0.07	5.5	5.1	5.5	5.68 ± 0.06	5.8	5.5	5.8	5.7 ± 0.13	5.9	5.3	5.9	5.58 ± 0.13	5.8	5.1	5.8	> 0.05	6.6	
Na	432.4 ± 41.32	565	312.6	565	478.48 ± 43.25	593.3	401.2	593.3	432.9 ± 38.37	573.1	357.2	573.1	469.06 ± 14.88	514.8	430.3	514.8	473.24 ± 14.05	520	431.8	520	> 0.05		
NO ₂	28.44 ± 3.45	38.4	20.2	38.4	27.52 ± 3.03	38.2	20.3	38.2	33.26 ± 1.71	38	28.9	38	32.54 ± 2.78	42.2	26.6	42.2	27.04 ± 3.94	36.5	14.2	36.5	> 0.05	50 mg/kg	[10]
NO ₃	73.1 ± 8.88	98.7	51.9	98.7	70.82 ± 7.8	98.3	52.2	98.3	86.1 ± 4.49	97.7	74.2	97.7	83.68 ± 7.13	108.5	68.4	108.5	69.58 ± 10.14	93.9	36.5	93.9	> 0.05	50 mg/kg	[10]
Fe	270.28 ± 22.99	320.9	204.1	320.9	259.24 ± 10.23	284.8	229.3	284.8	303.08 ± 11.57	332.4	278.8	332.4	205.28 ± 8.13	223.4	177.9	223.4	220.72 ± 15.32	275.8	187.5	275.8	< 0.001		
Mn	2.46 ± 0.43	4.09	1.81	4.09	3.27 ± 0.36	4.38	2.27	4.38	2.73 ± 0.48	4.24	1.48	4.24	4.02 ± 0.41	5.27	2.74	5.27	4.64 ± 0.47	6.43	3.85	6.43	< 0.01		
Zn	36.4 ± 6.18	53.8	22.6	53.8	36.12 ± 11.51	67.6	11.2	67.6	46.46 ± 8.29	63.4	16.8	63.4	68.94 ± 17.09	117.8	30.1	117.8	53.24 ± 14.12	95.2	19.2	95.2	> 0.05		
Cd	0.19 ± 0.08	0.4	0	0.4	0.03 ± 0.03	0.15	0	0.15	0.08 ± 0.08	0.4	0	0.4	0	0	0	0	0.22 ± 0.07	0.4	0.05	0.4	< 0.05	0.05 µg/g	[12]
Pb	0	0	0	0	0	0	0	0	0	0	0	0	0.08 ± 0.08	0.4	0	0.4	0.16 ± 0.04	0.06	0.06	0.3	< 0.05	0.10 mg/kg	[12]
As	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-		
Cl	97.26 ± 9.3	127.1	70.3	127.1	107.66 ± 9.73	133.5	90.3	133.5	97.4 ± 8.63	128.9	80.4	128.9	105.54 ± 3.35	115.8	96.8	115.8	106.48 ± 3.16	97.2	97.2	117	> 0.05		

Na, Fe, Mn, Zn standards are available as Recommended Maximum daily intake, $p < 0.05$, significant, $p < 0.001$, Highly significant, $p > 0.05$, no significance

ND below detected limit

Correlation coefficient matrices

In this study, the correlation coefficient matrix was used to show the linear strength and direction of the variables analysed which is shown in Tables 5, 6, 7 and 8 below. The result for canned fish revealed that pH strongly correlated with Zn ($r=0.7132$) and Pb ($r=0.8519$). Na correlated strongly with Mn ($r=0.7101$) and Cl ($r=1$). NO_2 correlated strongly with NO_3 ($r=0.9999$) and Zn ($r=0.8205$). NO_3 correlated strongly with Zn ($r=0.8242$), Mn with

Cl ($r=0.7115$), Zn with Pb ($r=0.6497$), Cd with Pb ($r=0.5469$) and Cl ($r=0.6391$).

In canned meat, pH correlated strongly with NO_2 ($r=0.7013$), NO_3 ($r=0.7026$) and Zn ($r=0.8293$), Na correlated strongly with Fe ($r=-0.7297$), Mn ($r=0.7815$) and Cl ($r=1$), NO_2 correlates strongly with NO_3 ($r=0.9999$) while Fe correlates strongly with Mn ($r=-0.8464$), Zn ($r=-0.7097$), Pb ($r=-0.7668$), and Cl ($r=-0.7293$). Similar trend was found with Mn which correlated strongly with Zn, Pb and Cl ($r=0.6679$, 0.9346 and 0.7817) respectively and Zn strongly correlated with Pb ($r=0.6213$).

