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Detection of Heavy Metals in Some Edible Grains Obtained from Two Markets in Bauchi Metropolis, Nigeria

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Abstract

This study investigated the level of heavy metals (Cd, Cr, Cu, Fe, Pb and Zn) in grains sold in Central and Muda Lawal markets in Bauchi. Our objectives include assessing heavy metal concentrations in the grains and evaluating associated health risks. We utilized Atomic Absorption Spectrophotometry following acid digestion of grains to determine heavy metal concentrations. In Central market-sourced crops, the mean concentrations of Cd, Cr, Cu, Fe, Pb, and Zn were 0.06, 0.49, 0.21, 1.16, 0.15, and 0.17mg/kg respectively. Meanwhile, crops from Muda Lawal market exhibited mean concentrations of 0.06, 0.58, 0.17, 1.62, 0.1, and 0.22 mg/kg for Cd, Cr, Cu, Fe, Pb, and Zn, respectively. Cd, Cr, Cu, Pb, and Zn levels were below the permissible limits. However, Fe exceeded permissible limits in small beans, Syria maize, and white guinea corn from Central market, as well as in Syria maize, Pearl millet II, and white guinea corn from Muda Lawal market. The daily intake of Cd, Cu, and Pb from most studied crops exceeded the oral reference dose, posing potential health risks. Conversely, Cr, Fe, and Zn intake levels were within acceptable limits, posing minimal health risks. Hazard quotient and hazard index values were below 1, suggesting that crop consumption is unlikely to pose health risks.

Keywords: Heavy metals, Grains, Health risk.

INTRODUCTION

Food grains, also known as staple crops, are essential components of human diets worldwide. These crops serve as primary sources of carbohydrates, proteins, and other vital nutrients necessary for maintaining a healthy diet. According to the Food and Agriculture Organization (FAO), grains contribute to more than 50% of the global caloric intake (FAO, 2021). Common food grains include rice, wheat, maize, barley, and oats, among others. These grains possess unique nutritional profiles, with rice being a rich source of energy and wheat offering a good balance of proteins. Grains play a significant role in addressing global food security, as they can be stored for extended periods without significant losses, providing a reliable food source during times of scarcity (FAO, 2021). Furthermore, the cultivation of diverse food grains promotes sustainable agriculture by enhancing soil fertility, reducing erosion, and minimizing the need for chemical inputs (Devi *et al.*, 2020).

Food grains, being a staple food for a significant portion of the global population, can serve as a potential source of heavy metal exposure to humans (Meharg *et al.*, 2013). Heavy metals such as lead, cadmium, arsenic, and mercury have been found to accumulate in grains due to

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various factors including contaminated soil, irrigation water, and the use of fertilizers or pesticides (Alloway, 2012; Kabata-Pendias, 2011). Studies have shown that chronic consumption of grains contaminated with heavy metals can pose significant health risks, including neurotoxicity, organ damage, and an increased risk of certain cancers (Meharg *et al*., 2013; Satarug *et al*., 2010). Therefore, it is crucial to implement effective monitoring, regulation, and mitigation strategies to ensure the safety of food grains and protect the health of consumers.

Heavy metals are a group of toxic elements that can be found naturally in the environment or introduced through various human activities, including industrial processes, mining, and agriculture (Agency for Toxic Substances and Disease Registry [ATSDR], 2007). These metals, which include lead, cadmium, mercury, and arsenic, have been recognized as significant environmental and health concerns due to their persistence, bioaccumulation, and potential to cause adverse effects on human health (Kumar *et al*., 2015). Chronic exposure to heavy metals has been linked to a range of health problems, including neurotoxicity, developmental disorders, organ damage, and an increased risk of certain cancers (Järup, 2003; Vahidnia *et al*., 2007; World Health Organization [WHO], 2019). Heavy metals are toxic to human, animal, and plant health (Järup, 2003; Azevedo and Lea, 2005). The excessive accumulation of heavy metals in the environment poses increasing challenges for all forms of life, particularly plants (Rascio & Navari-Izzo, 2011).

