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HEALTH RISK ASSESSMENT OF SOME HEAVY METALS IN TWENTY ONE WHEAT PRODUCTS SOLD IN NIGERIA

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ABSTRACT

This study assessed some heavy metals in twenty one wheat products originating from Nigeria and six other countries sold in local markets in Ijebu-Ode, Ibadan and Lagos cities in Nigeria and their possible health risks were also evaluated. Wheat-based food samples were digested and analyzed using Microwave Plasma coupled Atomic Emission Spectrometry (MP-AES) technique. The heavy metal contents in local and foreign wheat products ranged as follows: As (0.014-0.033 mg.kg^{-1}), Cd (0.067-0.330 mg.kg^{-1}), Ni (-0.002-0.104 mg.kg^{-1}) and Pb (0.166-0.655 mg.kg^{-1}). The mean contents of Cd and Pb exceeded the acceptable thresholds set by FAO/WHO while those of As and Ni were below permissible limits recommended by FAO/WHO. The health hazard indices for the four heavy metals, reported as follows: Ni (0.005), As (0.201), Pb (0.211), and Cd (0.490), fall within the low hazard range except for Ni whose hazard index could be regarded as negligible. The health hazard risk, which may be posed by each metal, occurred in a sequence of HQ (Ni) < HQ (As) < HQ (Cd) < HQ (Pb) <1, with each occurring within the safe limit set by the United States Environmental Protection Agency (USEPA). The combined non-carcinogenic risk of the four heavy metals (∑HQ = 0.906) occurred at the low-risk index. The carcinogenic risk index was below 1x 10^{-4} threshold recommended by USEPA, which indicates that the combined concentrations of the four metals possess a weak potential to modulate lifelong carcinogenic ailments for consumers of such wheat products.

Keywords: Wheat products, heavy metals, food security, carcinogenic risk, health hazard risk

INTRODUCTION

Wheat is a cereal grown in agro-climatic conditions, and it constitutes a significant source of protein and calories for about one-third of the global population's food chain (Abdel-Aal *et al*., 1998, Adams *et al*., 2002, Shewry, 2009). Wheat is grown in Nigeria, India, Pakistan, China, the United States and by countries in North Africa and Europe. Agu *et al*., (2007) reported that 3% of Nigeria's annual wheat consumption in 2011 was grown locally, and the remaining 97% came in via importation. Wheat grain is composed of germs (2-3%), bran (13-17%), and mealy endosperm (80-85%) thoroughly milled into wheat flour (Awika, 2011). Although several other varieties exist, the two commonly grown wheat species are hard wheat (*Triticum durum*) and soft wheat (*Triticum aesticum*) (Tejera *et al*., 2013).

Wheat flour, which is the major component of wheat grains, contains protein (10-12%), starch polysaccharides (70-75%), water (14%), non-starch polysaccharides (2-3%), and arabinoxylans and lipids (2%) (Goesaert *et al*., 2005). Food products, such as bread, crumpets, biscuits, cakes, muffins, noodles, pasta, pastries, crackers, crisp bread, sauces, cereal bars, and confectionaries, as well as snack foods and some beverages such as whiskey, tequila, gin rum, brandy, and bourbon, are made from wheat. Wheat-based food products are beneficial as they possess pentosan, a polysaccharide containing arabinoxylan and glucans, which reduces the risk of some chronic diseases such as diabetes, and cardiovascular diseases (Vitaglione *et al*., 2008; Aune *et al*., 2011; Trozzi *et al*., 2019). Wheat consumption may help prevent different types of cancer and reduce human mortality rates (Kumar *et al*., 2011).

Wheat contains certain mineral elements required in average quantity in the human body to perform some biological functions. Mineral elements such as iron, zinc, and selenium, present in wheat, are essential for DNA production and restoration, maintenance of homeostatic equilibrium, catalytic activities and activation of enzymes, wound healing, protein synthesis, cell division processes, and thyroid hormone production in the human body (Fu & Xi, 2020; Vignola *et al*., 2016; Zwolak & Zaporowska, 2012). Today, the administration of technology and modern techniques to improve agriculture is introducing a new set of contaminants to the natural environment. Studies have shown that excessive heavy metal accumulation in farmlands, industrial contamination of irrigation water sources, and sludge-manure agricultural practices are notable means by which crops accumulate toxic heavy metals (Antonious *et al*., 2012; Barman *et al.*, 2000; Fazeli *et al*., 1998; Rattan *et al*., 2005; Muchuweti *et al*., 2006; Tella *et al*., 2013).