Table 5 Correlation coefficient matrix for canned fish

	pH	Na	NO_2	NO_3	Fe	Mn	Zn	Cd	Pb	Cl
pH	1.0000									
Na	0.1152	1.0000								
NO_2	0.5092	-0.2922	1.0000							
NO_3	0.5111	-0.2996	0.9999	1.0000						
Fe	-0.1736	-0.1604	0.4460	0.4482	1.0000					
Mn	-0.2861	0.7101	-0.0073	-0.0142	0.4935	1.0000				
Zn	0.7132	-0.5237	0.8205	0.8242	0.0351	-0.5504	1.0000			
Cd	0.5136	0.6388	-0.1963	-0.1952	0.0385	0.2919	-0.1728	1.0000		
Pb	0.8519	-0.1853	0.3438	0.3508	0.0181	-0.4691	0.6497	0.5469	1.0000	
Cl	0.1154	1.0000	-0.2906	-0.2980	-0.1580	0.7115	-0.5232	0.6391	-0.1850	1

Table 6 Correlation coefficient matrix for canned meat

	pH	Na	NO_2	NO_3	Fe	Mn	Zn	Cd	Pb	Cl
pH	1.0000									
Na	0.0304	1.0000								
NO_2	0.7013	-0.4176	1.0000							
NO_3	0.7026	-0.4251	0.9997	1.0000						
Fe	-0.2585	-0.7297	0.2042	0.2229	1.0000					
Mn	0.4647	0.7815	-0.2331	-0.2396	-0.8464	1.0000				
Zn	0.8293	0.3272	0.5052	0.4925	-0.7097	0.6679	1.0000			
Cd	-0.2332	-0.2835	-0.5608	-0.5545	0.0683	0.0690	-0.3118	1.0000		
Pb	0.4708	0.5391	-0.2618	-0.2668	-0.7668	0.9346	0.6213	0.3768	1.0000	
Cl	0.0319	1.0000	-0.4163	-0.4238	-0.7293	0.7817	0.3279	-0.2844	0.5392	1.0000

Table 7 Correlation coefficient matrix for cannedbeans/peas

	pH	Na	NO_2	NO_3	Fe	Mn	Zn	Cd	Pb	Cl
pH	1.0000									
Na	-0.7464	1.0000								
NO_2	0.7843	-0.5671	1.0000							
NO_3	0.8386	-0.6836	0.9886	1.0000						
Fe	-0.1852	-0.1116	-0.5066	-0.4251	1.0000					
Mn	-0.6074	0.4820	-0.5551	-0.5800	0.7250	1.0000				
Zn	0.6988	-0.7573	0.1615	0.2894	0.2565	-0.4620	1.0000			
Cd	-0.6673	0.2783	-0.8244	-0.7858	0.1786	0.0817	-0.0020	1.0000		
Pb	-0.5194	0.7510	-0.7664	-0.8082	0.0476	0.2123	-0.1559	0.5742	1.0000	
Cl	-0.7476	1.0000	-0.5682	-0.6846	-0.1101	0.4835	-0.7578	0.2791	0.7506	1.0000

Table 8 Correlation coefficient matrix for sweet corn

	pH	Na	NO ₂	NO ₃	Fe	Mn	Zn	Cd	Pb	Cl
pH	1.0000									
Na	−0.7116	1.0000								
NO ₂	−0.0623	−0.6279	1.0000							
NO ₃	−0.0725	−0.6198	0.9999	1.0000						
Fe	−0.2225	−0.3387	0.8215	0.8281	1.0000					
Mn	−0.7530	0.7105	−0.1625	−0.1600	−0.2556	1.0000				
Zn	−0.2804	0.3997	−0.0621	−0.0637	−0.1272	0.7199	1.0000			
Cd	0.2951	−0.7218	0.5642	0.5555	0.0355	−0.1615	−0.2744	1.0000		
Pb	0.1131	−0.6838	0.7469	0.7403	0.2583	−0.0584	−0.1675	0.9610	1.0000	
Cl	−0.7116	1.0000	−0.6276	−0.6195	−0.3382	0.7105	0.4001	−0.7223	−0.6841	1.0000

In canned beans/peas, the pH correlated strongly with all parameters except Fe, while Na correlated strongly with NO₂ ($r = -0.5671$), NO₃ ($r = -0.6836$), Zn ($r = 0.7573$), Pb ($r = 0.7510$) and Cl ($r = 1$). NO₂ showed a strong correlation with NO₃ ($r = 0.9886$), Fe ($r = -0.5066$), Mn ($r = -0.5551$), Cd ($r = -0.8224$), Pb ($r = -0.7664$) and Cl ($r = -0.5682$). NO₃ strongly correlated with Mn, Cd, Pb and Cl ($r = -0.5800$, -0.7858 , -0.8082 , -0.6846) respectively. Fe correlated strongly with Mn ($r = 0.7250$), Zn correlated strongly with Cl ($r = -0.7578$), Cd with Pb ($r = 0.5742$) and Pb with Cl ($r = 0.7506$).

