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Concentration and Human Health Risk Assessment of Alkylphenols, Bisphenols and Some Heavy Metals in Selected Canned Foods in Lagos, Nigeria

AJAYI, AT; *NJOKU, KL

Department of Cell Biology and Genetics, University of Lagos, Akoka Lagos, Nigeria

**Corresponding Author Email: knjoku@unilag.edu.ng; kecynjoku@gmail.com*
Co-Author Email: ajayianjolaoluwa12@gmail.com

ABSTRACT: The concentrations and human health risk associated with alkylphenols, bisphenols, Pb, Fe, Cd, and Cr were evaluated in samples of eight different canned foods sold in Lagos, Nigeria using standard techniques. The concentrations of Pb ranged from 0.002 to 2.84 mg/kg, Fe values ranged from 1.05 to 140.34 mg/kg, Cd levels ranged from 0.03 to 0.65 mg/kg, Cr levels ranged from 0.35 to 0.77 mg/kg, and bisphenol-A (BPA) values ranged from 33.90 to 70.14 ng/g across the canned foods. The estimated daily intake (EDI) through the consumption of the different canned foods sampled ranged from $3.67x10^{-6}$ to $2.33x10^{-2}$ mg/kg/day for Pb, $1.02x10^{-3}$ to 1.43 mg/kg/day for Fe, $1.50x10^{-5}$ to $6.61x10^{-3}$ mg/kg/day for Cd, $7.80x10^{-5}$ to $7.83x10^{-3}$ mg/kg/day for Cr, and $1.70x10^{-5}$ to $5.81x10^{-4}$ mg/kg/day for BPA. Most canned food groups had EDI values that were lower than the recommended provisional tolerable daily intake for the Joint Expert Committee on Food Additives However, canned peas and canned beans had EDI values that were higher than the recommended limits for Pb, Fe, and Cr. The results from the hazard index (HI) suggest that there is a risk of a non-carcinogenic toxic effect for canned tomatoes, canned fish, canned corn, canned beans, and canned peas as their values were greater than 1. Results from this study can be used to inform regulatory decisions, guide industry standards for the production of these products and used by consumers to make informed decisions about which canned foods to purchase and consume.

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Commercialization of canned foods is widespread because canned items have a long shelf life, do not require refrigeration, and do not require special handling during transportation or distribution (Ainerua, *et al.*, 2019). Canned foods are significant components of the diet of most individuals in developed countries possibly due to their convenience and all-year-round availability (Enuneku, *et al.*, 2019). However, there are some concerns on canned foods which include high salt content, sugar, botulism, tissue damage, BPA exposure, metallic taste, low nutritional value, chemical additives, and high sodium content, which can contribute to different health problems (Andujar *et al.*, 2019). To properly execute food safety policies, laws, and standards, it is important to comprehend the notion of risk analysis in the context of food safety management. Science-based methods and risk assessment are closely related to procedures like excellent quality practices and are a crucial component of risk analysis to enhance contemporary food safety systems. The ability of conventional food safety systems to address current difficulties is strengthened by health risk analysis (Enuneku, *et al.*, 2019). Risk-based controls are currently used in place of food safety controls at every level of food production (Attrey, 2017).

**Corresponding Author Email: knjoku@unilag.edu.ng;*

Alkylphenols, bisphenols, their metabolites and heavy metals have all been identified as potentially harmful compounds because of their impact on human health (Salgueiro-González, *et al.,* 2017; Li, *et al.,* 2020). Humans are primarily exposed to bisphenols and alkylphenols through food since they are frequently used in the production of plastics (Seccia, *et al.,* 2018). Shaaban *et al*. (2022) reported the presence of BPA, BPE, and BPS in 84.3% of the food samples tested.

Bisphenols are produced through the condensation of phenol with ketones or aldehydes and are employed as a stabiliser, antioxidant, and plastic-mixing agent in polymers such as PVC (Dias *et al*., 2022). Bisphenols are used in plastic products like toys, dental parts, food and water containers, medical equipment, and electrical gadgets (Baute-Pérez *et al.,* 2022). Bisphenols are also used to make thermal paper, epoxy resins, and polycarbonate plastics, which are all used to make everyday things (Kim *et al.,* 2019). Bisphenol-A (BPA) plastics are very stable, robust, and able to withstand exposure to high temperatures as well as collisions with high forces. They are also useful parts of safety equipment due to their ability to survive heating in microwave ovens. Products for food and drink have a longer shelf life because of BPA (Shaaban *et al.,* 2022). BPA penetrates the environment and food supply via plastics containing BPA, and its estrogenic effect in the hypothalamus may impair male and female reproductive functions. EU regulation establishes the specific migration limit (SML) for BPA in food products at 0.6 mg/kg (Chen, *et al.*, 2016).

