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DETERMINATION OF SELECTED HEAVY METALS (HM) IN COCOYAM AND CASSAVA FLOUR SOLD IN EKE AWKA MARKET: A HEALTH RISK ASSESSMENT

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ABSTRACT

There is a tendency for food samples to be contaminated with heavy metals either from the soil where they are cultivated or during the processing. This study assessed the concentrations of the chosen heavy metals in the test and control cocoyam and cassava flour samples: arsenic, cadmium, lead, mercury, zinc, copper, and aluminum. The heavy metal contents of the control and test samples was assessed using the Thermo Elemental Atomic Absorption Spectometer. Probabilistic risk assessment techniques was used to estimate daily heavy metal intake, and calculate the Hazard Quotient, Hazard Index, and Incremental Life Cancer Risk linked with heavy metal exposure. While lead and arsenic for both samples were above the reference level for both adults and children, the estimated daily consumption for cadmium, copper, zinc, and aluminum for both the control and test samples of cocoyam flour was below the acceptable reference values. While copper, zinc, and aluminum were under the oral standard range for both adults and children, the estimated daily consumption of cadmium, arsenic, and lead for the cassava test sample was likewise higher than the reference level for children. In adults and children, the test and control samples of cocoyam and cassava flour had hazard quotients for copper, zinc, and aluminum that were all less than one, indicating no possible health hazards. Arsenic, lead, and cadmium had hazard quotients of more than one in the cassava test sample, which could be harmful to human health when consumed in cocoyam and cassava flour. A hazard index score greater than one showed the cumulative non-carcinogenic threat of the metals under investigation. The US Environmental Protection Agency's 10^{-4} priority risk threshold and the 10^{-6} acceptable risk limit were both exceeded by the cumulative cancer risk for the cocoyam and cassava test and control samples. This study has illustrated the possible health hazards that prolonged consumption of cocoyam and cassava flour contaminated with heavy metals could pose to the general public.

KEYWORDS: Estimated daily intake, Hazard quotient, Hazard index, Incremental life cancer risk, Heavy metals.

1. INTRODUCTION

The presence of heavy metals in the food chain exposes the local people to a range of potentially hazardous environmental sources. Several biological and metabolic processes in the body may be hampered by prolonged exposure to dangerously high concentrations of heavy metals in food (Bassie and Enoh, 2014). Heavy metals accumulate in both people and animals through the consumption of food or water that contains traces of these metals. Plants absorb heavy metals from the soil and water (Ahmad and Munirah, 2020). In Nigeria, the terms "cocoyam" and "Xanthosoma sagittaifolium" (tannia) are used interchangeably. Their tasty starchy store subterranean stems, known as corms and cormels, are the major reason these tropical herbaceous tubers are grown mostly as annuals. According to estimates, taro (Colocasia esculenta) is the sixth most harvested root crop worldwide at 9.0 million tonnes in 2011 (FAO, 2021). The quickly digested starch in the corms makes them a healthy source of carbs. In terms of digestibility, crude protein content, and important minerals like calcium, magnesium, and potassium, cocoyam is nutritionally superior to its main competitors, cassava and yam (FAO, 1990 and FAO 2021).

Corms of the cocoyam (taro) are very perishable because of their high moisture content. Making flour out of it could prevent it from spoiling as flour keeps far longer than unprocessed corn. When cocoyam is processed into flour, its shelf life is increased and it can be used year-round (Obiegbuna *et al*., 2014). Cocoyam tubers can be eaten raw or processed into flour, which can then be used to make noodles, pasta, biscuits, cookies, meat substitutes, yoghurt mixes, food thickeners, bioplastics, and edible films (WHO, 1993).

The domesticated plant known as cassava, or Manihot esculanta, is presently widely distributed throughout the Pacific region and is derived from one or more species in the Genus Manihot of the Euphorbiaceae family. One of the main sources of carbohydrates, which are used as fuel, is the starchy root vegetable cassava. Cassava processing has garnered a lot of attention lately due to its versatility, capacity to lower cyanide, longer shelf life, and potential for value addition—all of which support food security. Processed cassava is widely utilized as food and as useful industrial commodities. Several products are produced locally from the processing of cassava tubers, such as tapioca, farina, garri, fufu, starch, and others. The numerous processed food options are the most reasonably priced sources of staple foods in Africa (Edet *et al*., 2023)

The industrial usage of heavy metals, such as lead, mercury, cadmium, chromium, and arsenic, poses a threat to human health and the environment. Their toxicity varies according to individual features, exposure, and dose. Given how hazardous these metals are even at low concentrations, public health concerns are given top priority (Tchounwou *et al*., 2012).