In Canned Sweet corn, pH correlated strongly with Na, Mn, and Cl ($r = -0.7116$, -0.7530 , -0.7116) respectively while Na correlated strongly with NO₂ ($r = -0.6279$), NO₃ ($r = -0.6198$), Mn ($r = 0.7105$), Cd ($r = 0.7218$), Pb ($r = 0.6838$) and Cl ($r = 1$). NO₃ showed a positive correlation with Fe ($r = 0.8281$), Cd ($r = 0.5555$) Pb ($r = 0.7403$), but negatively with Cl ($r = -0.6195$). Mn showed a positively strong correlation with Zn ($r = 0.7199$) and Cl ($r = 0.7105$). Cd correlated strongly with Pb ($r = 0.9610$) and Cl ($r = -0.7223$) and Pb correlated negatively with Cl ($r = -0.6841$).

Health risk indices

In this study, health risk was assessed using Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI) and Dietary Exposure (DE) indices. Tables 9, 10, 11 and 12 below shows the EDI, DE, THQ and HI of all canned groups sampled across various products types.

The EDI values in $\text{mg kg}^{-1} \text{bw day}^{-1}$ for canned fish ranged from 0.099 to 0.151 for Fe, 0.001–0.002 for Mn, 0.01–0.0037 for Zn, 0.033–0.049 for NO₃ and 0.013–0.019 for NO₂. Cd and Pb were below detectable limit. The EDI for canned meat had the following ranged values in $\text{mg kg}^{-1} \text{bw day}^{-1}$; Fe (0.469–0.693), Mn (0.006–0.011), Zn (0.083–0.158), Cd (0–0.001), Pb (BDL), NO₃ (0.159–0.197) and NO₂ (0.062–0.076). The

results from the analyses revealed that canned beans/peas had the highest EDI with values (in $\text{mg mg kg}^{-1} \text{bw day}^{-1}$) ranging from 1.325 to 1.937 for Fe, 0.035–0.049 for Mn, Zn (0.515–0.885), Cd (0–0.003), Pb (0–0.002), NO₃ (0.705–0.953) and NO₂ (0.274–0.371). The ranged values obtained from the EDI of sweet corn in $\text{mg kg}^{-1} \text{bw day}^{-1}$ are; Fe (0.168–0.23), Mn (0.005–0.008), Zn (0.062–0.110), Cd and Pb (BDL), NO₃ (0.084–0.109) and NO₂ (0.033–0.042). The established EDI range from the various canned categories in this study were compared to established provisional tolerable daily intake (PTDI) and the values were within benchmark except for nitrates in canned meat which had a maximum value exceeding the benchmark as shown in Table 13.

The DE of the various parameters in the canned categories were also compared with recommended daily requirement set for each parameters as shown in Table 14. But the DE of canned fish for each parameters had values (in $\text{mg kg}^{-1} \text{day}^{-1}$) ranging from 6.957 to 10.564 for Fe, 0.062–0.114 for Mn, Zn ranged from 0.676 to 2.598, Cd (0–0.008), Pb (0–0.007), NO₃ (2.331–3.399), NO₂ (0.907–1.335) and Na (16.67–19.14). In canned meat, the ranged values ($\text{mg kg}^{-1} \text{day}^{-1}$) were; Fe (32.85–48.49), Mn (0.394–0.742), Zn (5.779–11.03), Cd (0–0.035), Pb (0–0.026), NO₃ (11.13–13.78), NO₂ (4.33–5.32) and Na (69.18–76.56). The highest DE ($\text{mg kg}^{-1} \text{day}^{-1}$) was recorded in the canned beans/peas categories. They are; Fe (92.78–135.62), Mn (2.435–3.44), Zn (36.03–61.96), Cd (0–0.206), Pb (0–0.107), NO₃ (49.32–66.68), NO₂ (19.18–25.94) and Na (236.15–325.69). DE of sweet corn ranged from 11.78 to 16.30, 0.33–0.53, 4.34–7.72, 0–0.019, 0–0.012, 5.91–7.63, 2.3–2.96 and 31.80–41.80 $\text{mg kg}^{-1} \text{bw day}^{-1}$ for Fe, Mn, Zn, Cd, Pb, NO₃, NO₂ and Na respectively.

THQ values for all canned foods categories were less than 1 except canned beans/peas with values greater than 1. HI ranged from 0.421 to 11.824 in the food categories as shown in Tables 9, 8, 10, 11 and 12.