Alkylphenols are produced by alkylating phenol or hydroxylating an acyclic ring-closing molecule, can enter food in various ways, and may affect the central nervous system by mimicking estrogenic feedback (Uğuz, *et al.,* 2009). Alkylphenols are active ingredients in spermicides, different laboratory detergents, personal care products, and some pesticide formulations (Toor and Sikka, 2017). Humans can ingest alkylphenols through contaminated food and water, as well as through contact with personal care products and detergents (Soares *et al.,* 2008). Due to their ability to disrupt the endocrine system, alkylphenols are one of the most dangerous new pollutants (Snedeker and Hay, 2014; Crini *et al.,* 2022).

Heavy metals are naturally occurring metals whose excessive levels are harmful to individuals and the environment and affect the biochemistry and physiology of plants, animals, and humans. Heavy metals get into foods from the soil and water through absorption and drinking and through food processing and packaging. Certain diets increase the metal burden of the body as they may accumulate and interfere with necessary physiological processes (Tchounwou, *et al.*, 2014).

The objective of this study was to evaluate the concentration and the health risk of alkylphenols, bisphenols, Pb, Fe, Cd, and Cr in samples of different canned foods sold in Lagos, Nigeria.

MATERIALS AND METHODS

Sample Collection: A total of eight samples of canned foods made by different brands and manufacturers were purchased from one of the largest supermarkets in Lagos, Nigeria. The canned foods used were fish, meat, beans, peas, tomato paste, milk, malt, and sweet corn. Each can was assigned a sample code.

Extraction and Determination of Bisphenol Analogues: The entire contents of a canned sample were fully blended using an Omni blender homogenizer. All content from canned samples was extracted by adding n-heptane and acetonitrile (20 ml + 20 ml) into a glass measure and using a homogeniser for 5 minutes. Canned samples that contained little lipids, such as meat, fish, vegetables, and drinks, were decanted. The mixture was steamed for 5 minutes, then diluted with water to 50 ml and placed in a 300 ml separating funnel. The milk and tomato samples were extracted by weighing 10 g of each sample, adding 20 ml of acetonitrile to a 50-ml glass beaker, and shaking it for 5 min with a shaker. The heptane solvent was gathered and bisphenol determinations were done using a GC/MS (Varian, 3800/4000) (IUPAC, 2002).

Extraction and Determination of Alkylphenol Analogues: Each sample was homogenised using a macerator for 5 minutes, then extracted and fortified with a 20 ml internal standard, 13C6 4-n-nonylphenol (1 µg/ml). 30 mL of methanol was added to this, and the mixture was shaken for 3 minutes before settling. A total of 25 ml of acidified water was added to the combined methanol extract and shaken by hand for another 2 minutes. The methanol/water mixture was then partitioned against 270 ml of cyclohexane, followed by a final partition into 60 ml of Cyclohexane (Selvaraj, *et al.,* 2014).

After heating in a muffle furnace for at least 4 hours, alumina was deactivated with 15% (w/w) water and the columns were packed with 5.6 g of deactivated alumina and topped with a 5-mm layer of anhydrous sodium sulphate. The concentrated extracts were chromatographed on the conditioned columns, which were eluted successively with 50 ml petroleum ether followed by 50 ml dichloromethane and purified further using FlorisilTM. The dichloromethane fraction was collected and concentrated to approximately 0.5 ml followed by the addition of 50 ml of the internal sensitivity standard (13C PCB 52, 0.8 µg/ml) and the extract concentrated to a final volume of approximately 100 ml, which was used for GC-MS (Varian, 3800/4000) analysis (IUPAC, 2002).

Digestion and Determination of Heavy Metals The levels of the heavy metals in (lead, chromium, iron and cadmium) in the canned food samples were determined using an atomic absorption spectrophotometer (N1100A model). Calibration solutions of lead, zinc, iron, cadmium, chromium, and arsenic were obtained by diluting standard samples obtained from Sigma. A total of 5.0 mL of HNO_3/HCl (3:2) was added to a 100-mL beaker containing 5.0g of each sample and digested at 130 °C on a hot plate. After cooling, the digested sample was filtered with a 0.45-mm membrane filter and stored in clean polyethene bottles. The samples were analysed using the standard method (APHA 1992).

Health Risk Assessment of Canned Foods

Estimated Daily Intake (EDI): EDI was calculated using the following equation recommended by the United States Environmental Protection Agency (USEPA) (USEPA, 1997).

$$EDI = \frac{C\ X\ IRX\ EF\ X\ ED}{BW\ X\ AT}$$

where EDI is the average daily intake or dose through ingestion (mg/kg/day); C is the parameter concentration in the exposure medium (mg/kg); IR is the ingestion rate (kg/day) (IR for canned tomatoes (0.05 kg/day), canned fish (0.03 kg/day), canned malt (0.03 kg/day), canned milk (0.11 kg/day), canned meat (0.013 kg/day), canned corn (0.072 kg/day), canned beans (0.61 kg/day), and canned peas (0.61 kg/day); EF is the exposure frequency (365 days/year); ED is the exposure duration (54 years which is the average age of adults in Nigeria); BW is the body weight (60kg) and AT is the time period over which the dose is averaged (365 days/year × number of exposure years, assumed to be 54 years for adults).

