

Heavy Metal Contamination and Health Risk Assessment of Packaged Fruit Juices Sold in Benin City, Nigeria

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Abstract

This study assessed the concentrations of selected heavy metals; zinc (Zn), copper (Cu), and manganese (Mn) in six commercially available fruit juices sold in Benin City, Edo State, Nigeria. Samples of *Chivita Exotic*, *Chivita Active*, *Frutta*, *Mr. Fruit*, *Caprison*, and *Ribena* were analyzed using Atomic Absorption Spectrophotometry (AAS) after wet acid digestion. The mean concentrations of Cu, Mn, and Zn across the samples ranged from 0.000–0.007 mg/L, 0.000–0.200 mg/L, and 0.000–0.100 mg/L, respectively. All values were below the World Health Organization (WHO) permissible limits of 2, 0.08 and 3mg/L for Cu, Mn and Zn in fruit juices respectively. However, health risk assessment based on Estimated Daily Intake (EDI) and Target Hazard Quotient (THQ) revealed that while most values were within safe limits, some samples exhibited THQ values exceeding 1, particularly for adults, indicating potential non-carcinogenic risks with prolonged consumption. The results suggest that although the fruit juices analyzed are generally safe for human consumption, continuous monitoring and strict adherence to production quality standards are essential to prevent heavy-metal contamination and protect public health.

Keywords: Heavy metals, Fruit juices, Contamination, Health risks assessment, Hazard quotient.

Introduction

The global demand for nutritious foods and beverages that support health and well-being has increased significantly, driven by rising healthcare costs and the desire for improved quality of life (Ogoko *et al.*, 2024). Among such beverages, are fruit juices widely consumed across all age groups in both developed and developing countries due to their refreshing taste, nutritional value, and bioactive compounds that promote wellness (Ozen *et al.*, 2012; Subedi *et al.*, 2022). In Nigeria, fruit juices and soft drinks are regularly served at social functions and are also consumed daily in homes and workplaces (Ofori *et al.*, 2013; Okafor *et al.*, 2022). The diversity of fruit juice brands available from reputable manufacturers to small-scale producers necessitates continuous monitoring of their safety and quality (Ajai *et al.*, 2014).

Fruit juices naturally contain essential elements such as zinc (Zn), copper (Cu), and manganese (Mn), which are required for various metabolic functions. However, heavy

metal contamination can occur through environmental pollution, packaging materials, contaminated raw materials and the use of poor-quality water during processing (Mahugija, 2018; Jayakumar *et al.*, 2021). Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are non-essential and toxic even at low concentrations, while essential metals like Zn, Cu, and Mn may also pose health risks when present at elevated levels (Khan *et al.*, 2016; Timothy & Williams, 2019; Ogoko *et al.*, 2024). These metals are of concern because they are non-biodegradable and can bioaccumulate in human tissues, leading to long-term health effects including neurological, renal and developmental disorders (Enuneku *et al.*, 2025).

Assessment of heavy metals in fruit juices is gaining attention owing to the buildup of heavy metals in food crops at greater concentrations posing a substantial risk to human health. Since ingestion is a primary source of heavy metal exposure, it is critical to track dietary consumption in order to quantify heavy metal exposure (Ackah *et al.*, 2014). The World Health Organization (WHO) have established permissible limits for heavy metals in beverages to ensure consumer safety. Nevertheless, studies from various regions have shown cases where metal concentrations in fruit juices exceed recommended levels. Ogidi *et al.* (2021) observed that the levels of Cd, and Pb in beverage drinks sold in Bayelsa State were above the WHO permissible levels and may pose serious health hazard. Gomaa *et al.* (2019) reported that the concentrations of Mn and Fe in juices and carbonated drinks sold in Egyptian market exceeded the recommended permissible limits of WHO but copper was found in concentrations lower than the permissible limits. Subedi *et al.* (2022) also observed that heavy metal concentrations in fruit juices sold in India were below permissible limits. Despite several studies (Ogidi *et al.* (2021; El-zwaey *et al.*, 2022; Subedi *et al.* (2022;) have documented the presence of heavy metals in fruit juices around the world. In Nigeria, recent studies on heavy metals and risk assessments of commercially available fruit juices are few and the available studies focused on a narrow range of fruit juices and/or natural fruits (Ajai *et al.*, 2014; Ogoko *et al.*, 2024). In Benin City where numerous local and imported fruit juice brands are sold, it is necessary to ascertain the safety of fruit juices in order to protect public health and inform policy decisions. However, there is currently no available research assessing heavy metals and health risks in fruit juices consumed in this region. The absence of such studies hinders the ability of regulatory agencies to make evidence-based policy decisions which limit the enforcement of NAFDAC quality standards and also compromises consumer safety. Therefore, this study addresses a critical knowledge gap by assessing heavy-metal concentrations in packaged fruit juices sold in Benin City, Edo State with the following objectives:

- Determine the concentration of heavy metals in selected packaged fruit juices.
- Compare concentrations of heavy metals in the selected fruit juices with WHO standards

- Estimate carcinogenic and non-carcinogenic health risks to humans through consumption of these fruit juices.

Literature Review

Studies on commercially available beverages have revealed measurable levels of toxic and essential elements across many product types. A notable U.S. study by Godebo *et al.*, (2023) quantified 25 elements in 60 popular beverages (including mixed-fruit juices and plant-based milks) and reported that several products contained arsenic, cadmium, manganese, nickel and other elements above U.S. drinking-water or federal limits. Lead was detected in most samples, although typically at low levels; some single products had arsenic or cadmium above federal limits. These results show that even in high-income markets, mixed-fruit beverages can contain concerning trace elements, presumably from raw ingredients or production inputs.

Subedi *et al.* (2022) analyzed the concentrations of zinc (Zn), manganese (Mn), iron (Fe), and lead (Pb) in packaged and fresh fruit juices, as well as powdered fruit drink mixes (Tangs), purchased from various stores in Kathmandu Valley using Flame Atomic Absorption Spectroscopy (FAAS). Samples of apple, orange, pineapple, pomegranate and mango were digested using the wet digestion method. The results showed variations in metal concentrations across different juice types, indicating dependence on the fruit source and processing method. However, the mean concentrations of all analyzed metals were below the maximum permissible limits, suggesting that all the tested fruit juices and drink mixes are safe for human consumption with respect to heavy metal contamination.

In another study, Khan *et al.* (2016) investigated heavy metal contamination in fruit juices produced by companies in Lahore, Pakistan, using Atomic Absorption Spectrophotometry (AAS). Samples of apple, mango, pineapple, red grape, peach and mixed fruit juices were analyzed for nickel (Ni), cadmium (Cd), and copper (Cu). The results showed variable concentrations of the metals, with Cu and Cd levels in all samples below the maximum permissible limits established by WHO. However, Ni exceeded the permissible limit in 24% of the samples, indicating potential health risks associated with prolonged consumption of the fruit juices.

Anastacio *et al.* (2018) investigated the concentrations of arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), manganese (Mn), and nickel (Ni) in twenty-one fruit juice samples from four brands available on the Portuguese market. The results revealed that As exceeded permissible limits in four samples, Ni in thirteen, and Mn in all twenty-one, according to Portuguese legislation. Comparisons with WHO and USEPA guidelines confirmed that certain samples surpassed acceptable thresholds, highlighting the need for strict monitoring and reduction of heavy metal levels in commercially available fruit juices. Another study conducted by Mohamed *et al.* (2020) on the determination of the metal content of some fruit juices from Yemen's market showed that Zn and Cu had mean concentration values ranging from 0.02 ± 0.01 to 5.38 ± 0.23 and 0.02 ± 0.01 to 2.47 ± 0.10

respectively. Considering the copper concentrations detected in the investigated fruit juices, it was determined that the population of Yemen was not particularly at danger from copper contamination from fruit juice intake.