Heavy metals, such as lead, cadmium, mercury, and arsenic, pose significant health risks when present in food. These toxic elements can contaminate food through various sources, including environmental pollution, agricultural practices, and food processing. Exposure to heavy metals through contaminated food has been linked to numerous adverse health effects. For instance, lead exposure has been associated with neurodevelopmental disorders, cognitive impairments, and cardiovascular diseases (World Health Organization [WHO], 2011). Cadmium ingestion, primarily through crops and seafood, is known to cause kidney damage, skeletal disorders, and an increased risk of certain cancers (International Agency for Research on Cancer [IARC], 2012). Mercury, commonly found in fish and seafood, can lead to neurological and developmental impairments, particularly in fetuses and young children (United States Environmental Protection Agency [US EPA], 2017). Arsenic, prevalent in rice and water, has been linked to skin lesions, various cancers, cardiovascular diseases, and diabetes (International Agency for Research on Cancer [IARC], 2004). Therefore, ensuring the safety of food by monitoring and minimizing heavy metal contamination is crucial for safeguarding public health.

MATERIALS AND METHODS

Study Area

The study was conducted at Abubakar Tafawa Balewa University, Bauchi which is located in Bauchi Metropolis, Bauchi State.

Sample Collection

Two varieties each of *Phaseolus vulgaris* (Iron beans and small beans), *Pennisetum glaucum* (Pearl millet I and II), *Oryza sativa* (Long grain and short grain rice), *Zea mays* (Hybrid and syria maize) and *Sorghum bicolor* (Red and white sorghum) grains were obtained from Muda Lawal and Central markets in Bauchi town. Samples were collected and stored in polythene bags according to their type and brought to Ecology laboratory of Abubakar Tafawa Balewa University for preparation and treatment.

Sample Preparation
The dried samples were crushed using a stainless steel blender and passed through a 2 mm sieve. The resulting fine powder was kept at room temperature before analysis as described by Sharma *et al*. (2008).

Digestion of Samples
Samples of grains from the markets (1.00±0.001 g each) were placed into 100 mL beakers separately. Fifteen (15) mL of tri-acid mixture (70% high purity (Nitric acid) $HN0_3$, 65% (Perchloric acid) $HCl0_4$ and 70% (Sulfuric) H_2S0_4 in 5:1:1 ratio) was added. The mixture was then digested at 80 ^{0}C till the solution became transparent (Sharma *et al.,* 2008). The resulting solution was filtered and diluted to 50 mL with deionized water and was analysed for Cd, Cr, Cu, Fe, Pb and Zn, using an atomic absorption spectrophotometer (210 VGP AAS).

Health Risk Assessment

Estimated daily intake
The degree of toxicity of heavy metals to human upon their daily intake (mg/kg/day) known as the estimated daily intake (EDI) was computed for each element as described by USEPA (2006).

$$\text{EDI}=\frac{\text{Cmetal} \times \textit{Average daily intake}}{\textit{BA}} \text{ mg/kg/day}$$

Cmetal=concentration of heavy metals in plants (mg kg_{-1}), Average daily intake of each grain in Bauchi for adults was taken, Adult body weight was taken as 70 kg. To determine the degree of toxicity the computed EDI values were compared with acceptable level of oral reference dose (Rfd) set by USEPA (2013).

Hazard quotient
The health risks to the local inhabitants from the consumption of grains was evaluated based on the hazard quotient (HQ), which is the ratio between exposure and oral reference dose (R_fD). It is represented by the formula written as follows;

$$\text{HQ}=\frac{\text{Dim}}{RfD}$$

The (RfD) is an estimation of human daily exposure that is likely to pose an appreciable risk of adverse health effects during a lifetime.

Hazard index
Potential risk to human health due to more than one heavy metal known as the hazard index (HI) was calculated as described by USEPA (2006). It was calculated using the equation depicted below:

$$\text{HI}=\sum \text{HQ}=\text{HQ}_{Cd} + \text{HQ}_{Pb} + \text{HQ}_{Cr} + \text{HQ}_{Cu} + \text{HQ}_{Zn} + \text{HQ}_{Fe}$$

The hazard index assumes that the magnitude of the adverse effect will be proportional to the sum of the multiple metal exposure.