In recent decades, food security and safety have generated a global concern among food researchers, the food and beverage industries, quality control analysts, public health officials, and the general public. Food and beverage produced for human consumption may contain residues of natural and synthetic contaminants such as fertilizers, pesticides, and toxic heavy metals. Whilst excessive use of mineral fertilizers and pesticides is culpable, a wide range of other human activities may also be responsible Artisanal small-scale mining has developed into a substantial environmental danger worldwide, especially in regions with weak government regulation, limited mining rules, and low environmental awareness (Hu *et al*., 2011; Li *et al*., 2015; WHO, 2015). The World Health Organization (WHO) Regional Assessment Study on Africa has connected artisanal small-scale mining activities to the environmental distribution of hazardous metals on the continent (WHO, 2015). The same study cited ten hazardous and harmful chemicals found in the food chain that could be harmful to the general public's health, including four toxic metals (arsenic, lead, mercury, and cadmium) (WHO, 2010; WHO, 2015).

According to research, the levels of exposure to toxic metals through food consumption vary globally. In Italy, the lead concentrations in three cow’s milk samples ranged from 8.9 to 15.9 $\mu g.kg^{-1}$ and those of six infant formula samples ranged from under the LOQ (<1.85) to 12.1 $\mu g.kg^{-1}$(Frazzoli & Bocca, 2008). In the United Kingdom, the survey conducted between 2003 and 2006 estimated that the mean lead concentrations detected in infant formula ranged between 6 and 8 $\mu g.kg^{-1}$(FSA, 2003, 2006). Ljung *et al*. (2011) reported a lead concentration range between 0.8 and 1.7 $\mu g.kg^{-1}$ in infant formula and between 1.1 and 13$\mu g.kg^{-1}$ in six-month-old infant food in Sweden. Human exposure to arsenic via the food chain can be traced to arsenic-infiltrated drinking and irrigation water as well as contaminated agricultural crops (Meharg *et al*., 2009; Podgorski *et al*., 2017). In addition

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to cigarette smoking, cadmium food chain exposure occurs through consumption of certain cereals, seafood, and vegetables (Satarug, 2012). Toxic metals have no known significance to human biology; rather, they induce life-threatening ailments in the body. Essentially, toxic metals interfere with the functions of the immune, reproductive, respiratory, endocrine and neurological systems (Charkiewicz and Backstrand, 2020; ECA, 2013b; WHO, 2015). There are possible health threats and unimaginable risks to the human population when they are exposed to dietary contaminants. This study assessed the levels of some heavy metals in wheat-based food products sold in Nigeria and any potential health hazards consuming such amounts poses to human health.

MATERIALS AND METHODS

Materials

Analytical grades of trioxonitrate (v) acid, hydrogen peroxide, distilled water, sodium borohydride ($NABH_4$), and sodium hydroxide (NaOH) were purchased from Sigma Aldrich. The laboratory hardware was purchased from Pyrex, United Kingdom. The MP-AES was purchased from Agilent Technology.

Methods

Sample Description and Collection

Twenty one varieties of local and foreign wheat-based food products were collected from Oke-Aje and New Markets both in Ijebu-Ode, Ogun State, and two Shoprite Malls both in Ibadan, Oyo State, and Lekki, Lagos. Foreign wheat-based food products collected were from Poland, South Africa, the United Kingdom, Denmark, Turkey, and the Netherlands. The wheat-based samples were dried in an oven at 85^0C temperature until constant weights were obtained. The dried samples were kept in air-tight glass bottles that had been pre-washed with nitric acid and stored at -20^0C temperature in a refrigerator ready for digestion.

Sample Preparation and Digestion

One gram (1 g) of dried rice samples was weighed, pulverized, and transferred into a 250 mL beaker and a 40 mL mixture of analytical grade HNO_3 and H_2O_2 (1:3; v/v) was added. The solution in the beaker was digested at 70^0C temperature for 40 mins and the digested mixture was allowed to cool down for about 1hr. The digest was diluted with 35 mL of distilled water. The same treatment was given to other rice samples.

Microwave Plasma-Atomic Emission Spectrometry Analysis

The Agilent 4200 MP-AES was deployed for the total metal determination of Cd, Ni, and Pb in the digested sample. A multi-purpose sample introduction system was used with an inert nebulizer, a double pass glass cyclonic spray chamber, orange/green pump tubing, and a pump speed of 15 rpm. The viewing position and background corrections were optimized automatically using the Agilent MP Expert software. The Agilent 4200 MP-AES's operating parameters (i.e. the wavelength and nebulizer flow) for sample analysis was set up as follows based on the metal to be measured: Arsenic (228.812 nm, 0.75 L/min), Cadmium (361.051 nm, 0.5 L/min), Nickel (352.454 nm, 0.7 L/min) and Lead (405.781 nm, 0.75 L/min). The metals' read time was programmed at 3 sec. The analyte samples were introduced in automatic sample introduction mode using the Agilent SPS 3. A range of working standards (0.2, 0.5, 1, 2, and 4 mg. L^{-1}) was prepared from an analytical reference standard using a multi-elements calibration standard. All calibration standards solutions were prepared in 5% HNO_3. The MP-

AES' analytical cycle was operated for 25 seconds of sample uptake, and the between-run cycle was stabilized for 20 seconds. Then target heavy metals were read at preselected wavelengths, and the process was repeated after conditioning for 40 seconds with 5% HNO_3. For Arsenic (As) measurement, the hydride generation method, aided by Multimode Sample Introduction System (MSIS) accessory, was used. The hydride generator consisted of 1.2% Sodium Borohydride ($NaBH_4$), 98%, 1.0% Sodium Hydroxide (NaOH) ACS Grade.