Some African studies report similar issues with quantifiable metal residues in juices and related beverages. In Accra, Ghana, Ofori *et al.* (2013) carried out a study on the concentrations of heavy metals; copper (Cu), iron (Fe), lead (Pb), and zinc (Zn) in fruit juices and soft drinks purchased from retail markets, to assess potential public health risks associated with heavy metal contamination. Twenty samples were analyzed using dry ashing, acid digestion, and Flame Atomic Absorption Spectrophotometry. The results revealed that metal concentrations followed the trend $Fe > Zn > Pb > Cu$ for both fruit juices and soft drinks. Mean concentrations in fruit juices were 0.83 ± 0.48 mg/L (Cu), 9.07 ± 3.62 mg/L (Fe), 1.59 ± 0.90 mg/L (Pb) and 3.33 ± 1.29 mg/L (Zn), while soft drinks contained 0.34 ± 0.05 mg/L (Cu), 7.72 ± 3.12 mg/L (Fe), 0.72 ± 0.99 mg/L (Pb), and 1.07 ± 0.66 mg/L (Zn). Comparisons with WHO guidelines showed that some values exceeded permissible limits, indicating potential health risks and necessitating the need for continuous monitoring of heavy metal contamination in commercially available beverages.

In East Africa, Mahugija (2018) analyzed heavy metals in drinking water, cosmetics and fresh fruit juices from Dar es Salaam, Tanzania using Atomic Absorption Spectrometry (AAS). Lead (Pb), zinc (Zn) and iron (Fe) were detected in water samples at variable concentrations while cadmium (Cd) was not detected. Notably, lead levels in 70.83% of the water samples exceeded WHO limits, indicating potential health risks. Copper (Cu) was detected in fruit juices and water used in their preparation (0.008 ± 0.003 – 0.215 ± 0.014 mg/L) and these levels were below WHO permissible limits, indicating minimal risk from juice consumption.

In Egypt and North Africa, Abdel-Rahman *et al.* (2019) documented that non-alcoholic beverage contained detectable levels of several metals (Fe, Zn, Cu, Sn) with some samples exceeding recommended limits for certain elements, illustrating regional prevalence of contamination in processed drinks. More recently, a large packaged-juice survey in Gondar, Ethiopia (Weldegebriel *et al.*, 2025) analyzed 80 packaged fruit-juice samples for Cd, Pb, Cr and Ni and reported ranges of Cd (0.01–0.10 mg/L), Cr (0.01–0.04 mg/L), Ni (0.0025–0.08 mg/L) and Pb (0.0003–0.008 mg/L); several samples exceeded international safety limits for Cd, Ni or Pb, although computed THQs for children were <1 in the study showing that no immediate non-carcinogenic risk by THQ metric. These findings shows that some packaged juices in Africa can contain metals approaching or exceeding safety guidelines and that risk outcomes depend on both concentration and consumption.

El-zwaey *et al.* (2022) examined heavy metal contamination in fifteen samples of canned fruit juices obtained from markets in Benghazi, Libya. Using Atomic Absorption Spectrophotometry (AAS), the concentrations of tin (Sn), cadmium (Cd), iron (Fe), lead (Pb), zinc (Zn), copper (Cu), manganese (Mn), and chromium (Cr) were analyzed across

eight juice varieties, including mango, peach, apple, grape, pineapple, orange, banana, and strawberry. The results revealed varying levels of heavy metals, with Sn showing the highest concentrations (0.8–3.49 mg/L), followed by Fe (0.709–2.307 mg/L), Cu (0.099–0.513 mg/L), Mn (0.01–0.102 mg/L), Pb (0.005–0.012 mg/L) and Zn (0.003–0.064 mg/L), while Cd and Pb were below detection limits (0.005 mg/L). Statistical analysis indicated significant differences ($P = 0.000$) between the concentrations of several metals (Sn, Fe, Zn, Cu, Cd, Pb, Mn, and Cr) and the permissible limits set by Libyan and WHO standards, highlighting potential public health concerns associated with heavy metal contamination in canned fruit juices.

Within Nigeria, a handful of studies have analyzed metals in beverages and foods. Ajai *et al.* (2014) on the assessment of trace metals and essential minerals in selected fruit juices in Minna, Nigeria reported that Mn was not detected in any of the samples and that Cu and Zn had concentrations ranging from 0.00 to 0.05 and 0.00 to 0.04 respectively. The metal levels were below the WHO permissible limits (10–75 mg/L for Zn and 2.0 mg/L for Cu) and were considered safe for human consumption without any potential health effects. Adegbola *et al.* (2015) conducted a study on the evaluation of some heavy metal contaminants in biscuits, fruit drinks, concentrates, candy, milk products and carbonated drinks sold in Ibadan, Nigeria and reported that the concentration of Cu in fruit drinks ranged from 0.01 ± 0.001 to 0.17 ± 0.001 mg/L and also that these concentrations were within the acceptable limit in food.