The toxicity of heavy metals is dose-dependent; while low amounts of these metals can benefit the body, concentrations exceeding a certain threshold are hazardous to human health (Ohiagu *et al*., 2022). Even at low concentrations, heavy metals are hazardous because they do not biodegrade (Madiha *et al*. 2022). These metals are released into the environment via several anthropogenic activities, such as mining, waste disposal, combustion, diffuse sources like pipelines, and other human activities (Briffa *et al*., 2020). In addition to polluting the environment, heavy metals contaminate soil in agriculture and have the potential to seriously damage crops and production. These include Cd, Pb, Cr, As, Hg, Ni, Cu, and Zn; if they are not taken up by plants or leached out, they remain in the soil. Even at low exposure levels, particularly hazardous metals such as Cd, Pb, As, Hg, and Cr are detrimental to plants (Rashid *et al*., 2023).

Even at modest exposure levels, heavy metals like lead, cadmium, and arsenic are hazardous and have no known beneficial effects on human metabolism. These are pervasive environmental pollutants that can cause cancer, toxicity, mutations, and birth defects, among other health problems. Target hazard quotients (THQ) for both individual and cumulative exposures must be computed in addition to food concentration monitoring to assess their risk (Bamuwamye *et al*., 2015). Thus, this study's goals were to: (1) measure the levels of lead (Pb), zinc (Zn), arsenic (As), cadmium (Cd), mercury (Hg), copper (Cu), and aluminium (Al) in commercially processed and control cocoyam and cassava flour; (2) estimate daily HM intake by consuming processed and unprocessed cocoyam and cassava flour; and (3) use probabilistic risk assessment models to determine the risks of cancer and non-cancer associated with the heavy metal (HM) intake.

2. MATERIALS AND METHODS

2.1 Sample collection

According to Asomugha *et al* (2016), a freshly harvested cocoyam and cassava sample was acquired from a residential area approximately five kilometres away from the industrial region, whereas a sample of processed cocoyam and cassava flour was taken from the Eke Awka market. The cocoyam was peeled twice and then cleaned twice more using deionized water. Air drying of the cocoyam was done with an electric fan. A spotless mortar and pestle was used to shred the dried cocoyam and cassava samples. The samples were sent out for heavy metal analysis after being tagged and placed in a sterile zip-lock bag.

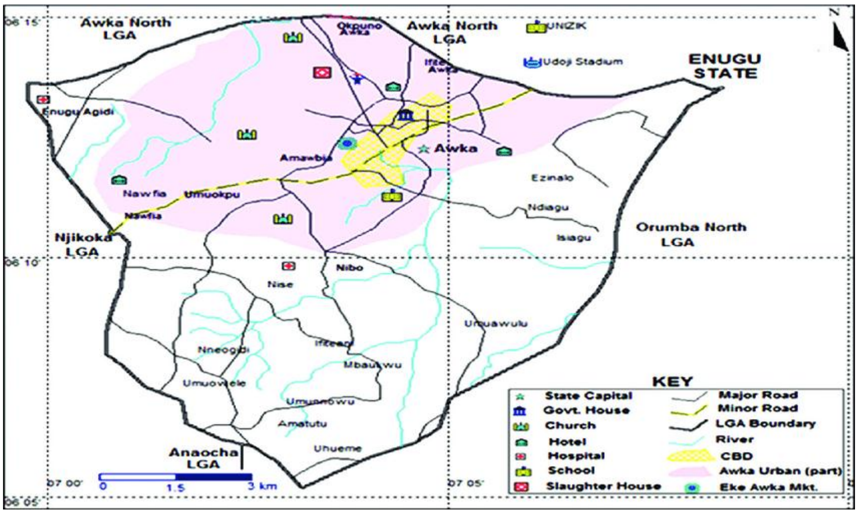

Figure 1: Map of Awka metropolis showing the location of Eke Awka.