Statistical Analyses

All the statistical analyses carried out in this work were done with IBM SPSS Statistical 20. The data generated from MP-AES were expressed in mean, standard deviation, standard error mean, and range. The correlation and paired sample t-test between the local and foreign wheat-based food products were computed. The statistical analyses were carried out at a 95% degree of confidence ($p < 0.05$).

Health Risk Assessment Analysis

The health risk associated with the consumption of wheat-based food products may be predicated on the levels of hazard potentials posed by heavy metals they contain as these may induce many health challenges including carcinogenic and non-carcinogenic health ailments. The implications of such hazard parameters are factored into the health risk assessment baseline of this work.

Non-carcinogenic Risk Analysis

The non-carcinogenic health risk can be defined as the probability for a heavy metal to accumulate with the unabated tendency of possibly contributing to the emergence or aggravation of other health problems other than cancer over a short time. The mathematical equation for predicting the non-carcinogenic risk of consuming heavy metals in wheat products is provided as follows (USEPA, 2007, 2015b):

$$CDI = \frac{MC \text{ x} CR \text{ x } FE \text{ x } ED}{BW \text{ x } AT} \quad (1)$$

The CDI measures the chronic dietary intake of heavy metals due to direct wheat products' consumption over a timeframe, usually a month or a lifetime period ($mg.kg^{-1}$) The MC corresponds to the concentration of heavy metals detected in the wheat products ($mg.kg^{-1}$). CR captures the maximum daily consumption rate of wheat products ($kg.person^{-1}.day^{-1}$), FE stands for the exposure frequency to wheat products (350 days. $year^{-1}$; USEPA, 2011a), and ED captures annual and lifetime exposure duration (30 days. $year^{-1}$ and lifetime, 70 years) (USEPA, 2002; USEPA, 2011b). The AT translates to the average exposure time (in days which cumulates to 365 x 70 = 25550 days; however, for non-carcinogenic risk, ED = AT) and BW stands for the average body weight of an adult (70 kg; USEPA, 1991). For CDI evaluation, the CR was conformed to the USDA (2007) which approves daily whole wheat consumption in the range of 172.08 -180.30 g and refined wheat of 152.80 -160.46 g for black and white adult Americans. For the sake of this study, an average daily wheat consumption value of 176g (= 0.176 kg) was adopted. The non-carcinogenic exposure risks of the heavy metals were calculated using equation (2) based on the Hazard Quotient suggested by USEPA (1989):

$$HQ = \frac{CDI}{RfD} \quad (2)$$

The RfD stands for the reference dose of each heavy metal (mg/kg/day) and their respective RfD values for As, Ni, Cd, and Pb are 0.0003, 0.02, 0.001, and 0.004 mg/kg body weight per day. (USEPA, 2003).

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The hazard index (HI) of the wheat products, which is the sum of HQs of each heavy metal investigated in the wheat products, was calculated using equation (3) as suggested by USEPA (1989) and Odukoya *et al*., (2006):

$$Hi = \sum_{i=1}^{i=n} HQ_i = HQ_{As} + HQ_{Cd} + HQ_{Ni} + HQ_{Pb} \quad (3)$$

The risk evaluation associated with wheat products' consumption was made based on the USEPA (2010) hazard risk classification. Hazard risk less than 0.1 is regarded as negligible under chronic risk index. For a hazard risk that is less than unity but greater than or equals to 0.1, the chronic risk index is regarded as low. For chronic risk index that is moderate, the hazard risk must be greater than or equals to 1.0 but less than 4.0. However, where hazard risk is far greater than 4.0, the chronic risk index is regarded as high.

Carcinogenic Risk Analysis

The carcinogenic risk analysis of the heavy metals in wheat products was calculated using equation (4) as suggested by Kim *et al*., (2013) and USEPA, (2000).

$$CR = CDI \times CSF \times ADAF \quad (4)$$

The CSF in the equation expresses the probable capacity of a potentially toxic heavy metal to raise the cancer risk through oral exposure and is measured in $kg.day.mg^{-1}$. The ADAF is the age-dependent adjustment factor (which is 1 for adults).