Another study conducted by Nwanya *et al.* (2023) in Enugu State Nigeria, assessed heavy metals in locally and foreign packaged non-alcoholic beverages consumed by adults, revealed that fruit juices contain variable levels of heavy metals. Zn had a mean range of 1.371 - 5.622 $\mu\text{g/g}$ in the locally packaged beverage samples and 1.114–2.677 $\mu\text{g/g}$ in the foreign packaged beverage samples. Cd had a mean range of 0.033 - 0.060 $\mu\text{g/g}$ in the locally packaged beverage samples and 0 - 0.018 $\mu\text{g/g}$ in the foreign packaged beverage samples. In the same vein, the mean Cu range in the locally packaged non-alcoholic samples was 1.672–2.182 $\mu\text{g/g}$ and 0.462 - 1.873 $\mu\text{g/g}$ in the foreign packaged non-alcoholic beverage samples. There was no risk associated with the dietary intake of the studied metals by the adult consumers of the investigated non-alcoholic beverage samples in Emene, Enugu State.

Extensive literature survey reveal that packaged fruit juices regularly contain measurable levels of both essential and toxic metals in some surveys exceeding permissible limits. Additionally, EDI/THQ assessments can reveal potential non-carcinogenic risks for frequent consumers, especially children. Yet, because contamination profiles are location-specific, generalized conclusions cannot substitute for local surveillance. This study therefore addresses that gap by quantifying Cu, Zn and Mn in six popular packaged fruit-juice brands sold in Benin City, comparing concentrations to WHO and NAFDAC standards and estimating EDI and THQ for children and adults to provide actionable, regionally relevant risk information.

Materials and Methods

Study area

Sampling was conducted in Lagos Street area of King Square (Ring Road), Benin City, Edo State, Nigeria. Benin City is a major urban market hub with a wide availability of locally produced and imported packaged fruit-juice brands.