2.2 Determination of heavy metals

Using the Solar Thermo Elemental Atomic Absorption Spectrometer, Model SN-SG 710906, the heavy metal content of the acid-digested samples was ascertained. In a clean bowl, the ground control and processed samples were kept apart. A weighing balance was utilized to accurately weigh 1.2 gms., of each of the control and test samples was weighed out and put in separate 125 ml Erlenmeyer flask that had been previously cleaned with acid and rinsed with deionized water. Under a fume hood, 2 milliliters of H_2SO_4 was added, followed by 12 milliliters of concentrated nitric acid, and 4 milliliters of perchloric acid, 15 milliliters of distilled water was then added and, the mixture was completely homogenized.

After moving the digesting vessel to the heating mantle and adjusting the temperature to 110°C, the heating process was continued until the thick, white fume stopped appearing. Two milliliters of concentrated HNO_3 were added to the flask when it had cooled, and it was once again digested to the fuming stage. After taking the flask off of the hot plate and letting it cool, 15 milliliters of distilled water were added. The mixture was then filtered through 0.5 mm Whatman filter paper and placed into a measuring cylinder. Finally, the digesting vessel was cleaned inside and out using a wash bottle. After adding enough solution, the top was covered with a plastic cork and stored in a polythene container. After calibrating the instrument with the preferred calibrating standard, it was inhaled using an atomic absorption spectrometer for the metals of interest using a suitable hollow cathode lamp. For every sample, this process was performed three times (He *et al.*, 2024) and (Madjar *et al*.2020).

2.3 Health risks assessment of heavy metals

To develop toxicological reference values, health risk assessments usually entail evaluating exposure levels, such as by environmental monitoring or bio-monitoring, and comparing those. Regulations aimed at safeguarding the public's health are guided by these values in determining allowable exposure limits. Based on the estimated daily intake (EDI) of metal, hazard quotient (HQ), hazard index (HI), and cancer risk (CR), the dangers to human health were assessed (Gnonsoro *et al*., 2022).

2.3.1 Exposure assessment

Using the following equation (Asomugha *et al*., 2016), the Estimated Daily Intake (EDI) was computed to estimate the average daily metals introduction into the body system of a specific body weight of a consumer: where C_{metal} is the concentration of heavy metals in plants expressed in mg/kg. The daily consumption of cocoyam is measured in kilogrammes per person. The average body weight (kg/person) is denoted by B. Adults and children were found to consume 0.5 kg and 0.25 kg of cocoyam flour daily, respectively, while their average body weight was found to be 24 kg and 70 kg, respectively (Madjar *et al*., 2020). The oral reference dose and the EDI were contrasted.

2.3.2 Non-Carcinogenic risk assessment

The non-carcinogenic danger of long-term human exposure to heavy metals from fruits, vegetables, and medicinal plants is measured using the Hazard Quotient (HQ). The following formula is used to determine the HQ:

Where EDI is the estimated daily intake of cocoyam (mg/kg/day) and RfD is the oral reference dose of the metal (mg/kg/day), it is the daily tolerable exposure to which a person is expected to have without any significant risk of harmful effects during a lifetime (Meseret *et al*., 2020).

Oral reference dose for Pb, Zn, Cd, As, Hg, Cu and Al is 0.0035 mg/kg/day, 0.3000 mg/kg/day, 0.0005 mg/kg/day, 0.0003 mg/kg/day, 0.0003 mg/kg/day, 0.04mg/kg/day and 1mg/kg/day respectively (USEPA,1989). Owing to the cumulative impact of many heavy metal exposures, the total non-carcinogenic risk to human health is assessed using the Hazard Index (HI). If HQ or HI is less than 1, there are no expected health effects from exposure; if HQ or HI is larger than 1, there may be health issues (Luo *et al*., 2021). According to the following equation. HI is the total of each heavy metal's hazardous quotient (HQ): HQCd + HQZn + HQPb + HQHg + HQAs + HQAl + HQCu = ∑ HI

2.3.3 Cancer risk assessment

A person's lifetime chance of acquiring cancer due to exposure to a possible carcinogen is referred to as their cancer risk.