RESULTS
Levels of Heavy Metals in Crops
The concentration of heavy metals in crops from the central market (Table 1) exhibited variability among different grain types. For *Phaseolus vulgaris, Zea mays, Pennisetum glaucum, Oryza sativa*, and *Sorghum bicolor*, the levels of Cd ranged from 0.01 to 0.06 mg/L, Cr ranged from 0.01 to 0.49 mg/kg, Cu ranged from 0.03 to 0.21 mg/kg, Fe ranged from 0.05 to 1.16

mg/kg, Pb ranged from 0.01 to 0.15 mg/kg, and Zn ranged from 0.06 to 0.17 mg/kg. Cd and Fe were detected in all the crops. Cr was not detected in hybrid maize and red guinea corn, Cu was not detected in rice I. Pb was not detected in millet I, rice II and both varieties of guinea corn and Zn was not detected in white guinea corn. The concentration of Cd, Cr, Cu, Fe, Pb and Zn in all the grains were below the permissible limit except in small beans, Syria maize and white guinea corn for Fe which exceeded the permissible limit.

Table1: Concentration of heavy metals in the assayed grains obtained from Central market, Bauchi.

Common name	Scientific Name	Hausa name	Concentration	± SD	(mg/kg)			
			Cd	Cr	Cu	Fe	Pb	Zn
Iron beans	*Phaseolus vulgaris*	Jan wake	0.06 ± 0.02	0.44 ± 0.26	0.12 ± 0.05	0.05 ± 0.44	0.08 ± 0.03	0.16 ± 0.08
Small beans	*Phaseolus vulgaris*	Pereru	0.03 ± 0.01	0.4 ± 0.27	0.13 ± 0.10	0.84 ± 0.90	0.03 ± 0.07	0.06 ±0.10
Hybrid Maize	*Zea mays*	Farar masara	0.02 ± 0.00	ND	0.03 ± 0.20	0.2 ± 0.13	0.05 ± 0.20	0.14 ± 0.07
Syria Maize	*Zea mays*	Yaluwar masara	0.06 ± 0.03	0.49 ± 0.30	0.09 ± 0.05	0.94 ± 0.29	0.15 ± 0.13	0.15 ± 0.03
Millet I	*Pennisetum glaucum*	Maiwa/Dauro	0.02 ± 0.01	0.07 ± 0.20	0.21 ± 0.12	0.25 ± 0.26	ND	0.17 ± 0.01
Millet II	*Pennisetum glaucum*	Gero	0.04 ± 0.01	0.1 ± 0.34	0.07 ± 0.04	0.15 ± 0.07	0.01 ± 0.14	0.13 ± 0.02
Rice I	*Oryza sativa*	Jamila	0.03 ± 0.01	0.01 ± 0.11	ND	0.64 ± 0.50	0.14 ± 0.15	0.12 ± 0.04
Rice II	*Oryza sativa*	Mai Kwalli	0.03 ± 0.01	0.13 ± 0.30	0.03 ± 0.08	0.3 ± 0.33	ND	0.16 ± 0.04
Red guinea corn	*Sorghum bicolor*	Jar Dawa	0.02 ± 0.01	ND	0.11 ± 0.09	0.05 ± 0.36	ND	0.1 ± 0.02
White guinea corn	*Sorghum bicolor*	Farar Dawa	0.01 ± 0.01	0.07 ± 0.30	0.1 ± 0.05	1.16 ± 0.44	ND	ND
[a]Safe limit			0.2	2.3	40	0.7	0.3	60

[a]FAO/WHO (2019)
Key:
FAO/WHO – Food and Agriculture Organization/World Health Organization
ND - Not Detected
SD - Standard Deviation

Table 2: Concentration of heavy metals in the assayed grains obtained from Muda Lawal market, Bauchi