Target Hazard Quotient: The target hazard quotient (THQ) for human health risk posed by contaminant exposure was calculated by dividing the estimated daily intake (EDI) by the reference dose (RfD) (USEPA, 1997). The THQ based on non-cancer toxic risk was determined as

$$THQ = \frac{Estimated\ Daily\ Intake\ (EDI)}{Reference\ Dose\ (RfD)}$$

Hazard Index: The target hazard quotient (THQ) of different contaminant pathway was added up to get the hazard index (HI). The HI gives an estimate of the total risk from multiple contaminant pathways (USEPA, 1997). It was calculated as

$$HI = \sum(THQ_1\ , THQ_2, THQ_3 \ldots\ldots THQ_n)$$

If the value of HI is less than 1, the risk of non-carcinogenic toxic effects is assumed to be low. When it exceeds 1, there may be concerns about potential health risks associated with overexposure (Ainerua *et al.*, 2019).

Statistical Analysis: The concentrations of alkylphenols, bisphenols, and heavy metals in the various canned food samples were subjected to correlation analysis and two-way analysis of variance (ANOVA) using GraphPad Prism 9.0 and the level of significance was chosen at $p < 0.05$.

RESULTS AND DISCUSSION

Table 1 shows that the levels of lead ranged from 0.002 to 2.84 mg/kg for all the selected canned groups and were above 0.01 mg/kg, which is the European Food Safety Authority standard (EFSA) and WHO standard, except for canned milk, which was below the limit (FAO/WHO, 2006; EFSA, 2010). Lead in this study was higher than the findings of Dallatu *et al.* (2013), who assessed the level of heavy metals in fresh and canned foods consumed in north central Nigeria and reported Pb to range from 0.1051 to 0.2852 mg/kg in canned foods. It was also higher than the result obtained by Ojezele *et al.*, (2021) whose Pb values ranged from 1.40 to 1.76 mg/kg. It was also lower in canned tomatoes at 2.95 mg/kg and canned beans at 3.00 mg/kg in a study by Massadeh and Al-Massaedh (2017). The use of lead in product packaging materials or low-level plant lead absorption may be the cause of the presence of lead in canned food. Lead has been discovered to be a potential enzyme inhibitor, a carcinogen, and an obstruction to fertility. It also damages the kidneys. Pregnant women and children under the age of six are more susceptible to the negative effects of lead exposure on their health (Enuneku *et al.*, 2019).

Iron values ranged from 1.05 to 140.34 mg/kg across the canned food categories and most of them were below 40 mg/kg, which is the European Directorate for the Quality of Medicines and Healthcare (EDQM) standard, except for canned fish, canned beans, and peas, which had Fe above the limit (43.12, 72.87, and 140.34 mg/kg) (EDQM, 2022). The concentration of iron in this study was higher than that obtained by Korfali and Hamdan (2013), who reported Fe values as high as 13.23 µg/g in canned fish, 16.00 µg/g in canned meat, and 8.25 µg/g in canned peas. Food products can become contaminated by packing materials which migrate toxic trace components into the food, resulting in tainted canned meals (Fiamegos *et al.,* 2016). Children are more vulnerable to iron toxicity because they are exposed to the greatest number of iron-containing items; hence, iron poisoning has always been a topic of interest, especially to paediatricians. The major issue of excessive iron absorption is the risk of cancer (Jaishankar *et al.,* 2014).

Cadmium levels in the canned food samples used in this study ranged from 0.03 mg/kg to 0.65 mg/kg and were all above 0.005 mg/kg and 0.003 mg/kg, which are the EFSA standard and WHO standard acceptable limits in food, respectively (FAO/WHO, 2001; EFSA, 2009). Cadmium in this study was also higher than the findings of Dallatu *et al.*, (2013) who reported Cd to range from 0.0091 to 0.0297 mg/kg in canned foods. It was lower in canned tomatoes (0.49 mg/kg) and higher in canned beans (0.52 mg/kg in a study by Massadeh and Al-Massaedh (2017). Both short-term and long-term intoxications from cadmium are possible. Cadmium accumulates in the proximal tubular cells in increasing quantities, which is particularly harmful to the kidney. Through renal failure or bone injury, cadmium can trigger bone mineralization. Studies on humans and animals have shown that the adverse effects of cadmium exposure include hypercalciuria, renal stone formation, changes in calcium metabolism, and osteoporosis (skeletal deterioration). Higher doses of cadmium can cause gastrointestinal inflammation, which can cause vomiting and diarrhoea. If cadmium exposure is high during human pregnancy, problems including premature birth and low birth weights result (Jaishankar *et al.,* 2014).