RESULTS AND DISCUSSIONS

Statistical Analyses

The two-tailed Pearson, Kendell, and Spearman statistical correlations were conducted to know whether there was a significant difference between the local and foreign wheat-based products analyzed in this work. The data showed significant correlation in all the three statistical correlational models {r (3)= 1.0; p = 0.01} (Table 1.0). The two-tailed paired sample t-test was also conducted to know if there was a significant difference in metal contents between the local and foreign wheat products {t (3) = 0.888, p = 0.441} (Table 2.0). This result implied that there was no significant difference in their heavy metal contents between the local and foreign wheat products analyzed. Based on this conclusion, the average of metal contents in local and foreign wheat products was used for the health risk assessment of metals in this work.

Table 1.0: Correlation Analysis between Local and Foreign Wheat Products

(a) Pearson Correlational Analysis between Heavy Metal Contents in Local and Foreign Wheat Products.

Wheat Products	Correlation	Local Wheat Products	Foreign Wheat Products
Local	Correlation Coefficient	1.000	0.997**
	Sig. (2-tailed)		0.003
	N	4	4
Foreign	Correlation Coefficient	0.997**	1.000
	Sig. (2-tailed)	0.003	
	N	4	4

Source: SPSS data, 2021; **Correlation is significant at 0.01 (2-tailed)

(b) Kendall's Tau_b and Spearman Correlational Analysis between Heavy Metal Contents in Local and Foreign Wheat Products.

Wheat Products	**Correlation**	**Local Wheat Products**	**Foreign wheat Products**
Kendall's Tau_b//Spearman			
Local	Correlation Coefficient	1.000	1.000**
	Sig (2-tailed)		0.01
	N	4	4
Foreign	Correlation Coefficient	1.000**	1.000
	Sig(2-tailed)	0.01	
	N	4	4

Source: SPSS data, 2021; **Correlation is significant at 0.01 level (2-tailed)

Table 2.0: Paired Samples t-test Between Local and Foreign Wheat Products

				95% confidence interval of the difference				
	Mean	SD	SEM	Lower	Upper	t	df	Sig(2-tailed)
Local Wheat Pdts-Foreign Wheat Pdts	0.011	0.026	0.013	-0.029	0.052	0.888	3	0.440

*SD = Standard Deviation, SEM = Standard Error Mean, df = Degree of freedom; Pdts = products; Sig = p-value.

Contents of Heavy Metals in Wheat Products

This work confirmed the presence of potentially toxic metals in wheat products consumed locally and across the world. Tables 3.0 and 4.0 show the mean concentrations of cadmium, nickel, arsenic, and lead in the various local and foreign wheat-based food samples. The contents, scatterplots, and distributions of these potentially toxic metals in both wheat-based food products are presented in Figures 1-3(a) and (b).

Table 3.0: Concentrations of Heavy Metals Present in Collection of the Local Wheat-based Food Products Analyzed (n=3)

Samples	**Arsenic ($mg.kg^{-1}$)**		**Cadmium ($mg.kg^{-1}$)**		**Nickel ($mg.kg^{-1}$)**		**Lead ($mg.kg^{-1}$)**	
	Mean	**RSD**	**Mean**	**RSD**	**Mean**	**RSD**	**Mean**	**RSD**
WBLP1	0.024	36.85	0.101	6.22	0.029	6.40	0.281	2.08
WBLP2	0.025	43.89	0.237	7.32	0.112	1.36	0.438	2.05
WBLP3	0.0253	25.09	0.330	2.91	0.121	0.8	0.367	0.67
WBLP4	0.014	61.30	0.233	7.00	0.014	4.39	0.279	3.11
WBLP5	0.022	60.02	0.196	10.25	0.024	1.84	0.524	1.14
WBLP6	0.019	67.76	0.228	8.80	0.026	2.14	0.587	1.66
WBLP7	0.019	58.42	0.188	5.19	0.024	3.15	0.168	7.33
WBLP8	0.018	89.42	0.109	4.00	0.024	1.08	0.269	0.60
WBLP9	0.027	25.83	0.154	4.13	0.000	0.28	0.250	3.36

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WBLP10	0.030	23.71	0.291	5.15	0.104	1.52	0.655	1.15
WBLP11	0.020	25.72	0.267	3.97	0.031	2.17	0.419	1.97
WBLP12	0.024	31.43	0.250	5.19	0.037	2.13	0.408	2.36
WBLP13	0.029	31.94	0.067	2.27	-0.002	3.48	0.227	2.43
Mean	0.023		0.204		0.042		0.375	

Table 4.0: Levels of Heavy Metals Present in Collection of the Foreign Wheat-based Food Products Analyzed (n=3)