Common name	Scientific name	Hausa name	Heavy	metal	± SD	(mg/kg)		
			Cd	Cr	Cu	Fe	Pb	Zn
Iron Beans	*Phaseolus vulgaris*	Iron Beans	0.06 ± 0.01	0.28 ±0.19	0.15 ± 0.03	0.68 ± 0.46	0.07 ± 0.08	0.17 ± 0.08
Pereru Beans	*Phaseolus vulgaris*	Pereru	0.04 ± 0.02	0.47 ±0.30	0.1 ± 0.11	0.38 ± 0.36	ND	0.16 ±0.03
Hybrid Maize	*Zea mays*	Hybrid	0.01 ± 0.00	ND	0.11 ± 0.02	0.37 ± 0.43	ND	0.22 ± 0.05
Syria Maize	*Zea mays*	Syria	0.04 ± 0.01	0.4 ± 0.24	0.11 ± 0.14	1.62 ± 0.57	0.05 ± 0.21	0.17 ± 0.02
Pearl millet II	*Pennisetum glaucum*	Maiwa/Dauro	0.03 ± 0.01	ND	0.16 ± 0.05	0.2 ± 0.38	ND	0.13 ± 0.02
Pearl millet II	*Pennisetum glaucum*	Gero	0.04 ± 0.01	0.58 ± 0.22	0.03 ± 0.16	0.85 ±0.84	ND	0.13 ± 0.01
Long grain rice	*Oryza sativa*	Jamila	0.02 ± 0.01	0.29 ± 0.35	0.04 ± 0.01	0.37 ± 0.13	ND	0.08 ± 0.01
Short grain rice	*Oryza sativa*	Mai Kwalli	0.03 ± 0.02	0.39 ± 0.45	ND	0.52 ± 0.17	0.1 ± 0.32	0.15 ± 0.06
Red guinea corn	*Sorghum bicolor*	Jar Dawa	0.03 ±0.01	0.19 ± 0.21	0.17 ± 0.06	0.29 ± 0.36	ND	0.07 ± 0.06
White guinea corn	*Sorghum bicolor*	Farar Dawa	0.02 ±0.00	ND	0.02 ± 0.18	0.89 ± 0.50	ND	0.06 ± 0.01
[a]Safe limit			0.2	2.3	40	0.7	0.3	60

[a]FAO/WHO (2019)

Key:
FAO/WHO – Food and Agriculture Organization/World Health Organization

ND- Not Detected
SD- Standard Deviation

The heavy metal concentrations from Muda Lawal market exhibited variation among different grains assayed. Cd levels ranged from 0.01 to 0.06 mg/kg, Cr ranged from 0.19 to 0.58 mg/kg, Cu ranged from 0.02 to 0.17 mg/kg, Fe ranged from 0.2 to 1.62 mg/kg, Pb ranged from 0.07 to 0.1 mg/kg, and Zn ranged from 0.06 to 0.22 mg/kg in *Phaseolus vulgaris, Zea mays, Pennisetum glaucum, Oryza sativa,* and *Sorghum bicolor* grains, respectively. Cd, Fe and Zn were detected in all the grains, Cr was not detected in hybrid maize and white guinea corn, Cu was not detected in rice II. Pb was only detected in iron beans, Syria maize and short grain rice. The concentrations of Cd, Cr, Cu, Fe, Pb and Zn in all the grains were below the permissible limit except in small beans, Syria maize, pearl millet II and white guinea corn for Fe which exceeded the permissible limit

Estimation of Daily Intake of Heavy Metals

Table 3 displays the EDI of metals from consuming grains sourced from the central market. The EDI results indicate a range of 0.01 to 0.76 mg/kg/bw/day for Cd, 0.01 to 0.56 mg/kg/bw/day for Cr, 0.02 to 0.17 mg/kg/bw/day for Cu, 0.03 to 1.33 mg/kg/bw/day for Fe, 0.01 to 0.61 mg/kg/bw/day for Pb, and 0.06 to 0.76 mg/kg/bw/day for Zn. The results showed that the consumption of grains harbouring Cd, Cu and Pb which had exceeded the USEPA (2013) oral reference dose could pose human health risk. Notwithstanding, hybrid maize, pearl millet II, and short grain rice which are within the acceptable oral reference dose for Cu and are unlikely to pose health risks. EDI values for Cr, Fe and Zn were within the oral reference dose (RfD). However, iron beans, hybrid maize, and long grain rice had exceeded the RfD for Fe. Small beans had also exceeded the oral reference dose for Zn.

Table 3: Estimated daily intake of grains obtained from Central market, Bauchi.

Common name	Scientific Name	Hausa name	(EDI)					
			Cd	Cr	Cu	Fe	Pb	Zn
Iron beans	*Phaseolus vulgaris*	Jan wake	0.76	0.56	0.15	0.06	0.1	0.2
Small beans	*Phaseolus vulgaris*	Pereru	0.04	0.51	0.17	1.07	0.04	0.76
Hybrid Maize	*Zea mays*	Farar masara	0.01	ND	0.02	1.13	0.03	0.09
Syria Maize	*Zea mays*	Yaluwar masara	0.04	0.32	0.06	0.61	0.61	0.1
Pearl millet I	*Pennisetum glaucum*	Maiwa/Dauro	0.01	0.04	0.13	0.15	ND	0.1
Pearl millet II	*Pennisetum glaucum*	Gero	0.02	0.06	0.04	0.09	0.01	0.08
Long grain rice	*Oryza sativa*	Jamila	0.06	0.02	ND	1.33	0.29	0.24
Short grain rice	*Oryza sativa*	Mai Kwalli	0.02	0.1	0.02	0.23	ND	0.12
Red guinea corn	*Sorghum bicolor*	Jar Dawa	0.01	ND	0.07	0.03	ND	0.06
White guinea corn	*Sorghum bicolor*	Farar Dawa	0.01	0.04	0.06	0.7	ND	ND
RfD[a]			0.001	1.5	0.04	0.7	0.004	0.3