The values for chromium we reported in this study ranged from 0.35 to 0.77 mg/kg and were all below 1 mg/kg and 13 mg/kg, which are the EFSA standard and WHO standard acceptable limit in food, respectively (FAO/WHO, 1966; EFSA, 2014). The concentration of chromium in this study was far higher than that reported by Ojezele *et al.;* (2021) in their study in which Cr ranged from 0.00 to 0.41 mg/kg. It was also higher than the result obtained by Korfali and Hamdan (2013), who reported Cr values as high as 0.76 µg/g in canned fish, 2.40 µg/g in canned meat, and 44.78 µg/g in canned peas. Hexavalent chromium compounds are more quickly absorbed by the digestive system and airways than trivalent chromium compounds. Once absorbed, they can damage the lining of the stomach and intestines, leading to irritation, inflammation, and ulceration. This can cause symptoms such as nausea, vomiting, and abdominal pain. Higher levels of chromium compounds in humans can block erythrocyte glutathione reductase, which in turn reduces the ability to convert methaemoglobin to haemoglobin (Jaishankar *et al.,* 2014).

Bisphenol-A values ranged from 33.90 to 70.14 ng/g across the canned food categories and were below 600 ng/g, which is the European Union's acceptable limit in food (EFSA, 2015). The concentrations of BPA in canned meat (84.00 ng/g) in this study were higher than the concentration reported in canned meat (11.9 ng/g) by Adeyi and Babalola (2019) and higher in the canned meat in the study done by Cao *et al.,* (2011) (10.5 ng/g). Canned fish (33.90 ng/g) in this study was higher than what was reported in canned fish (8.41 ng/g) by Adeyi and Babalola (2019) and lower in the canned fish in the study done by Cao *et al.,* (2011) (106 ng/g). The concentration in canned tomatoes (70.14 ng/g) in this study was higher than the concentration reported in canned tomatoes (1.38 ng/g) by Adeyi and Babalola (2019) and higher in the canned tomatoes in the study done by Cao *et al.,* (2011) (2.59 ng/g). In comparison to food packaged in plastic, glass, or paper containers, Shaaban *et al*. (2022) found that canned food had greater quantities of total bisphenols. Due to the fact that bisphenols are present in everyday products, humans are exposed to them (Dias *et al.,* 2022). Bisphenols damage the reproductive system and interfere with endocrine function. Chronic low-dose bisphenol exposure reduces prolactin, follicle-stimulating hormones, and luteinizing hormones while exhibiting estrogenic and antiandrogenic effects and altering spermatogenesis (Dias *et al.,* 2022). Bisphenol exposure has been linked to a number of neurological dysfunctions, including memory and cognitive impairment, as well as aggression, hyperactivity, anxiety, depression, autism, and neuroinflammation (Kim *et al.*, 2019). Infertility, breast cancer, and prostate cancer are among the harmful consequences of BPA on health. Additionally, some data suggest that it may also lead to heart difficulties, liver issues, and diabetes (Lang *et al.,* 2008; Konieczna *et al.,* 2015). The detection of bisphenols in the canned foods in our study therefore calls for caution in the consumption of such foods.

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

Table 2 shows EDI values for Pb ranged from 0.00367 mg/kg/day in canned milk to 0.0233 mg/kg/day in canned beans and were mostly found to be below the provisional tolerable daily intake (PTDI) of 0.00357 mg/kg/day set by the Joint Expert Committee on Food Additives (JECFA) except for canned beans, which exceeded this limit (JECFA, 1993). The EDI values for canned tomatoes, canned fish, canned corn, and canned beans were all above the PTDI of 0.64 µg/kg/day for the European Directorate for the Quality of Medicines and HealthCare (EDQM) (EDQM, 2022). The EDI for Pb in this study was lower than 0.002 mg/kg/day reported by Ainerua *et al.*, (2019) except for canned tomatoes and canned beans.

A lower estimated daily intake (EDI) of lead than the recommended provisional tolerable daily intake is generally considered safe and is not likely to result in adverse health effects. However, it's still important to monitor exposure to lead, as even low levels of the heavy metal can build up in the body over time and cause harm. It is also worth noting that some people like pregnant women and young children, may be more sensitive to lead exposure and may require a lower EDI than the PTDI to avoid health risks. A higher estimated daily intake (EDI) of lead than the recommended provisional tolerable daily intake (PTDI) can have serious health implications. Lead is a toxic metal that can cause damage to the nervous system, kidneys, and reproductive and cardiovascular systems. It is particularly harmful to children and can cause developmental delays, learning difficulties, and behavioural problems (Massadeh and Al-Massaedh, 2017; Ojezele *et al.*, 2021).