Samples	**Arsenic (mg.kg^{-1})**		**Cadmium (mg.kg^{-1})**		**Nickel (mg.kg^{-1})**		**Lead (mg.kg^{-1})**	
	Mean	**RSD**	**Mean**	**RSD**	**Mean**	**RSD**	**Mean**	**RSD**
WBFP1	0.029	26.78	0.272	8.98	0.062	3.24	0.288	3.44
WBFP2	0.029	44.41	0.310	7.05	0.078	2.12	0.303	1.30
WBFP3	0.023	14.47	0.201	5.20	0.041	2.74	0.212	4.85
WBFP4	0.021	52.95	0.246	3.48	0.053	4.35	0.256	1.70
WBFP5	0.023	37.38	0.196	3.88	0.028	1.00	0.561	0.66
WBFP6	0.028	19.31	0.269	6.15	0.058	4.92	0.370	2.47
WBFP7	0.033	23.28	0.128	10.84	0.047	2.73	0.443	1.80
WBFP8	0.023	31.93	0.169	4.61	-0.015	9.13	0.166	5.16
Mean	0.026		0.203		0.044		0.325	

The target heavy metals were chosen because of their potential to induce cellular toxicity at low concentrations. Arsenic is a metallic element that rarely occurs in an isolated state in nature but occurs in the environment due to persistent anthropogenic activities. Exposure to arsenic at elevated but sub-lethal levels can induce health problems such as wart formation, dermatitis, pigment keratosis of the skin, and lung cancer (Tuzen, 2009). The respective mean levels of arsenic obtained in both local and foreign wheat-based food products in this study were 0.023 and 0.026 mg.kg^{-1}. These values were found to be lower than those published by Williams *et al*., 2005 and Ahmed *et al*, 2015 on Bangladeshi wheat but higher than 0.038 mg.kg^{-1} reported by Huang *et al*., 2008. Song *et al*., 2015 reported mean arsenic concentration of 0.39 mg.kg^{-1} in rice whilst Zheng *et al*., 2020 reported 0.014 and 0.026 mg.kg-1 of As in maize and rice respectively in Pearl River Delta urban agglomeration of China. The As contents recorded in this work were below the permissible limit of 0.100 mg.kg^{-1} set for cereals by FAO/WHO (2001)

Cadmium is a ubiquitous metallic element found in the environment due to severe anthropogenic activities such as the application of fertilizers, sewage sludge agricultural application, and myriad industrial processes. Human exposure to cadmium has been traced to food consumption much more than its occurrence in water and air. The mean levels of Cd detected in the wheat products were 0.203 and 0.203 mg.kg^{-1} respectively which exceeded 0.011, 0.021, and 0.055 mg.kg^{-1} reported in published studies conducted by Ahmed *et al*., 2015, Zheng *et al*., 2007 and Huang *et al*., 2008 respectively as well as the permissible limit of 0.100 mg.kg^{-1} set for cereals by FAO/WHO (2001). Song *et al*., 2015 reported a mean concentration of 0.230 mg.kg^{-1} for Cd in their study conducted on rice. Zheng *et al*., 2020 reported Cd concentrations of 0.100 and 0.170 $mg.kg^{-1}$ respectively in maize and rice sampled from the Pearl River Delta urban agglomeration in China.

Nickel is a metallic element widely distributed in the environment due to its use as liquid and solid fuels, and industrial applications. Chronic human exposure to nickel can lead to cardiovascular and kidney diseases, lung fibrosis, and lung and nasal cancer. The mean Ni levels recorded in local and foreign wheat-based food products were 0.042 $mg.kg^{-1}$ and 0.044 $mg.kg^{-1}$ respectively. These amounts were less than 0.062 $mg.kg^{-1}$ reported by Santos *et al*., 2004, 0.145 $mg.kg^{-1}$ reported by Ahmed *et al*., 2015, and 0.148 $mg.kg^{-1}$ reported by Huang *et al*., 2008 in wheat grains. The values recorded in this work fell below the permissible limit of 66.900 $mg.kg^{-1}$ set for cereals by FAO/WHO (2001)

Lead is categorized as one of the non-essential elements found in the environment due to human activities such as burning fossil fuels, mining, and manufacturing. It can cause diseases such as neurotoxicity and nephrotoxicity at chronic exposure in humans. The mean contents of Pb detected in the wheat products were 0.375 $mg.kg^{-1}$ and 0.325 $mg.kg^{-1}$ corresponding to values of local and foreign products, both of which exceeded 0.221 $mg.kg^{-1}$ reported by Ahmed *et al*., 2015, 0.042 $mg.kg^{-1}$ reported by Zheng *et al*., 2007 and 0.177 $mg.kg^{-1}$ published by Huang et al., 2008. However, the mean content of Pb (2.010 $mg.kg^{-1}$) reported by Song *et al*., 2015 in rice from Suxian County exceeded that recorded in this study. Similarly, the Pb contents reported in this work exceeded the maximum acceptable limit of 0.300 $mg.kg^{-1}$ set for cereals by FAO/WHO (2001).