The incremental lifetime cancer risk (ILCR) is a measure of an individual's lifetime chance of developing any type of cancer after being exposed to a specific daily dose of a carcinogenic substance for 70 years (Bamuwamye *et al*., 2015).

The following equation is used to estimate the incremental life cancer risk (ILCR); ILCR is equal to CDI times CSF.

The lifelong average daily dose of exposure to the chemical is represented by the CDI (chronic daily intake of chemical, mgkg-1 BWday-1). The following equation was used to determine the CDI value: EDI X EFr X EDtot / AT = CDI where; EDI is the estimated daily intake of metal, EFr is exposure frequency (365 days/year); EDtot is the exposure duration of 70 years, AT is the period of exposure for non-carcinogenic effects (equal to EFr X EDtot), and 70-year lifetime for carcinogenic effects (i.e., 70 years X 365 days/year) (Bamuwamye *et* *al*., 2015). The total cancer risk as a result of exposure to multiple contaminants due to the consumption of processed or controlled cocoyam powder was assumed to be the sum of the individual metal incremental risks ∑ILCR.

The oral carcinogenic slope factor (mg/kg/day) for Cd, As, and Pb is 6.1, 1.5, and 8.5 for CSF, respectively.[19,20,21,12] It has been determined that arsenic, cadmium, lead, and chromium are carcinogenic elements by the International Agency for Research on Cancer (IARC). Thus, prolonged exposure to low concentrations of As, Cd, and Pb may result in the development of certain cancers.

2.4 Statistical analysis

IBM-SPSS23, a statistical package for social sciences, was used to analyze study data. The findings were displayed as the average ± standard deviation. One-way analysis of variance (ANOVA) was used to analyse the treated sample statistically against the control sample, i.e., the processed cocoyam flour sample.

The least significant difference (LSD) was used to determine the difference between means at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1 Concentration of heavy metals

The amount of Arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb), Copper (Cu), Zinc (Zn), and Aluminum (Al) present in the test cocoyam flour sample in mg/kg was 1.693, 0.02, below the detection limit (BDL), 2.748, 3.328, 5.032, 2.693. While the amount of Arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb), Copper (Cu), Zinc (Zn), and Aluminum (Al) present in the control cocoyam sample in mg/kg is 0.342, BDL, BDL, 1.715, 0.416, 4.324, 1.324. The amount of Arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb), Copper (Cu), Zinc (Zn), and Aluminum (Al) present in the test cassava flour sample in mg/kg was 2.471, 0.061, BDL, 3.612, 4.894, 6.593, 1.532. While the amount of Arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb), Copper (Cu), Zinc (Zn), and Aluminum (Al) present in the control cocoyam sample in mg/kg was 1.294, 0.014, BDL, 2.067, 1.784, 3.170, 0.490 (Table 1). The amount of Arsenic and Lead in both the test and the control samples for both cocoyam and cassava were above the permissible limits according to the FAO/WHO 1995 regulatory standard. While cadmium, mercury, copper, zinc, and aluminum were all below the permissible limit for both cocoyam and cassava. There was a significant ($p < 0.05$) increase in arsenic, cadmium, lead, copper, zinc and aluminium when compared to the control. Although copper, zinc, aluminum and cadmium were within the permissible limit set by the regulatory bodies, some of these metals especially zinc and copper are essential elements, therefore, consumption of these metals in a tolerable amount poses no health risks as they help in the bodily function due to their importance for plant growth even at very low concentrations, Even though the control area was distant from industry, it still had excessive arsenic and lead, likely from human activities like fertilizer use and pesticides. The test sample had even higher levels, possibly due to machinery exhaust, vehicle emissions, dust, or transportation contamination.

Table 1: Mean and Standard deviation of heavy metals present in Cocoyam and Cassava flour samples.