[a]Source: USEPA (2013).
Key:
ND – Not Detected
RfD – Oral reference dose
USEPA- United States Environmental Protection Agency

Table 4: Estimated daily intake of crops obtained from Muda Lawal market, Bauchi.

Common name	Scientific Name	Hausa name	EDI

			Cd	Cr	Cu	Fe	Pb	Zn
Iron beans	*Phaseolus vulgaris*	Jan wake	0.76	0.36	0.19	0.87	0.09	0.22
Small beans	*Phaseolus vulgaris*	Pereru	0.05	0.6	0.13	0.48	ND	0.2
Hybrid Maize	*Zea mays*	Farar masara	0.01	ND	0.07	0.24	ND	0.14
Syria Maize	*Zea mays*	Yaluwar masara	0.03	0.26	0.07	1.06	0.03	0.11
Pearl millet I	*Pennisetum glaucum*	Maiwa/Dauro	0.02	ND	0.1	0.12	ND	0.08
Pearl millet II	*Pennisetum glaucum*	Gero	0.02	0.36	0.02	0.52	ND	0.08
Long grain rice	*Oryza sativa*	Jamila	0.04	0.6	0.08	0.77	ND	0.17
Short grain rice	*Oryza sativa*	Mai Kwalli	0.02	0.29	ND	0.39	0.08	0.11
Red guinea corn	*Sorghum bicolor*	Jar Dawa	0.02	0.11	0.1	0.17	ND	0.04
White guinea corn	*Sorghum bicolor*	Farar Dawa	0.01	ND	0.01	0.54	ND	0.04
RfD[a]			0.001	1.5	0.04	0.7	0.004	0.3

[a]Source: USEPA (2013).
Key:
ND – Not Detected
RfD – Oral reference dose
USEPA- United States Environmental Protection Agency

The data presented in Table 4 illustrates the EDI of metals resulting from the consumption of grains acquired from Muda Lawal market. The EDI values, measured in mg/kg/bw/day, exhibited a range of 0.01 to 0.76 for Cd, 0.11 to 0.6 for Cr, 0.01 to 0.19 for Cu, 0.12 to 1.06 for Fe, 0.03 to 0.09 for Pb, and 0.04 to 0.22 for Zn. The results show that the consumption of all assayed grains have exceeded the USEPA (2013) oral reference dose for Cd, Cu and Pb and could pose human health risk. However, pearl millet II and white guinea corn, which remained within the acceptable oral reference dose for Cu are unlikely to pose health risks. EDI values for Cr, Fe and Zn were within the oral reference dose (RfD). However, iron beans, syria maize, and long grain rice had exceeded the RfD for Fe.

Table 5: Hazard quotient and hazard index of grains obtained from central market, Bauchi.

Common name	Scientific Name	Hausa name	HQ						Hazard Index
			Cd	Cr	Cu	Fe	Pb	Zn	(HI)
Iron beans	*Phaseolus vulgaris*	Jan wake	0.76	0.0004	0.00375	0.0015	0.025	0.00067	0.79132
Small beans	*Phaseolus vulgaris*	Pereru	0.04	0.00034	0.00425	0.00009	0.01	0.00253	0.05721
Hybrid Maize	*Zea mays*	Farar masara	0.01	ND	0.0005	0.00019	0.0075	0.0003	0.01849
Syria Maize	*Zea mays*	Yaluwar masara	0.04	0.00021	0.0015	0.00087	0.1525	0.00033	0.19541
Pearl millet I	*Pennisetum glaucum*	Maiwa/ Dauro	0.001	0.00003	0.00325	0.00021	ND	0.00033	0.00482
Pearl millet II	*Pennisetum glaucum*	Gero	0.02	0.00004	0.001	0.00013	0.0025	0.00027	0.02394
Long grain rice	*Oryza sativa*	Jamila	0.06	0.00005	ND	0.0019	ND	0.0008	0.06275
Short grain rice	*Oryza sativa*	Mai Kwalli	0.02	0.00007	0.0005	0.00033	ND	0.0004	0.0213
Red guinea corn	*Sorghum bicolor*	Jar Dawa	0.01	ND	0.00175	0.00004	ND	0.0002	0.01199
White guinea corn	*Sorghum bicolor*	Farar Dawa	0.01	0.00003	0.0015	0.001	ND	ND	0.01253