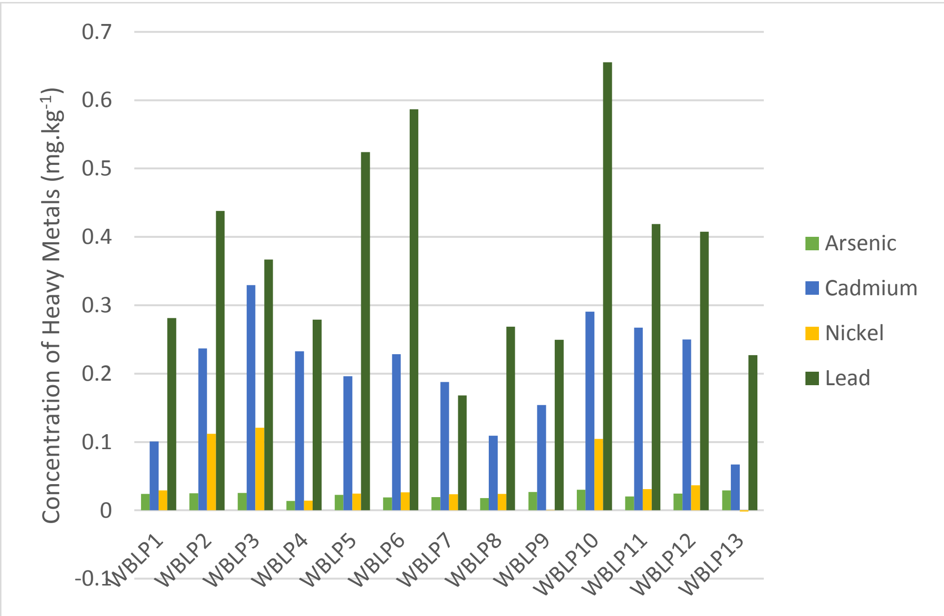

Figure 1.0 (a): Toxic Heavy Metals in Local Wheat-based Food Products

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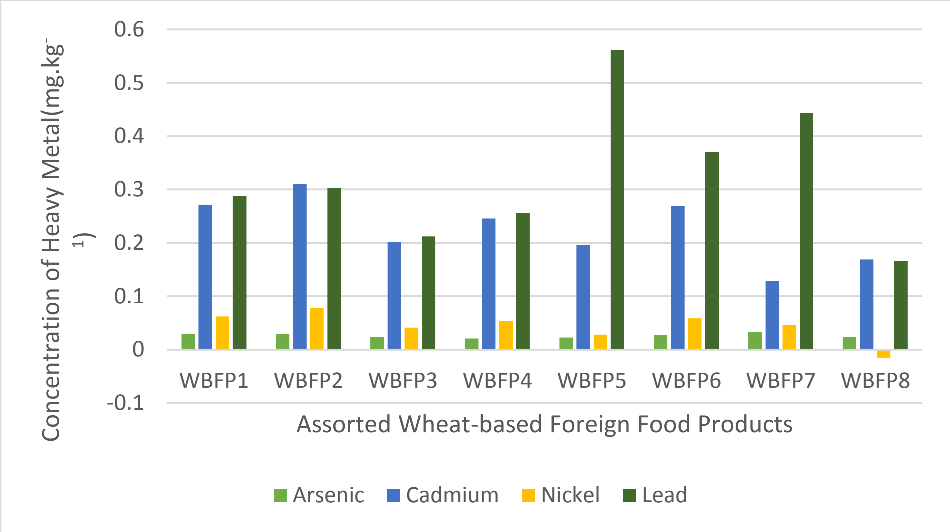