Table 9 Health risk indices in canned fish

Parameters	RfD	EDI (mg kg ⁻¹ bw day ⁻¹)	DE (mg kg ⁻¹ day ⁻¹)	THQ	HI
Product type A					
Fe	0.7	0.140	9.813	0.200	0.661
Mn	0.14	0.001	0.085	0.009	
Zn	0.3	0.030	2.070	0.099	
Cd	0.001	0.000	0.008	0.111	
Pb	0.0036	0.000	0.007	0.029	
NO ₃	1.6	0.047	3.320	0.030	
NO ₂	0.1	0.018	1.289	0.184	
Na			17.905		
Product type B					
Fe	0.7	0.099	6.957	0.142	0.560
Mn	0.14	0.001	0.062	0.006	
Zn	0.3	0.037	2.589	0.123	
Cd	0.001	0.000	0.004	0.052	
Pb	0.0036	0.000	0.004	0.015	
NO ₃	1.6	0.049	3.431	0.031	
NO ₂	0.1	0.019	1.335	0.191	
Na			17.199		
Product type C					
Fe	0.7	0.151	10.564	0.216	0.558
Mn	0.14	0.001	0.087	0.009	
Zn	0.3	0.024	1.711	0.081	
Cd	0.001	0.000	0.003	0.037	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.048	3.343	0.030	
NO ₂	0.1	0.019	1.299	0.186	
Na			16.699		
Product type D					
Fe	0.7	0.105	7.325	0.149	0.421
Mn	0.14	0.001	0.087	0.009	
Zn	0.3	0.010	0.676	0.032	
Cd	0.001	0.000	0.006	0.080	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.033	2.331	0.021	
NO ₂	0.1	0.013	0.907	0.130	
Na			18.418		
Product type E					
Fe	0.7	0.133	9.292	0.190	0.571
Mn	0.14	0.002	0.114	0.012	
Zn	0.3	0.021	1.477	0.070	
Cd	0.001	0.000	0.006	0.080	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.049	3.399	0.030	
NO ₂	0.1	0.019	1.325	0.189	
Na			19.138		

Table 10 Health risk indices in canned meat

Parameters	RfD	EDI (mg kg ⁻¹ bw day ⁻¹)	DE (mg kg ⁻¹ day ⁻¹)	THQ	HI
Product type A					
Fe	0.7	0.618	43.245	0.883	2.389
Mn	0.14	0.006	0.394	0.040	
Zn	0.3	0.083	5.824	0.277	
Cd	0.001	0.000	0.030	0.434	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.167	11.696	0.104	
NO ₂	0.1	0.065	4.550	0.650	
Na			69.184		
Product type B					
Fe	0.7	0.593	41.478	0.846	1.974
Mn	0.14	0.007	0.523	0.053	
Zn	0.3	0.083	5.779	0.275	
Cd	0.001	0.000	0.005	0.069	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.162	11.331	0.101	
NO ₂	0.1	0.063	4.403	0.629	
Na			76.557		
Product type C					
Fe	0.7	0.693	48.493	0.990	2.454
Mn	0.14	0.006	0.437	0.045	
Zn	0.3	0.106	7.434	0.354	
Cd	0.001	0.000	0.013	0.183	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.197	13.776	0.123	
NO ₂	0.1	0.076	5.322	0.760	
Na			69.264		
Product type D					
Fe	0.7	0.469	32.845	0.670	2.175
Mn	0.14	0.009	0.643	0.066	
Zn	0.3	0.158	11.030	0.525	
Cd	0.001	0.000	0.000	0.000	
Pb	0.0036	0.000	0.013	0.051	
NO ₃	1.6	0.191	13.389	0.120	
NO ₂	0.1	0.074	5.206	0.744	
Na			75.050		
Product type E					
Fe	0.7	0.505	35.315	0.721	2.527
Mn	0.14	0.011	0.742	0.076	
Zn	0.3	0.122	8.518	0.406	
Cd	0.001	0.001	0.035	0.503	
Pb	0.0036	0.000	0.026	0.104	
NO ₃	1.6	0.159	11.133	0.099	
NO ₂	0.1	0.062	4.326	0.618	
Na			75.718		