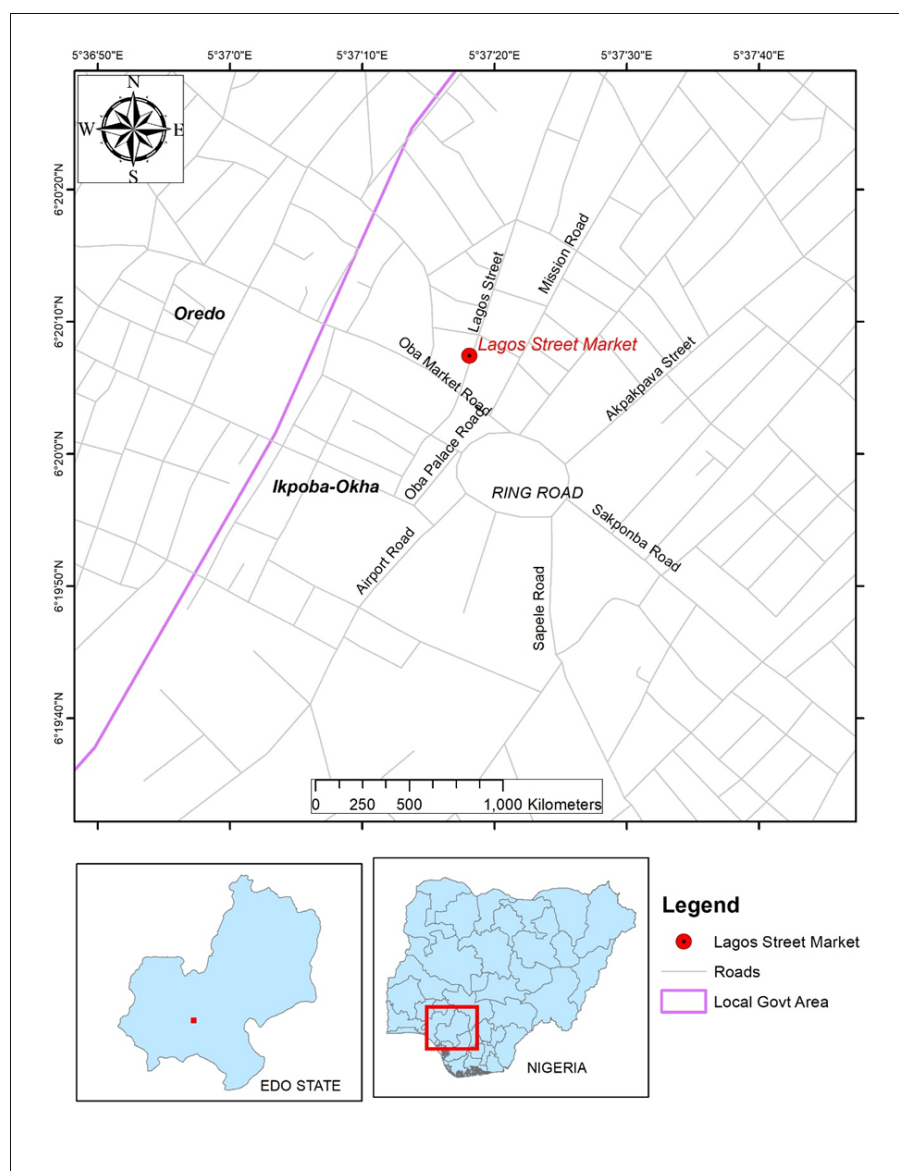


Figure 1: Map of the study area

Study Design

This study adopted an experimental cross-sectional design aimed at assessing heavy-metal contamination and potential health risks associated with the consumption of packaged fruit juices sold in Benin City, Edo State, Nigeria. The design involved systematic sampling of

commercially available juice brands within the study area, laboratory analysis of selected metals (Cu, Zn and Mn) using Atomic Absorption Spectrophotometry (AAS) and health-risk modeling based on Estimated Daily Intake (EDI) and Target Hazard Quotient (THQ).

The cross-sectional design was chosen because it provides a snapshot of contaminant levels at a specific point in time across multiple brands and product categories. This approach allows comparison among brands, determination of compliance with WHO standards and estimation of possible health implications for consumers. Quantitative laboratory data were statistically analyzed to identify significant differences among samples and to evaluate potential exposure risks for adults and children.

Sample Collection and Preparation

Six popular Nigerian fruit juice brands (Chivita exotic, Chivita active, Frutta, Mr. Fruits, Ribena, and Caprison) were acquired in triplicate from various booths (both wholesale and retail), resulting in a total of 18 samples. The samples were placed in clean, sterilized, and properly labeled plastic bottles and delivered to the laboratory for analysis. The samples were stored in a clean dry place prior to digestion and analysis.

Sample Digestion

A 10.0 mL aliquot of each juice sample was measured into a clean digestion flask. To each flask 10.0 mL of concentrated HNO₃ was added, and the mixture was heated on a sand bath under a fume hood. Digestion was continued until brown NO_x fumes subsided and a clear solution was obtained. The digest was then cooled to room temperature, transferred to a 50.0 mL volumetric flask and diluted to volume with deionized water. Procedural blanks and digestion spike samples were prepared in the same manner.

Sample Analysis

Atomic Absorption Spectroscopy methods were employed to quantify heavy metals (zinc, manganese, and copper) in all eighteen (18) samples (Ackah *et al.*, 2014). Calibration standards for AAS analysis were created by serially diluting concentrated stock solutions of the corresponding metals. A calibration curve of absorbance vs concentration was constructed for each metal and used to determine concentrations in the samples. For each brand, three samples were analyzed giving three replicates. The AAS method used acetylene as the fuel and air as the oxidant and the wavelength used for the analysis was 248.3 nm with a limit of detection of 0.002mg/L.

Quality Assurance

To ensure the credibility of the findings, comprehensive quality assurance and quality control techniques were employed throughout the investigation. High-purity chemicals and reagents were used, and glassware was meticulously cleaned with a brush, soap, and water to remove any potential contamination. Following washing, the glassware was

carefully dried and properly labelled. Distilled water was used entirely for all dilution purposes. Furthermore, the absorbance results from the AAS were translated to concentrations using standard calibration curves.