Figure 1.0(b): Toxic Heavy Metals in Foreign Wheat-based Food Products

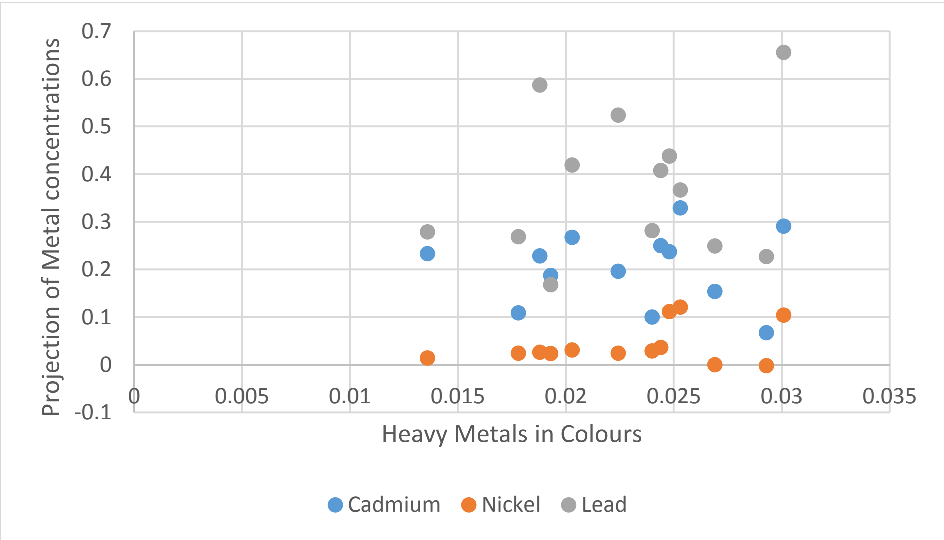

Figure 2.0 (a): Scatterplot of Toxic Metals in Local Wheat-based Food Products

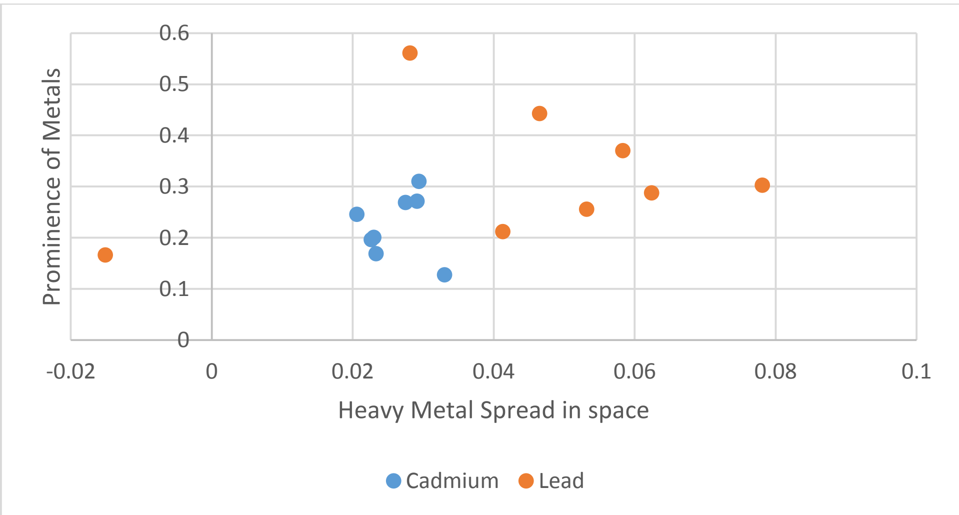

Figure 2.0 (b): Scatterplot of Toxic Metals in Foreign Wheat-based Food Products

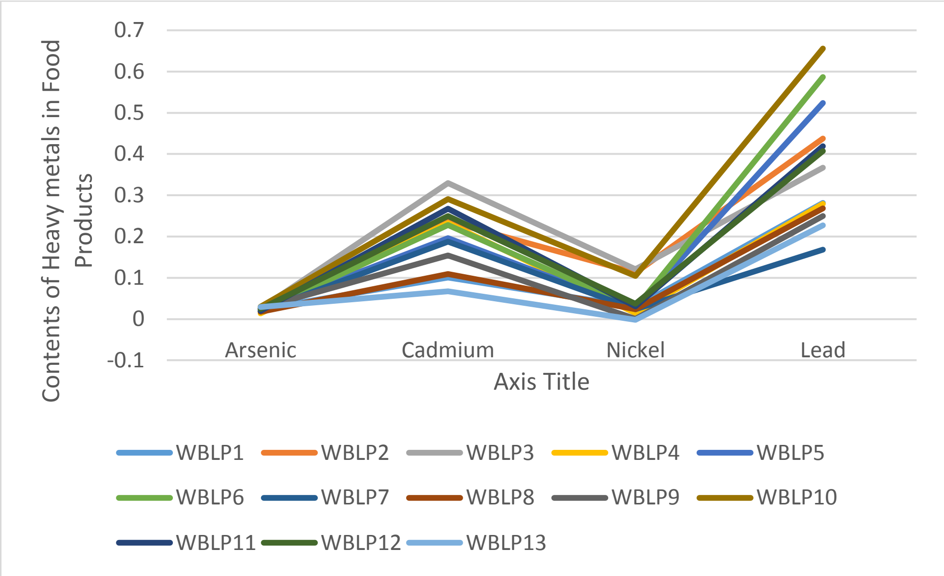

Figure 3.0 (a): Distribution of Toxic Metals in Various Local Wheat-based Food Products