Table 1: Heavy Metals, Bisphenols and Alkylphenols in Canned Food (mg/kg)

Parameters	Canned Tomatoes	Canned Fish	Canned Malt	Canned Milk	Canned Meat	Canned Corn	Canned Beans	Canned Peas
Pb	2.84	1.81	0.23	0.002	0.51	0.63	2.29	BDL
Fe	43.12	30.16	2.04	1.05	16.57	34.56	72.87	140.34
Cd	0.38	0.03	0.04	BDL	0.30	0.17	0.54	0.65
Cr	0.54	0.35	ND	BDL	0.36	BDL	0.77	0.70
BPE	0.022	0.0267	0.0325	0.0283	0.0371	0.0956	0.0568	0.0202
BPC	0.0423	0.026	0.0406	0.058	0.0604	0.0936	0.0273	0.0278
BPA	0.0701	0.0339	0.034	0.0415	0.084	0.0686	0.0466	0.0571
BPZ	ND	ND	ND	ND	ND	ND	0.013	ND
BPG	0.0953	0.0345	0.0462	0.0506	0.0551	0.042	0.0245	0.0409
BPAF	ND	ND	ND	ND	0.0275	ND	ND	ND
BPP	ND	ND	ND	ND	0.012	ND	ND	ND
BPA-DGE	ND	ND	ND	ND	0.0209	ND	ND	ND
BPTMC	0.0866	0.0636	0.0816	0.0933	0.0613	0.0645	0.202	0.0889
2-methyl phenol	0.00403	0.00382	0.00431	0.0036	0.00325	0.00375	0.00775	0.00764
3,5-dimethyl phenol	0.0243	0.0241	0.0243	0.0247	0.0246	0.0246	ND	ND
2,6-dimethyl phenol	0.0461	0.026	0.0263	0.0268	0.0265	0.0265	0.00654	ND
4-butyl phenol	ND	ND	ND	0.0017	0.00798	0.00207	0.0251	0.0251
4-tert-butyl-2-methyl phenol	0.0183	0.018	0.0184	0.0201	0.0204	0.0201	0.0249	0.0247
4-hexyl phenol	0.0109	0.0165	0.0177	0.0108	0.0136	0.0168	0.0253	0.0252
4-octyl phenol	ND	ND	ND	ND	ND	ND	ND	0.00516
4-pentyl phenol	0.02	0.00835	0.00962	0.00892	0.00875	0.00892	0.019	0.00847
Nonylphenol	0.00194	ND	ND	ND	ND	ND	0.0137	0.00879
6-tert-butyl-2,4-dimethyl phenol	0.0119	0.00554	0.00541	0.0169	0.0659	0.00664	ND	ND

**ND = not detected, BDL= below detectable limit*

The EDI values for Fe ranged from 0.00102 mg/kg/day in canned malt to 1.43 mg/kg/day in canned peas and were mostly found to be below the PTDI of 0.8 mg/kg/day set by the Joint Expert Committee on Food Additives (JECFA), except for canned peas, 1.43 mg/kg/day, which exceeded this limit (JECFA, 1983). Canned beans and canned peas' EDI values were the only ones that were above the PTDI of 0.28 mg/kg/day set by the Expert Group on Vitamins and Minerals (EVM) (EVM, 2003).

Table 2: Estimated Daily Intake of Heavy Metals, Bisphenols and Alkylphenols in Canned Food (mg/kg/day)

Parameters	Canned Tomatoes	Canned Fish	Canned Malt	Canned Milk	Canned Meat	Canned Corn	Canned Beans	Canned Peas
Pb	0.00237	0.000905	0.000115	0.00000367	0.000111	0.000756	0.0233	NA
Fe	0.0359	0.0151	0.00102	0.00193	0.00359	0.0415	0.741	1.43
Cd	0.000317	0.000015	0.00002	NA	0.000065	0.000204	0.00549	0.00661
Cr	0.00045	0.000175	NA	NA	0.000078	NA	0.00783	0.00712
BPE	0.0000183	0.0000134	0.0000163	0.0000519	0.00000804	0.000115	0.000577	0.000205
BPC	0.0000353	0.000013	0.0000203	0.000106	0.0000131	0.000112	0.000278	0.000283
BPA	0.0000584	0.000017	0.000017	0.0000761	0.0000182	0.0000823	0.000474	0.000581
BPZ	NA	NA	NA	NA	NA	NA	0.000132	NA
BPG	0.0000794	0.0000173	0.0000231	0.0000928	0.0000119	0.0000504	0.000249	0.000416
BPAF	NA	NA	NA	NA	0.00000596	NA	NA	NA
BPP	NA	NA	NA	NA	0.0000026	NA	NA	NA
BPA-DGE	NA	NA	NA	NA	0.00000453	NA	NA	NA
BPTMC	0.0000722	0.0000318	0.0000408	0.000171	0.0000133	0.0000774	0.00205	0.000904
2-methyl phenol	0.00000336	0.00000191	0.00000216	0.0000066	0.0000007	0.0000045	NA	0.0000777
3,5-dimethyl phenol	0.0000203	0.0000121	0.0000122	0.0000453	0.00000533	0.0000295	0.0000788	NA
2,6-dimethyl phenol	0.0000384	0.000013	0.0000132	0.0000491	0.00000574	0.0000318	0.0000665	NA
4-butyl phenol	NA	NA	NA	0.00000312	0.00000172	0.00000248	0.000255	0.000255
4-tert-butyl-2-methyl phenol	0.0000153	0.000009	0.0000092	0.0000369	0.00000442	0.0000241	0.000253	0.000251
4-hexyl phenol	0.00000908	0.00000825	0.00000885	0.0000198	0.00000295	0.0000202	0.000257	0.000256
4-octyl phenol	NA	NA	NA	NA	NA	NA	NA	0.0000525
4-pentyl phenol	0.0000167	0.00000418	0.00000481	0.0000164	0.00000109	0.0000107	0.000193	0.0000861
Nonylphenol	0.00000162	NA	NA	NA	NA	NA	0.000139	0.0000894
6-tert-butyl-2,4-dimethyl phenol	0.00000992	0.00000277	0.00000271	0.000031	0.0000143	0.00000797	NA	NA