Table 11 Health risk indices in canned beans/peas

Parameters	RfD	EDI (mg kg ⁻¹ bw day ⁻¹)	DE (mg kg ⁻¹ day ⁻¹)	THQ	HI
Product type A					
Fe	0.7	1.397	97.795	1.996	10.133
Mn	0.14	0.040	2.769	0.283	
Zn	0.3	0.515	36.025	1.715	
Cd	0.001	0.002	0.142	2.029	
Pb	0.0036	0.000	0.007	0.028	
NO ₃	1.6	0.904	63.289	0.565	
NO ₂	0.1	0.352	24.623	3.518	
Na			288.856		
Product type B					
Fe	0.7	1.898	132.869	2.712	11.824
Mn	0.14	0.039	2.741	0.280	
Zn	0.3	0.885	61.955	2.950	
Cd	0.001	0.002	0.128	1.826	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.928	64.951	0.580	
NO ₂	0.1	0.348	24.339	3.477	
Na			236.146		
Product type C					
Fe	0.7	1.776	124.321	2.537	9.107
Mn	0.14	0.047	3.280	0.335	
Zn	0.3	0.580	40.612	1.934	
Cd	0.001	0.000	0.000	0.000	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.953	66.683	0.595	
NO ₂	0.1	0.371	25.943	3.706	
Na			287.422		
Product type D					
Fe	0.7	1.325	92.783	1.894	10.281
Mn	0.14	0.035	2.435	0.249	
Zn	0.3	0.714	49.998	2.381	
Cd	0.001	0.001	0.092	1.319	
Pb	0.0036	0.001	0.071	0.282	
NO ₃	1.6	0.921	64.482	0.576	
NO ₂	0.1	0.358	25.077	3.582	
Na			293.926		
Product type E					
Fe	0.7	1.937	135.624	2.768	11.608
Mn	0.14	0.049	3.436	0.351	
Zn	0.3	0.583	40.839	1.945	
Cd	0.001	0.003	0.206	2.941	
Pb	0.0036	0.002	0.107	0.423	
NO ₃	1.6	0.705	49.317	0.440	
NO ₂	0.1	0.274	19.184	2.741	
Na			325.691		

Table 12 Health risk indices in canned sweet corn

Parameters	RfD	EDI (mg kg ⁻¹ bw day ⁻¹)	DE (mg kg ⁻¹ day ⁻¹)	THQ	HI
Product type A					
Fe	0.7	0.196	13.692	0.279	1.336
Mn	0.14	0.006	0.411	0.042	
Zn	0.3	0.064	4.496	0.214	
Cd	0.001	0.000	0.019	0.276	
Pb	0.0036	0.000	0.012	0.047	
NO ₃	1.6	0.106	7.405	0.066	
NO ₂	0.1	0.041	2.881	0.412	
Na			31.799		
Product type B					
Fe	0.7	0.203	14.213	0.290	0.957
Mn	0.14	0.005	0.327	0.033	
Zn	0.3	0.062	4.348	0.207	
Cd	0.001	0.000	0.000	0.000	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.094	6.614	0.059	
NO ₂	0.1	0.037	2.570	0.367	
Na			34.621		
Product type C					
Fe	0.7	0.168	11.784	0.240	0.954
Mn	0.14	0.008	0.529	0.054	
Zn	0.3	0.084	5.856	0.279	
Cd	0.001	0.000	0.000	0.000	
Pb	0.0036	0.000	0.000	0.000	
NO ₃	1.6	0.084	5.909	0.053	
NO ₂	0.1	0.033	2.297	0.328	
Na			41.797		
Product type D					
Fe	0.7	0.200	14.006	0.286	1.238
Mn	0.14	0.007	0.500	0.051	
Zn	0.3	0.110	7.718	0.368	
Cd	0.001	0.000	0.004	0.060	
Pb	0.0036	0.000	0.004	0.017	
NO ₃	1.6	0.101	7.093	0.063	
NO ₂	0.1	0.039	2.759	0.394	
Na			36.261		
Product type E					
Fe	0.7	0.233	16.301	0.333	1.193
Mn	0.14	0.007	0.475	0.048	
Zn	0.3	0.076	5.326	0.254	
Cd	0.001	0.000	0.003	0.048	
Pb	0.0036	0.000	0.005	0.020	
NO ₃	1.6	0.109	7.626	0.068	
NO ₂	0.1	0.042	2.957	0.422	
Na			37.635		

Table 13 Comparing EDI with recommended intake values from various standards

Canned food	Parameter	EDI (mg kg ⁻¹ bw day ⁻¹) range	Provisional tolerable daily intake (mg kg ⁻¹ bw day ⁻¹)	References
Fish	Fe	0.099–0.151	0.8	[14]
	Mn	0.001–0.002	0.067	[15]
	Zn	0.01–0.0037	1	[16]
	Cd	0-BDL	0.001	[17]
	Pb	0-BDL	0.00357	[18]
	NO ₃	0.033–0.049	0–3.7	[19]
	NO ₂	0.013–0.019	0–0.07	[19]
Meat	Fe	0.469–0.693	0.8	[14]
	Mn	0.006–0.011	0.067	[15]
	Zn	0.083–0.158	1	[16]
	Cd	0–0.001	0.001	[17]
	Pb	0-BDL	0.00357	[18]
	NO ₃	0.159–0.197	0–3.7	[19]
	NO ₂	0.062–0.076	0–0.07	[19]
Beans/Peas	Fe	1.325–1.937	0.8	[14]
	Mn	0.035–0.049	0.067	[15]
	Zn	0.515–0.885	1	[16]
	Cd	0–0.003	0.001	[17]
	Pb	0–0.002	0.00357	[18]
	NO ₃	0.705–0.953	0–3.7	[19]
	NO ₂	0.274–0.371	0–0.07	[19]
Sweet corn	Fe	0.168–0.233	0.8	[14]
	Mn	0.005–0.008	0.067	[15]
	Zn	0.062–0.110	1	[16]
	Cd	0-BDL	0.001	[17]
	Pb	0-BDL	0.00357	[18]
	NO ₃	0.084–0.109	0–3.7	[19]
	NO ₂	0.033–0.042	0–0.07	[19]