Key:
ND – Not Detected

The HQ values for Cd, Cr, Cu, Fe, Pb, and Zn, obtained from crops sold at the central market, varied within the ranges of 0.01-0.76, 0.00003-0.0004, 0.0005-0.00425, 0.00004-0.019, 0.0025-0.1525, and 0.0002-0.00253, respectively. Among these, the highest HQ for Cd was found in iron beans, while the lowest was observed in hybrid maize, pearl millet I, and both types of guinea corn. The combined HI for all the metals studied ranged from 0.01199 in red guinea corn to 0.79132 in iron beans.

Table 6: Hazard quotient and hazard index of crops obtained from Muda Lawal market.

Common name	Scientific Name	Hausa name	Hazard Quotient (HQ)						Hazard Index
			Cd	Cr	Cu	Fe	Pb	Zn	(HI)
Iron beans	*Phaseolus vulgaris*	Jan wake	0.76	0.00024	0.0048	0.0012	0.0225	0.0007	0.78944
Small beans	*Phaseolus vulgaris*	Pereru	0.05	0.0004	0.0033	0.0007	ND	0.0007	0.0551
Hybrid Maize	*Zea mays*	Farar masara	0.01	ND	0.0018	0.0003	ND	0.0005	0.0126
Syria Maize	*Zea mays*	Yaluwar masara	0.03	0.00017	0.0018	0.0015	0.0075	0.0004	0.04137
Pearl millet I	*Pennisetum glaucum*	Maiwa/ Dauro	0.02	ND	0.0025	0.0002	ND	0.0003	0.023
Pearl millet II	*Pennisetum glaucum*	Gero	0.02	0.00024	0.0005	0.0007	ND	0.0003	0.02174
Long grain rice	*Oryza sativa*	Jamila	0.04	0.0004	0.002	0.0011	ND	0.0006	0.0441
Short grain rice	*Oryza sativa*	Mai Kwalli	0.02	0.00019	ND	0.0006	0.02	0.0004	0.04119
Red guinea corn	*Sorghum bicolor*	Jar Dawa	0.02	0.00007	0.0025	0.0002	ND	0.0001	0.02287
White guinea corn	*Sorghum bicolor*	Farar Dawa	0.01	ND	0.0003	0.0008	ND	0.00013	0.01123

The HQ values from crops obtained at Muda Lawal market varied in the following ranges: Cd (0.01-0.76), Cr (0.00007-0.0004), Cu (0.0003-0.0048), Fe (0.0002-0.0015), Pb (0.0075-0.0225), and Zn (0.0003-0.0007). The highest HQ for Cd was found in iron beans, the lowest was observed in hybrid maize and white guinea corn. The combined HI for all the metals in this study ranged from 0.01123 in white guinea corn to 0.78944 in iron beans.

DISCUSSION

Among the heavy metals, the mean concentration of Fe was the highest across all studied grains obtained from the Central market, followed by Cr, Zn, Cu, Pb, and Cd. White guinea corn had the lowest mean Cd concentration, while iron beans exhibited the highest. Hybrid maize and red guinea corn did not contain detectable levels of Cr, whereas Syria maize had the highest concentration. Long grain rice showed no detectable Cu levels, while pearl millet I had the highest Cu concentration. Iron beans and red guinea corn had the lowest Fe concentration, whereas white guinea corn had the highest. Pearl millet I, short grain rice, and both varieties of guinea corn did not contain detectable Pb, while Syria maize had the highest Pb concentration. White guinea corn did not have detectable Zn levels, while pearl millet I had the highest. The mean concentrations of Cd, Cr, Cu, Pb and Zn in the investigated crops were lower compared to those found in Plateau state in crops sprayed with pesticides which ranged from 0.5-0.5, 0.17-5.50, 0.83-28.75, 0.17-54.33 and 0.171-0.75mg/kg respectively by Bawa *et al.* (2021a) and also lower than those found in Gombe state by Bawa et al. (2021b) which ranged from 0.33-4.68, 0.67-16.83, 9.01-43.675, 1.75-38.08 and 0.17-20.80mg/kg of Cd, Cr, Cu, Pb and Zn respectively. These findings are in contrast with those reported by Adam *et al*. (2022), where Pb and Cd were below the detection threshold, and Cu and Zn ranged from 0.023 to 0.039 and 0.003 to 0.042 mg/kg, respectively. Wei *et al*. (2023) also reported heavy metal concentrations in rice to be generally lower than the results in this study (0.068 and 0.121