**NA = not applicable*

Liver damage, liver cirrhosis, pancreatic islet cell damage, diabetes, hypothyroidism, and hypogonadism can occur due to excess iron in the body (McDowell *et al* 2022). The EDI of Fe in this study was found to be lower than 1.94 mg/kg/day as reported by Ainerua *et al.*, (2019) in their study of canned foods. A lower estimated daily intake (EDI) of iron than the recommended provisional tolerable daily intake (PTDI) can result in iron deficiency, which is the most common nutritional deficiency in the world. Iron is an essential nutrient that is needed for the production of haemoglobin, which carries oxygen in the blood. Iron deficiency can cause fatigue, weakness, and decreased immunity, while a higher estimated daily intake of iron than the recommended PTDI can lead to iron toxicity, also known as iron poisoning (Korfali and Hamdan, 2013). EDI values for Cd ranged from 0.000015 mg/kg/day in canned fish to 0.00661 mg/kg/day in canned peas and were mostly found to be below the PTDI of 0.001 mg/kg/day set by the Joint Expert Committee on Food Additives (JECFA) and 0.00036 mg/kg/day set by the European Directorate for the Quality of Medicines and Healthcare (EDQM) except for canned beans and canned peas, 0.00549 and 0.00661 mg/kg/day, which exceeded these limits (JECFA, 1993; EDQM, 2022).

The EDI for Cd for canned beans and canned peas was found to be higher than 0.001 mg/kg/day reported by Ainerua *et al.* (2019). A lower estimated daily intake (EDI) of cadmium than the recommended provisional tolerable daily intake (PTDI) is generally considered safe and is not likely to result in adverse health effects from cadmium exposure. However, it is still important to monitor exposure to cadmium, as even low levels of the metal can build up in the body over time and cause harm, while a higher estimated daily intake of cadmium than the recommended provisional tolerable daily intake can result in cadmium toxicity and lead to serious health problems. Cadmium is a toxic metal that can accumulate in the body and cause damage to the kidneys, bones, and other organs (Massadeh and Al-Massaedh, 2017). The EDI values for Cr (0.00078mg/kg/day for canned meat to 0.00783mg/kg/day for canned beans) we obtained in this study were lower than the PTDI set by the European Directorate for the Quality of Medicines and HealthCare (EDQM) of 0.3 mg/kg/day (EDQM, 2022). A lower estimated daily intake (EDI) of chromium than the recommended provisional tolerable daily intake (PTDI) can result in chromium deficiency, which is a rare condition. Chromium is an essential trace mineral that plays a role in glucose metabolism and insulin function. Health issues like increased blood sugar, increased cholesterol levels, diabetes and heart attacks can result from Cr deficiency. Also, a deficiency in chromium can lead to symptoms such as impaired glucose tolerance and insulin resistance (Ojezele *et al.,* 2021). The EDI values of BPA in the studied canned food were lower than the PTDI limit of 0.01 mg/kg/day as determined by the European Commission Scientific Committee on Food (SCF, 2002). The EDI values of BPA in canned tomatoes (0.0584 µg/kg/day), canned fish (0.017 µg/kg/day), canned milk (0.0761 µg/kg/day), and canned meat (0.0182 µg/kg/day) in this study were lower than the EDI values reported in canned tomatoes (1.70 mg/kg/day), canned fish (3.43 mg/kg/day), canned milk (3.21 mg/kg/day), and canned meat (2.34 mg/kg/day) by Adeyi and Babalola (2019) in their study. BPA has adverse effects on human health, including developmental and reproductive effects and changes in metabolism and hormone levels, but some experts are concerned that even low levels of BPA exposure may be harmful to human health, especially in vulnerable populations such as pregnant women, infants, and young children. If an individual has a lower estimated daily intake (EDI) of BPA than the PTDI, they are likely not at significant risk of adverse health effects from BPA exposure. The human health risks posed by contaminant exposure are usually characterised by the target hazard quotient (THQ) and hazard index (HI). When THQ is greater than 1, there may be worries about potential health problems linked to overexposure to that specific substance. If THQ is less than 1, the risk of non-carcinogenic adverse effects from the substance is thought to be low. A particular food or drink is assumed to have a low risk of harmful non-carcinogenic effects if the value of HI is less than 1. When it is greater than 1, potential health problems from consuming too much of that particular food or drink may be an issue (Ainerua *et al.,* 2019). Iron had the highest THQ value of all canned foods which contributed largely to the high HI values of all canned food tested (Table 3). THQ values for Fe were greater than 1 for canned tomatoes, canned fish, canned corn, canned beans and canned peas suggesting that consumption of such foods without caution can lead to iron toxicity. THQ values for all parameters tested in canned malt, canned milk and canned meat were all lesser than 1, indicating that each of the parameters separately does not pose a risk of non-carcinogenic toxic effect and low health risk associated with the consumption of such canned food. The HI values for canned malt, canned milk, and canned meat were less than 1while canned tomatoes, canned fish, canned corn, canned beans, and canned peas had HI values greater than 1, suggesting that there is a risk of a non-carcinogenic toxic effect via the consumption of such foods. The HI values of (greater than 1) are similar to the findings of Shaaban *et al.* (2022). Liver damage, liver cirrhosis, pancreatic islet cell damage, diabetes, hypothyroidism, and hypogonadism can occur due to excess iron in the body (McDowell *et al* 2022). The EDI of Fe in this study was found to be lower than 1.94 mg/kg/day as reported by Ainerua *et al.,* (2019) in their study of canned foods. A lower estimated daily intake (EDI) of iron than the recommended provisional tolerable daily intake (PTDI) can result in iron deficiency, which is the most common nutritional deficiency in the world. Iron is an essential nutrient that is needed for the production of haemoglobin, which carries oxygen in the blood. Iron deficiency can cause fatigue, weakness, and decreased immunity, while a higher estimated daily intake of iron than the recommended PTDI can lead to iron toxicity, also known as iron poisoning (Korfali and Hamdan, 2013).