Heavy metals	Amount in cassava samples (mg/kg)		Amount in cocoyam samples (mg/kg)	
	Control cassava sample	Test cassava sample	Control cocoyam sample	Test cocoyam sample
Arsenic	1.294 ± 0.0003	2.471 ± 0.0006*	0.343 ± 0.0056	1.693 ± 0.000*
Aluminum	0.490 ± 0.0003	1.532 ± 0.0000*	0.490 ± 0.0003	2.693± 0.0000*
Cadmium	0.014 ± 0.0000	0.061 ± 0.0003*	<0.001	0.027 ± 0.0003*
Copper	1.784 ± 0.0000	4.984 ± 0.0003*	0.416 ± 0.0003	3.328 ± 0.0003*
Lead	2.067 ± 0.02683	3.612 ± 0.0000*	1.715 ± 0.0003	2.748 ± 0.0003*
Mercury	<0.001	$<0.001^{ns}$	<0.001	$<0.001^{ns}$
Zinc	3.170 ± 0.0003	6.593 ± 0.0000*	4.324 ± 0.0003	5.031 ± 0.0006*

3.2 Estimation of daily heavy metals intake

The estimated daily intake (EDI) values of Cd, Cu, Zn and Al for the test and control samples of cocoyam flour for adults and children were all below the oral reference dose (RfD) of 0.0005mg/kg/day for cadmium, 0.0003mg/kg/day for mercury,0.04mg/kg/day for copper, 0.3mg/kg/day for zinc, and 1mg/kg/day for aluminum respectively according to USEPA, 2012. Hence, posing no potential health risks. As and Pb had higher EDI values in adults and children than the oral reference dose (RfD) of 0.0003mg/kg/day and 0.0035mg/kg/day respectively in all the samples, thus posing potential health risks. In the test cassava sample, the estimated daily intake (EDI) for adult for aluminum (0.0109 mg/kg/day), cadmium (0.0004 mg/kg/day), copper (0.0352 mg/kg/day), and zinc (0.0471 mg/kg/day) are below the oral reference dose (RfD), thus poses no potential health risk to the populace exposed to the food. Arsenic (0.0177 mg/kg/day) and lead (0.0258 mg/kg/day) were higher than the oral reference dose (RfD), thus poses a potential health risk to the populace on exposure, while in Children the (EDI) levels of arsenic (0.0257 mg/kg/day), cadmium (6.35×10^{-5} mg/kg/day), copper (0.0519 mg/kg/day), and lead (0.0376 mg/kg/day) were above the RfD which poses health risk to the populace exposed to the sample. Aluminum (0.0160 mg/kg/day), zinc (0.0687 mg/kg/day) levels was seen to be below the RfD, thus poses no potential health risk to the populace exposed to the food. However, for the control cassava sample, the EDI of Cd, Cu, Zn and Al for the test and control samples of cassava flour for adults and children were all below the oral reference dose (RfD) while, As and Pb were above RfD which poses health risks to the populace exposed to the sample.

Table 2: Estimated Daily Intake of test and control cocoyam flour compared to their oralreference dose (RfD).

	EDI (mg/kg/day) for control cocoyam sample		EDI (mg/kg/day) for test cocoyam sample		
Metal	**Adults ≥ 18 years**	**Children 6 – 12 years**	**Adults ≥ 18 years**	**Children 6-12 years**	**RfD (mg/kg/day)**
Arsenic	0.00245	0.00357	0.01209	0.01764	0.0003
Cadmium	BDL	BDL	0.00019	0.00028	0.0005
Mercury	BDL	BDL	BDL	BDL	0.0003
Lead	0.0123	0.0179	0.0196	0.0286	0.0035
Copper	0.00297	0.00433	0.0237	0.0347	0.04
Zinc	0.0308	0.0524	0.059	0.0524	0.3
Aluminum	0.00945	0.0138	0.019	0.0281	1

Table 3: Estimated Daily Intake of test and control cassava flour samples compared to their oral reference dose (RfD).