mg/kg for Cd and Cr respectively). However, Pb exhibited a higher concentration (0.065 mg/kg). On the average, the heavy metal concentrations in all tested grains from the central market remained below the permissible limits set by FAO/WHO (2019). However, the concentrations of Fe in small beans, Syria maize, and white guinea exceeded the FAO/WHO (2019) permissible limit.

Across the heavy metals, the mean concentration of Fe was the highest in all the examined grains obtained from Muda Lawal market, followed by Cr, Zn, Cu, Pb, and Cd. Hybrid maize had the lowest mean Cd concentration, while iron beans had the highest. White guinea corn did not contain detectable Cr, while red guinea corn had the lowest concentration, and pearl millet II had the highest. Short grain rice did not have detectable Cu, while white guinea corn had the lowest, and red guinea corn had the highest. Pearl millet I had the lowest Fe concentration, whereas Syria maize had the highest. Pb was only detected in iron beans, Syria maize, and short grain rice, with the minimum concentration in Syria maize and the maximum concentration in short grain rice. White guinea corn had the lowest Zn concentration, while hybrid maize had the highest Zn concentration. On average, the heavy metal concentrations in all crops from Muda Lawal market remained below the permissible limits set by FAO/WHO (2019). However, the concentration of Fe in Syria maize, pearl millet II, and white guinea corn exceeded the FAO/WHO (2019) permissible limit. The mean concentrations of Cd, Cr, Cu, Pb and Zn in the investigated grains were lower compared to those found in Plateau state by Bawa *et al.* (2021a) in crops sprayed with pesticides which ranged from 0.5-0.5, 0.17-5.50, 0.83-28.75, 0.17-54.33 and 0.171-0.75 mg/kg respectively. The concentrations are also lower than those found by Bawa *et al*. (2023) in Kaduna state, Nigeria which ranged from 0.13-1.33, 0.25-1.50, 3.17-31.8, 0.50-5.33 and 14.08-44.00 mg/kg of Cd, Cr, Cu, Pb and Zn respectively.

Furthermore, Liu *et al*. (2020) reported the mean concentration of Cd, Cu, Cr, Pb and Zn in corn grown on different soil types in China to range from 0.05-0.09, 1.25-1.4, 0.14-0.17, 0.47-1.16 and 10.81-2.15 mg/kg respectively. These concentrations are higher than those found in this study. Moreover, Sharma and Bisla (2022) reported the mean concentration of Cd and Pb in *Phaseolus vulgaris* obtained from a local market in India to be 0.27 and 0.19 mg/kg respectively which are also lower than those found in this study. Furthermore, the mean concentration of Cd, Cu, Cr, Fe, Pb and Zn of corn in this study are lower than those found in red and white corn irrigated with waste water in Pakistan as reported by Atta *et al.* (2023) who recorded 0.12, 20, 2.4, 58.3, 0.34 and 16.1 mg/kg in red corn and 0, 13.8, 1.34, 64.6, 0.22 and 17.5 mg/kg respectively. The differences in heavy metal concentrations in crops of the different regions can be influenced by various factors such soil composition, agricultural practices, industrial activities and environmental regulations. For instance, variations in geological characteristics and farming methods can impact the absorption of heavy metals by crops (Xu *et al*., 2022). Additionally, regional differences in industrial pollution and regulatory measures may contribute to varying levels of heavy metal contamination in agricultural crops (Rai *et al*., 2019).