EDI values for Cd ranged from 0.000015 mg/kg/day in canned fish to 0.00661 mg/kg/day in canned peas and were mostly found to be below the PTDI of 0.001 mg/kg/day set by the Joint Expert Committee on Food Additives (JECFA) and 0.00036 mg/kg/day set by the European Directorate for the Quality of Medicines and Healthcare (EDQM) except for canned beans and canned peas, 0.00549 and 0.00661 mg/kg/day, which exceeded these limits (JECFA, 1993; EDQM, 2022). The EDI for Cd for canned beans and canned peas was found to be higher than 0.001 mg/kg/day reported by

Ainerua *et al.* (2019). A lower estimated daily intake (EDI) of cadmium than the recommended provisional tolerable daily intake (PTDI) is generally considered safe and is not likely to result in adverse health effects from cadmium exposure. However, it is still important to monitor exposure to cadmium, as even low levels of the metal can build up in the body over time and cause harm, while a higher estimated daily intake of cadmium than the recommended provisional tolerable daily intake can result in cadmium toxicity and lead to serious health problems. Cadmium is a toxic metal that can accumulate in the body and cause damage to the kidneys, bones, and other organs (Massadeh and Al-Massaedh, 2017). The EDI values for Cr (0.00078mg/kg/day for canned meat to 0.00783mg/kg/day for canned beans) we obtained in this study were lower than the PTDI set by the European Directorate for the Quality of Medicines and HealthCare (EDQM) of 0.3 mg/kg/day (EDQM, 2022). A lower estimated daily intake (EDI) of chromium than the recommended provisional tolerable daily intake (PTDI) can result in chromium deficiency, which is a rare condition. Chromium is an essential trace mineral that plays a role in glucose metabolism and insulin function. Health issues like increased blood sugar, increased cholesterol levels, diabetes and heart attacks can result from Cr deficiency. Also, a deficiency in chromium can lead to symptoms such as impaired glucose tolerance and insulin resistance (Ojezele *et al.,* 2021). The EDI values of BPA in the studied canned food were lower than the PTDI limit of 0.01 mg/kg/day as determined by the European Commission Scientific Committee on Food (SCF, 2002). The EDI values of BPA in canned tomatoes (0.0584 µg/kg/day), canned fish (0.017 µg/kg/day), canned milk (0.0761 µg/kg/day), and canned meat (0.0182 µg/kg/day) in this study were lower than the EDI values reported in canned tomatoes (1.70 mg/kg/day), canned fish (3.43 mg/kg/day), canned milk (3.21 mg/kg/day), and canned meat (2.34 mg/kg/day) by Adeyi and Babalola (2019) in their study.