	EDI (mg/kg/day) for control cassava flour sample		EDI (mg/kg/day) for test cassava flour sample		
Metal	Adults ≥ 18 years	Children 6 – 12 years	Adults ≥ 18 years	Children 6 – 12 years	RfD (mg/kg/day)
Arsenic	0.0092	0.0135	0.0177	0.0257	0.0003
Cadmium	0.0001	0.000146	0.00044	0.00064	0.0005
Mercury	BDL	BDL	BDL	BDL	0.0003
Lead	0.015	0.0215	0.0258	0.0376	0.0035
Copper	0.0127	0.0186	0.0356	0.0519	0.04
Zinc	0.0226	0.0330	0.0471	0.0687	0.3
Aluminum	0.0035	0.0051	0.0109	0.0160	1

3.3 Human health risk

3.3.1 Non cancer risk

The hazard quotient (HQ) is <1 or >1 for the non-carcinogenic risk. In the test and control sample of the cocoyam flour, HQ values for cadmium, copper, zinc and aluminum were < 1 for adults and children, implying that the long-term consumption of these cocoyam samples poses no health risks due to these metals in both adults and children. However Arsenic and Lead had high HQ values > 1 in both adults and children implying that the long-term consumption of these cocoyam samples poses health risks due to these metals (Table 4). The hazard index (HI) which signifies the combined non carcinogenic risk of the evaluated metals for the test sample for adults and children was >1 (46.72 and 68.61), while that of the control sample for adults and children was also >1 (11.81 and 17.27) respectively. In the test cassava flour sample, the HQ value for cadmium, copper, zinc and aluminum were < 1 for adults while, the HQ values for arsenic and lead were > 1. In children the HQ values for aluminum, mercury and zinc for the consumption of control cassava flour were also seen to be < 1 while arsenic, cadmium, copper and lead were >1 posing a health risk in long term exposure to these populaces (Table 5). In the control sample of the cassava flour, HQ values for cadmium, copper, zinc and aluminum were < 1 for adults and children while, Arsenic and Lead had high HQ values of> 1 in both adults and children (Table 5). The hazard index (HI) of the combined risk of heavy metal toxicity in test and control cassava flour sample is > 1 in Adults and Children (68.528, 35.916) and (99.27, 52). This indicates that the combined effect of heavy metals present in the test and control cassava poses a health risk in the long term for anadult and children who consumes it. Arsenic and Lead were the main contributors for HQ greater than 1.

Table 4: Hazard quotient (HQ) of selected heavy metals from the consumption of Test and Control cocoyam flour sample.

	HQ for test cocoyam flour sample		**HQ control cocoyam flour sample**	
Metal	**Adults ≥ 18**	**6 – 12 years**	**Adults ≥ 18**	**6 – 12 years**
Arsenic	40	58.8	8.1	11.9
Cadmium	0.386	0.56	BDL	BDL
Mercury	BDL	BDL	BDL	BDL
Lead	5.6	8.17	3.5	5.1
Copper	0.59	0.88	0.10	0.11
Zinc	0.12	0.17	0.07	0.15
Aluminum	0.019	0.0281	0.00945	0.0137

Table 5: Hazard quotient (HQ) of selected heavy metals from the consumption of test and control cassava flour sample.

	HQ for test cassava flour sample		HQ control cassava flour sample	
Metal	**Adults ≥ 18**	**6 – 12 years**	**Adults ≥ 18**	**6–12 years**
Arsenic	59	85.67	30.67	45
Cadmium	0.872	1.27	0.2	0.2916
Mercury	BDL	BDL	BDL	BDL
Lead	7.371	10.74	4.285	6.143
Copper	0.89	1.298	0.318	0.465
Zinc	0.157	0.157	0.075	0.11
Aluminum	0.0109	0.016	0.0035	0.00051

3.3.2 Cancer risk

The total Cancer risk for the test cocoyam sample for adults and children were computed to be, 1.3×10^{-2} and 4.6×10^{-3}, for the control cocoyam flour sample the total cancer risk for adults and children was computed to be, 3.8×10^{-3} and 5.5×10^{-3}. These risk values indicate that test cocoyam consumption would result in an excess of 13 cancer cases per 1000 people for adults and 46 cancer cases per 10,000 in children, while consumption of the control sample would result in 38 cancer cases per 10,000 people for adults and 55 cancer cases per 10,000 in children, The total cancer risk for the test cassava sample for adults and children were computed to be, 2.9×10^{-2} and 4.3×10^{-2} for the control cassava flour sample the total cancer risk for adult and children was computed to be, 1.5×10^{-2} and be 2.1×10^{-2} . These risk values indicate that the test cassava flour consumption would result in an excess of 43 cancer cases per 1000 people for adults and 29 cancer cases per 1000 in children, while consumption of the control cassava flour sample would result in 15 cancer cases per 1000 people for adults and 21 cancer cases per 1000 in children (Table 6). Arsenic and cadmium were the predominant contaminants contributing to the ILCR in both the processed and the control flour samples, this suggests that consumption of these flour samples for both adults and children is of a public health concern as they are above the USEPA acceptable level.