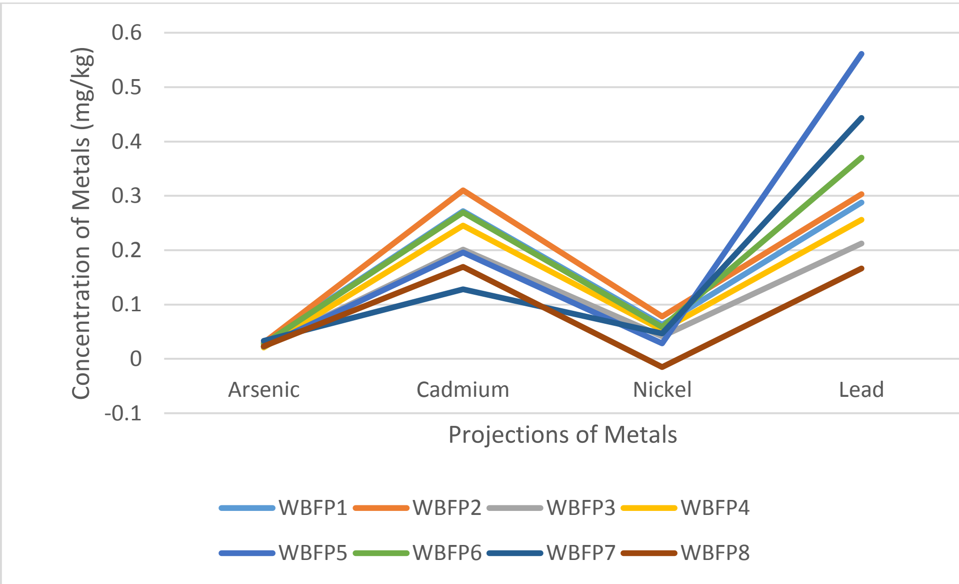

Figure 3.0(b): Distribution of Toxic Metals in Various Foreign Wheat-based Food Products

Health Risk Assessment of Heavy Metals in Wheat Products

Non-carcinogenic risk Analysis

Evaluation of human health risks involves identifying, determining, and measuring the magnitude of potential adverse health effects such a human population will be exposed to over a short time in a contaminated environment. The hazard Quotients for the four heavy metals were greater than 0.1 except for Ni whose HQ was 0.005 (Table 5.0). The Hazard Index for this study (HI = 0.906) was less than unity which constitutes a low-risk index according to the USEPA (1989). The heavy metal contents in these wheat products are below the amount that could induce health risk in consumers. Nevertheless, consideration of potential hazard quotients of other metals (not evaluated in this study) may raise the non-carcinogenic risk level beyond the safe limit.

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Table 5.0: Non-carcinogenic and Carcinogenic Health Risks of Heavy Metals Based on Food Exposure Pathway.

Metal	**Content ($mg.kg^{-1}$)**	**CDI* ($x\ 10^{-5}$)**	**HQ**	**CDI** ($x\ 10^{-6}$)**	**CSF**	**ADAF**	**CR ($x\ 10^{-6}$)**
As	0.025	6.027	0.201	0.165	1.5	1	0.248
Cd	0.203	48.940	0.489	1.341	6.1	1	8.179
Ni	0.043	10.370	0.005	0.284	0.84	1	0.235
Pb	0.350	84.380	0.211	2.312	8.5	1	19.651
		HI =∑HQs =	0.906			∑CR=	28.313

CDI* = Chronic Daily Intake for Non-carcinogenic risks; CDI**=Chronic Daily Intake for Carcinogenic Risks; CSF = Cancer Slope Factor ($kg.day.mg^{-1}$); ADAF = Age-dependent Adjustment Factor (Adult = 1)

Carcinogenic Risk Analysis

The probable carcinogenic risks associated with the consumption of wheat products were statistically evaluated and ranked using the USEPA (2015a) model which recommended a carcinogenic risk (CR) safety range of $1 \times 10^{-6} – 1 \times 10^{-4}$(USEPA, 2010). The CR values in this work were in ascending sequence of Ni < As < Cd < Pb (Table 5.0). The CR values of all the heavy metals were lower than 1×10^{-4}, the maximum threshold set for cancer lifetime occurrence. The data from this study indicated a total CR value of 2.832×10^{-5}, suggesting non-carcinogenic health risk over a lifetime for wheat-product consumers.

CONCLUSION

This study showed the occurrence of four heavy metals in local and foreign wheat products with their average contents occurring in increasing order of As > Ni > Cd > Pb. The Cd and Pb contents reported in this work exceeded the FAO/WHO permissible limits but those of As and Ni were below the FAO/WHO permissible limits (2001). The United States Environmental Protection Agency's models on health risks were used to determine the carcinogenic and non-carcinogenic risks of consuming potentially toxic metals in wheat-based food products. The health hazard (HI<1) of the four metals validates that consumption of wheat-based products will induce no known health risks in adults and children. Since the HQs of the four metals are additive, there is a possibility that the overall health risk threshold may tip over after completing the HQ computation of the other metals. In essence, there are chances that chronic human exposure to such products may compromise human health and well-being over time. However, the carcinogenic risk assessment model has predicted that consuming wheat-based products with such a CR level cannot modulate cancerous health ailments over a lifetime. Therefore, consumers depending on such wheat-based food products in their daily dietary meals are safe.

Conflict of Interest

The authors declare no conflict of interest of any sort.

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