The EDI findings revealed that the consumption of grains obtained from the central market exceeded the RfD established by USEPA (2013) for Cd, Cu, and Pb. This overstepping of the RfD suggests potential human health risks, with exceptions found in the case of hybrid maize, pearl millet II, and short grain rice for Cu, which remained within the acceptable oral reference dose and are unlikely to pose health risks. Bawa *et al*. (2021a) also reported that the EDI for Pb through the consumption of *Zea mays, Capsicum annuum, Spinacia oleracea, Brassica oleracea* and *Lactuca savitus* exceeded the RfD and are likely to cause severe human health risk. Regarding Cr, Fe, and Zn, their EDI values did not surpass the established RfD, indicating no significant human health risks. However, there are exceptions, such as elevated Fe levels in iron beans, hybrid maize, and long grain rice, as well as excessive Zn levels in small beans, which exceeded the RfD. It is worth noting that Cd and Fe were detected in all the assayed grains, while Cr was absent in hybrid maize and red guinea corn, Cu was absent in long grain rice, Pb was absent in pearl millet I, short grain rice, and both guinea corn varieties, and Zn was absent in white guinea corn. Consequently, grains lacking these specific metals pose no associated health risks when consumed.

The EDI outcomes indicate that the consumption of grains obtained from Muda Lawal market had exceeded the RfD established by USEPA (2013) for Cd, Cu, and Pb, potentially posing health risks. However, exceptions exist, with pearl millet II and white guinea corn remaining within the acceptable RfD for Cu, suggesting no significant risk. Bawa *et al*. (2021a) reported that the EDI for Pb through the consumption of *Zea mays, Capsicum annuum, Spinacia oleracea, Brassica oleracea* and *Lactuca savitus* had exceeded the RfD and are likely to cause severe human health risk. In the case of Cr, Fe, and Zn, their EDI values did not surpass the established RfD, implying minimal health risk. Nevertheless, there are exceptions, such as elevated Fe levels in iron beans, Syria maize, and long grain rice. It is noteworthy that a study by Abua et al. (2023) reported EDI values for Cu and Zn below the RfD, while EDI values for Mn and Fe exceeding the RfD. Among the studied grains, Cd, Fe, and Zn were detected consistently. Cr was absent in hybrid maize, pearl millet I, and white guinea corn, Cu was absent in short grain rice, and Pb was detected only in iron beans, Syria maize, and short grain rice. The highest intake of Cd was observed in iron beans, Cr intake was highest in small beans and long grain rice, Cu was highest in iron beans, Fe in Syria maize, and Pb and Zn in iron beans.

All HQ and HI values in this research were below 1, indicating no significant human health risk. Although, the highest HQ was found in iron beans, possibly due to pesticide residues, as beans are prone to pest infestations (Singh, 1985). Similarly, Ahmad *et al*. (2023) also reported HI values below 1 in barley, maize, wheat, spinach, and garlic. Furthermore, the HI values reported by Ahmad *et al*. (2023) ranged from 0.0055 to 0.0115 for Pb and Zn in barley, maize, wheat, spinach, and garlic. These values are lower than the HI values observed in our study which ranged from 0.01199 to 0.79132 (for grains obtained from central market) and 0.01123 to 0.78944 (for grains obtained from Muda Lawal market). In contrast, a previous study by Kacholi & Sahu (2018) reported HI values greater than 1, suggesting a potential human health risk.

CONCLUSION

The presence of heavy metals (Cd, Cr, Cu, Fe, Pb and Zn) were detected in the studied grains (*Phaseolus vulgaris, Zea mays, Pennisetum glaucum, Oryza sativa* and *Sorghum bicolor*) obtained from Central and Muda Lawal markets in Bauchi. Heavy metal concentrations varied with metal type and grains. The concentration of Fe in some of the grains exceeded the FAO/WHO (2019) permissible limit while the concentrations of all the other heavy metals in this study were within the FAO/WHO (2019) permissible limits. The EDI values for Cd, Cu and Pb exceeded the USEPA (2013) Rfd whereas the EDI values for Cr, Fe and Zn did not exceed the Rfd in most of the crops obtained from both markets. The HQ values through the consumption of all the studied grains were <1 and therefore unlikely to pose health risk to humans. There is need to enforce effective screening and monitoring of pesticides for heavy metals contents before entry into Nigeria markets. Government and non-governmental agencies should assist farmers to remediate heavy metals that have contaminated agricultural lands through effective phytoremediation technologies.

Conflict of Interests

No conflict of interest.

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