However, untreated high lead levels in the body can lead to mortality, anemia, coma, and irreversible brain damage. Prolonged exposure can harm the kidneys, immune system, and reproductive system. Children, who absorb lead more readily, are especially vulnerable. Even low blood lead levels can affect the intellectual development and IQ of young children (Ekhator *et al*., 2017). Chronic exposure to arsenic has been associated with various health issues, including skin lesions, cardiovascular diseases, and an increased risk of certain cancers, such as lung, bladder, and skin cancer (Winara *et al*., 2022). Cadmium exposure has been linked to a wide range of aberrant clinical manifestations, including skeletal demineralization. Severe cadmium poisoning, decreased libido, fertility, and serum testosterone levels have all been linked to osteomalacia and osteoporosis (Chandel and Ghand, 2014). A similar study by Dibofori-orji *et al*(2015) on the effects of heavy metals in processed cassava flour sold along the roadside of a busy highway revealed a significant increase in the amount of iron, zinc, cadmium and chromium in exposed and unexposed cassava flour, while lead was below the estimated daily intake.

Table 6: Carcinogenic risk in heavy metals in Test and Control Cocoyam and Cassava flour samples.

	Test cocoyam flour sample		Control cocoyam flour sample		Test cassava flour sample		Control cassava flour sample	
Metal	**Adults ≥18**	**Children (6 – 12)**	**adults ≥ 18**	**Children (6 – 12)**	**adults ≥ 18**	**Children (6 – 12)**	**adults ≥ 18**	**Children (6 – 12)**
Arsenic	1.8×10^{-2}	2.6×10^{-2}	3.7×10^{-3}	5.4×10^{-3}	2.7×10^{-2}	3.9×10^{-2}	1.4×10^{-2}	2.0×10^{-2}
Cadmium	1.2×10^{-3}	1.7×10^{-3}	BDL	BDL	2.7×10^{-3}	3.9×10^{-3}	6.1×10^{-4}	8.9×10^{-4}
Lead	1.7×10^{-4}	2.4×10^{-4}	1.1×10^{-4}	1.5×10^{-4}	2.2×10^{-4}	3.2×10^{-4}	1.3×10^{-4}	1.8×10^{-4}
∑ILCR	1.9×10^{-2}	2.8×10^{-2}	3.8×10^{-3}	5.5×10^{-3}	2.9×10^{-2}	4.3×10^{-2}	1.5×10^{-2}	2.1×10^{-2}

4. CONCLUSION

The objectives of this study were to estimate the daily intake of heavy metals, quantify the levels of heavy metals in processed and unprocessed cocoyam and cassava flour samples, and use probabilistic risk assessment models to estimate the risks of cancer and non-cancer diseases associated with exposure to these particular heavy metals. Taking into account the approximate daily consumption of the chosen heavy metals, it was discovered that the processed and control flour samples had levels of lead and arsenic exceeding the allowable limits established by the EU, PTWI, and WHO/FAO, respectively.

The lead and arsenic HQ, HI, and ILCR values are above the set threshold, suggesting a possible health concern to the exposed population. Because heavy metals are present in the environment (air, water, and soil) and have a tendency to accumulate in biological tissues, there is an inescapable risk of food contamination to human health. These food kinds may be contaminated by storage facilities, human activity, and exhaust emissions from dust, processing equipment, or transportation materials. Given the results of this investigation, Nigerian regulatory agencies ought to ensure that food is processed and stored aseptically and educate processors and consumers about the dangers of these food pollutants.

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Conflict of interest

No conflict of interest.

Authors consent

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