Table 3: Target Hazard Quotient and Hazard Index of Heavy Metals, Bisphenols and Alkylphenols in Canned Food

Parameters	**Rfd (mg/kg/day)**	**Canned Tomatoes**	**Canned Fish**	**Canned Malt**	**Canned Milk**	**Canned Meat**	**Canned Corn**	**Canned Beans**	**Canned Peas**
Pb	0.0035	0.677	0.259	0.0329	0.00105	0.0317	0.216	6.66	NA
Fe	0.007	5.13	2.16	0.146	0.276	0.513	5.93	105.86	204.29
Cd	0.0005	0.634	0.03	0.04	NA	0.13	0.408	10.98	13.22
Cr	0.0003	1.5	0.583	NA	NA	0.26	NA	26.1	23.73
BPE	0.05	0.000366	0.000268	0.000326	0.00104	0.000161	0.0023	0.0115	0.0041
BPC	0.05	0.000706	0.00026	0.000406	0.00212	0.000262	0.00224	0.00556	0.00566
BPA	0.05	0.00117	0.00034	0.00034	0.00152	0.000364	0.00165	0.00948	0.0116
BPZ	0.05	NA	NA	NA	NA	NA	NA	0.00264	NA
BPG	0.05	0.00159	0.000346	0.000462	0.00186	0.000238	0.00101	0.00498	0.00832
BPAF	0.05	NA	NA	NA	NA	0.000119	NA	NA	NA
BPP	0.05	NA	NA	NA	NA	0.000052	NA	NA	NA
BPA-DGE	0.05	NA	NA	NA	NA	0.000091	NA	NA	NA
BPTMC	0.05	0.00144	0.000636	0.000816	0.00342	0.000266	0.00155	0.041	0.0181
2-methyl phenol	0.3	0.000011	0.000006	0.000007	0.000022	0.000002	0.000015	NA	0.000259
3,5-dimethyl phenol	0.3	0.000068	0.000040	0.000041	0.000151	0.000018	0.000098	0.000263	NA
2,6-dimethyl phenol	0.3	0.000128	0.000043	0.000044	0.000164	0.000019	0.000106	0.000222	NA
4-butyl phenol	0.3	NA	NA	NA	0.000010	0.000006	0.000008	0.00085	0.00085
4-tert-butyl-2-methyl phenol	0.3	0.000051	0.00003	0.000031	0.000123	0.000015	0.000080	0.000843	0.000837
4-hexyl phenol	0.3	0.000030	0.000028	0.000030	0.000066	0.00001	0.000067	0.000857	0.000853
4-octyl phenol	0.3	NA	NA	NA	NA	NA	NA	NA	0.000175
4-pentyl phenol	0.3	0.000056	0.000014	0.000016	0.000055	0.000006	0.000036	0.000643	0.000287
Nonylphenol	0.3	0.000005	NA	NA	NA	NA	NA	0.000463	0.000298
6-tert-butyl-2,4-dimethyl phenol	0.3	0.000033	0.000009	0.000009	0.000103	0.000048	0.000028	NA	NA
Hazard Index (HI)		**7.95**	**3.03**	**0.221**	**0.288**	**0.936**	**6.56**	**149.68**	**241.29**

**NA = not applicable*

BPA has adverse effects on human health, including developmental and reproductive effects and changes in metabolism and hormone levels, but some experts are concerned that even low levels of BPA exposure may be harmful to human health, especially in vulnerable populations such as pregnant women, infants, and young children. If an individual has a lower estimated daily intake (EDI) of BPA than the PTDI, they are likely not at significant risk of adverse health effects from BPA exposure.

The human health risks posed by contaminant exposure are usually characterised by the target hazard quotient (THQ) and hazard index (HI). When THQ is greater than 1, there may be worries about potential health problems linked to overexposure to that specific substance. If THQ is less than 1, the risk of non-carcinogenic adverse effects from the substance is thought to be low. A particular food or drink is assumed to have a low risk of harmful non-carcinogenic effects if the value of HI is less than 1. When it is greater than 1, potential health problems from consuming too much of that particular food or drink may be an issue (Ainerua *et al.*, 2019). Iron had the highest THQ value of all canned foods which contributed largely to the high HI values of all canned food tested (Table 3). THQ values for Fe were greater than 1 for canned tomatoes, canned fish, canned corn, canned beans and canned peas suggesting that consumption of such foods without caution can lead to iron toxicity. THQ values for all parameters tested in canned malt, canned milk and canned meat were all lesser than 1, indicating that each of the parameters separately does not pose a risk of non-carcinogenic toxic effect and low health risk associated with the consumption of such canned food. The HI values for canned malt, canned milk, and canned meat were less than 1while canned tomatoes, canned fish, canned corn, canned beans, and canned peas had HI values greater than 1, suggesting that there is a risk of a non-carcinogenic toxic effect via the consumption of such foods. The HI values of (greater than 1) are similar to the findings of Shaaban *et al.* (2022).

Conclusion: This study has shown that the concentrations of Pb, Fe, and Cd in the samples of canned food analysed were higher than the permissible limits established by various health organisations. The estimated daily intake of BPA, Pb, Fe, Cd, and Cr was less than the international provisional tolerable level per day. Consuming canned tomatoes, fish, corn, beans, and peas poses a risk of non-carcinogenic toxic effects as well as potential Pb, Fe, and Cd toxicity. The health risk associated with BPA exposure from daily consumption of the selected canned items in this study was under the permitted limit and may not cause any health risk to consumers, but the accumulation over time may be of concern.

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