Discussion

The mean concentration heavy metals, Nitrate and Nitrite, (Fe, Zn, Cd, Pb, Mn and As across the canned food categories are presented in Figs. 1 and 2. The mean values for nitrates ranged from 54.22 ± 9.52 to 93.92 ± 3.73 mg kg⁻¹ and the values were above Food Standards Australia New Zealand (FSANZ) bench marks. Nitrites mean values ranged from 21.1 ± 3.69 to 36.54 ± 1.45 mg kg⁻¹ across the canned food categories and were below FSANZ bench marks. Heavy metals concentrations across the canned food categories ranged from 130.68 ± 1.74 to 303.08 ± 11.57 mg kg⁻¹ (Fe), 1.44 ± 0.34 – 6.3 ± 0.35 mg kg⁻¹ (Mn), 15.72 ± 3.49 – 91.88 ± 3.95 mg kg⁻¹ (Zn), $0–0.23 \pm 0.04$ mg kg⁻¹ (Cd), and $0–0.17 \pm 0.08$ mg/kg (Pb). Cd was above EU standard in all canned groups while Pb exceeded same standard in canned meat.

Health risk estimations showed as EDI and DE are shown in Tables 9, 10, 11 and 12. The values of EDI ranged from

0.033 to 0.953 mg kg⁻¹ bw day⁻¹ and 0.013 to 0.371 mg kg⁻¹ bw day⁻¹, for nitrates and nitrites respectively.

The Fe concentration in this study was far higher than that reported by Zarei et al. [24]. In their study, Fe ranged from 0.009 to 14.207 µg g⁻¹ in canned tuna fish. It was also higher than the result obtained by Iwuoha et al. [25] were the Fe level in canned Geisha and Founty Mackerel in Choba market ranged from 0 to 0.0379 mg kg⁻¹. Zn in this study were higher than the findings of Dallatu et al. [26,] who assessed the level of heavy metals in fresh and canned foods consumed in Northern central Nigeria reported Zn to range from 0.0526 to 1.5472 mg kg⁻¹ in canned foods and 0.17841–6.41113 in fresh food samples. Cd in this study corroborates with that of Dallatu et al. [26] where the Cd assessed in fresh and canned foods were found to be higher than WHO standards and the values ranged from 0.0073 to 0.1919 mg kg⁻¹. This may pose a threat considering the fact that accumulation of Cd in the human body may induce kidney dysfunction, skeletal damage and reproductive deficiencies [27]. Lead in this study did not corroborate the findings

Table 14 Comparing DE with recommended intake values from various standards

Canned food	Parameter	DE (mg kg ⁻¹ day ⁻¹)	Recommended daily requirement (mg day ⁻¹)	References
Fish	Fe	6.957–10.564	10–15	[20]
	Mn	0.062–0.114	2–9	[21]
	Zn	0.676–2.589	15–22	[16]
	Cd	0–0.008	–	–
	Pb	0–0.007	0.075	[22]
	NO ₃	2.331–3.399	–	–
	NO ₂	0.907–1.335	–	–
	Na	16.699–19.138	2300	[23]
Meat	Fe	32.845–48.493	10–15	[20]
	Mn	0.394–0.742	2–9	[21]
	Zn	5.779–11.030	15–22	[16]
	Cd	0–0.035	–	–
	Pb	0–0.026	0.075	[22]
	NO ₃	11.133–13.776	–	–
	NO ₂	4.326–5.322	–	–
	Na	69.184–76.557	2300	[23]
Beans/Peas	Fe	92.783–135.624	10–15	[20]
	Mn	2.435–3.436	2–9	[21]
	Zn	36.025–61.955	15–22	[16]
	Cd	0–0.206	–	–
	Pb	0–0.107	0.075	[22]
	NO ₃	49.317–66.683	–	–
	NO ₂	19.184–25.943	–	–
	Na	236.146–325.691	2300	[23]
Sweet corn	Fe	11.784–16.301	10–15	[20]
	Mn	0.327–0.529	2–9	[21]
	Zn	4.348–7.718	15–22	[16]
	Cd	0–0.019	–	–
	Pb	0–0.012	0.075	[22]
	NO ₃	5.909–7.626	–	–
	NO ₂	2.297–2.957	–	–
	Na	31.799–41.797	2300	[23]

of Bordajandi et al. [28] which reported Pb values as high as 217 µg/g in sardine, 17.1 µg g⁻¹ in canned tuna and 69.6 in canned sardines.

The results for Nitrate and Nitrite from this study were found to be higher than results obtained from the New Zealand's nitrates and nitrites diet study were ninety-seven percent (97%) of the processed foods and meat analysed complied with the Australia New Zealand Food Standards with two meat samples containing low levels of nitrate and one with excessive nitrite [29]. The high levels recorded could be dangerous because nitrates are generally regarded to be of low toxicity but the toxicological squeals of nitrate exposure are considered to be virtually attributed to its conversion to nitrite. Nitrite reacts with haemoglobin (Hb) to form methaemoglobin (MetHb) in

the blood which is the toxicological end point following nitrate and nitrite exposure. MetHb levels of up to 10% are typically not associated with clinical signs in humans. At a higher level, MetHb is associated with clinical signs including cyanosis, impaired aerobic respiration, and metabolic acidosis and in severe cases, death [30, 31]. Outside the use of nitrates and nitrites as additives in canned foods, the high level in this study may suggest a synergistic effect of the use of nitrogen rich fertilizer for cultivation alongside the contribution during manufacture process for preservation.

The observed pH values from this study did not differ widely from each canned categories assessed as shown in Fig. 3. This shows that the values are largely maintained within different canned foods.

Fig. 1 Mean concentration (mg kg^{-1}) of heavy metals across canned food categories. The metal concentrations across canned categories tend to vary. Manganese appears to increase significantly from canned fish to canned sweetcorn. Cadmium was highest in canned beans/peas. Values are mean $\pm$ SE ($n = 25$ per category)

Fig. 2 Mean concentration (mg kg^{-1}) of chemical additives across canned food categories. The additives tend to be similar across the canned categories with no wide variation. Values are mean $\pm$ SE ($n = 25$ per category)

Health assessment

In this study, possible health risk on consumption of the canned foods was assessed using Health risk indices reported as Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI) and Dietary Exposure (DE).

EDI values in $\text{mg kg}^{-1} \text{ bw day}^{-1}$ for Fe ranged from 0.099 to 0.15, 0.469–0.693, 1.325–1.937, 0.168–0.23 for canned fish, meat, beans/peas and sweet corn respectively were mostly found to be within PTDI of $0.8 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ set by Joint Expert Committee on Food Additives (JECFA) [14]

Fig. 3 pH of the canned foods. There was slight difference in the pH values recorded across the foods sampled. Canned fish and meat showed no significant variation in the different canned products analysed ($P > 0.05$) but canned beans/peas and canned sweet corn showed a high significant difference across the product types ($P < 0.001$). Values are mean $\pm$ SE ($n = 25$ per category)

except for canned beans/peas which exceeded this limit. EDI of Fe in this study was found to higher than $0.09 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ that reported by Korfali and Hamdan [32] in their study of canned foods in Lebanon.

That of Mn ranged from 0.001 to 0.002, 0.006–0.011, 0.035–0.049, 0.005–0.008 $\text{mg kg}^{-1} \text{ bw day}^{-1}$ for canned fish,

meat, beans/peas and sweet corn. These values were lower than the PTDI set by Food Safety and Inspection Service (FSIS) [15] of $0.067 \text{ mg kg}^{-1} \text{ bw day}^{-1}$.

In a similar way, the EDI for Zn were found to be below $1 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ set by JECFA [16] and the range from this study was $0.01\text{--}0.0037$, $0.083\text{--}0.158$, $0.515\text{--}0.885$, $0.062\text{--}0.110 \text{ mg kg}^{-1} \text{ bw day}^{-1}$.

However, EDI for Cd was above the PTDI of $0.001 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ set by JECFA [17] in canned beans/peas, but canned meat recorded an EDI of $0.001 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ which is same as the PTDI but was below detectable limit for canned fish and sweet corn. The EDI for Cd in this study was found to be higher than those from previous studies; $0.11 \mu\text{g kg}^{-1} \text{ bw day}^{-1}$ reported by Bordajandi et al. [28] and $0.14 \mu\text{g kg}^{-1} \text{ bw day}^{-1}$ reported by Urieta et al. [33].

EDI for Pb was not recorded for all canned groups except canned beans/peas which recorded a range of $0\text{--}0.002 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ which was slightly below the PTDI of $0.00357 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ set by JECFA [18]. The EDI for Pb in this study was higher than $0.38 \mu\text{g/kg bw/day}$ reported by Bordajandi et al. [27] and also higher than $0.55 \mu\text{g kg}^{-1} \text{ bw day}^{-1}$ reported by Urieta et al. [33].

EDI calculated for NO_3 was within PTDI of $0\text{--}3.7 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ set by JECFA [19] which was between 0.033 and $0.953 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ across the canned groups. That of NO_2 was found to be higher than the PTDI set values of $0\text{--}0.07 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ in canned beans ($0.274\text{--}0.371 \text{ mg kg}^{-1} \text{ bw day}^{-1}$) and canned meat ($0.062\text{--}0.076 \text{ mg kg}^{-1} \text{ bw day}^{-1}$). The result from this study agrees with that of Thompson [29] that reported the EDI for New Zealand adults to nitrate and nitrite to range from 0 to $5 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ and $0\text{--}0.10 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ respectively.

The DE in this study was assessed to determine the values available on consumption of any of the canned products. Most diets are fortified with metals such as Fe and Zn but they are required in diet within a dietary intake level certified not to cause any form of toxicity. Hence, for this study, DE for Fe in the canned foods sampled ranged from 6.957 to $135.624 \text{ mg kg}^{-1} \text{ bw day}^{-1}$. This value were above the recommended daily requirement of $10\text{--}15 \text{ mg kg}^{-1} \text{ day}^{-1}$ set by Nordic Council of Ministers (NCM) [20] except for canned fish whose values were within the recommended intake level per day. This shows that consumption of these foods will not expose the consumer to any chance of anaemia. DE for Mn ranged from 0.062 to $3.436 \text{ mg kg}^{-1} \text{ day}^{-1}$ which was within the daily requirement recommended in food by WHO [21] which is $2\text{--}9 \text{ mg kg}^{-1} \text{ bw day}^{-1}$. Zn was found to have a DE within the daily recommended intake of $15\text{--}22 \text{ mg kg}^{-1} \text{ day}^{-1}$ set by JECFA [16] except for canned beans/peas with a DE of $36.025\text{--}61.955 \text{ mg kg}^{-1} \text{ bw day}^{-1}$. Cd, NO_3 and NO_2 recorded DE values which ranged from 0 to 0.206 ,

$2.331\text{--}66.683$, $0.907\text{--}25.943 \text{ mg kg}^{-1} \text{ day}^{-1}$ respectively with no data for comparison. There is a concern of Pb toxicity in canned beans/peas which had a DE of $0.107 \text{ mg kg}^{-1} \text{ day}^{-1}$ slightly above the daily requirement of $0.075 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ set by US FDA [22].

There is no risk of Na induced hypertension because the DE of Na in this study was far below the daily requirement of $2300 \text{ mg kg}^{-1} \text{ bw day}^{-1}$ as specified by Centres for Disease Control and Prevention (CDC) [23]. The DE for the various parameters in this study may not totally account for their availability in a single diet. This is because, when they are used alongside other food substances in food preparation, the levels may likely increase hence increasing the risk associated with each parameters due to synergistic effect.

The human health risks posed by contaminant exposure are usually characterized by the target hazard quotient (THQ) [6]. If the value of THQ is less than 1, the risk of non-carcinogenic toxic effects is assumed to be low. When it exceeds 1, there may be concerns for potential health risks associated with overexposure. In this study, the THQ values for all canned foods categories were less than 1 except canned beans/peas with values greater than 1 in all of its parameters except Mn suggesting that there is a risk of a non-carcinogenic toxic effect. HI ranged from 0.421 to 11.824 in the food categories.

Results from this study revealed potential Cd toxicity and risk of non-carcinogenic toxic effect from canned beans/peas consumption; it is therefore imperative to monitor possible contamination of canned foods. This study also became an eye opener, because it demonstrated that some canned foods sold in Nigeria markets do not carry NAFDAC Registration No. NAFDAC (National Agency for Food and Drug Administration and Control) is an arm of the Nigeria Government whose mission is to safeguard the public health by ensuring that only the right quality of food, drugs and other regulated products are manufactured, exported, imported, advertised, sold and used. It is imperative therefore that such agency should collaborate with Institutions all over the country to help conduct research regularly and use the results as a monitoring guide. I also recommend that a total diet study be carried out to cover the scope outside of this research.

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Compliance with ethical standards

Conflict of interest This work has been extensively discussed in parts and whole at the 7th international toxicology symposium in Africa held in South Africa in August 2015. Martins Oshioriamhe Ainerua received a travel Grant from the University of Benin to the 7th international toxicology symposium in South Africa.

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