Statistical Analysis

Samples were collected in triplicates, and descriptive statistics (mean $\pm$ SD, range) were computed using IBM SPSS Statistics version 25.0. One-way Analysis of Variance (ANOVA) at 95% confidence interval tested for significant differences ($p < 0.05$) in metal concentrations among juice brands. Where significant differences were found, Tukey's post hoc test was used for multiple comparisons. Graphical presentations were generated using Microsoft Excel.

Results

The result of the concentrations of heavy metals in six brand of fruit juices samples are presented in Table 1. Figures 2 – 7 depict the amounts of heavy metals in various fruit juices. When one-way ANOVA was conducted on the samples with IBM SPSS version 25 at a confidence level of 0.05, a significant difference was observed as shown in Figures 8, 9 and 10.

Table 1: Summary of heavy metal concentration in fruit juice.

	Chivita exotic	Capri son	Ribena	Mr fruit	Chivita active	Frutta		
Metals (mg/L)	mean $\pm$ S D (min- max)	mean $\pm$ S D (min- max)	mean $\pm$ S D (min- max)	mean $\pm$ S D (min- max)	mean $\pm$ S D (min- max)	mean $\pm$ S D (min- max)	F- Val ue	p- valu e
Cu	0.007 $\pm$ 0. 005a (0.000- 0.010)	0.006 $\pm$ 0. 005a (0.000- 0.010)	0.006 $\pm$ 0. 005a (0.000- 0.010)	0.003 $\pm$ 0. 005a (0.000- 0.010)	0.000 $\pm$ 0. 006a (0.000- 0.010)	0.006 $\pm$ 0. 005a (0.000- 0.010)	0.5 2	p>0. 05
Mn	0.200 $\pm$ 0. 000a (0.200- 0.200)	0.033 $\pm$ 0. 057a (0.000- 0.100)	0.033 $\pm$ 0. 057a (0.000- 0.100)	0.000 $\pm$ 0. 057a (0.000- 0.000)	0.000 $\pm$ 0. 00a (0.000- 0.000)	0.067 $\pm$ 0. 057a (0.000- 0.100)	0.2 0	p>0. 05
Zn	0.1 $\pm$ 0.00 0a (0.100- 0.100)	0.000 $\pm$ 0. 000b (0.000- 0.000)	0.067 $\pm$ 0. 057ab (0.000- 0.100)	0.067 $\pm$ 0. 057ab (0.000- 0.100)	0.083 $\pm$ 0. 015ab (0.070- 0.100)	0.083 $\pm$ 0. 028ab (0.05-- 0.100)	6.7 0	p<0. 05

a – No significant difference, ab – significant difference

Table 2: Comparison of mean heavy metal concentrations (mg/L) in Packaged fruit juices sold in Benin City with WHO and NAFDAC Permissible Limits (NAFDAC, 2019; WHO, 2022)

Metal	Sample/Brand	Mean $\pm$ SD (mg/L)	WHO Permissible Limit (mg/L)	NAFDAC Permissible Limit (mg/L)
Cu	Chivita exotic	0.007 $\pm$ 0.005	2.0	5.0
	Caprison	0.006 $\pm$ 0.005		
	Ribena	0.006 $\pm$ 0.005		
	Mr fruit	0.003 $\pm$ 0.005		
	Chivita active	0.000 $\pm$ 0.006		
	Frutta	0.006 $\pm$ 0.005		
Mn	Chivita exotic	0.200 $\pm$ 0.000	0.08	1.0
	Caprison	0.033 $\pm$ 0.057		
	Ribena	0.033 $\pm$ 0.057		
	Mr fruit	0.000 $\pm$ 0.057		
	Chivita active	0.000 $\pm$ 0.000		
	Frutta	0.067 $\pm$ 0.057		
Zn	Chivita exotic	0.100 $\pm$ 0.000	3.0	5.0
	Caprison	0.000 $\pm$ 0.000		
	Ribena	0.067 $\pm$ 0.057		
	Mr fruit	0.067 $\pm$ 0.057		
	Chivita active	0.083 $\pm$ 0.015		

	Frutta	0.083 ± 0.028		
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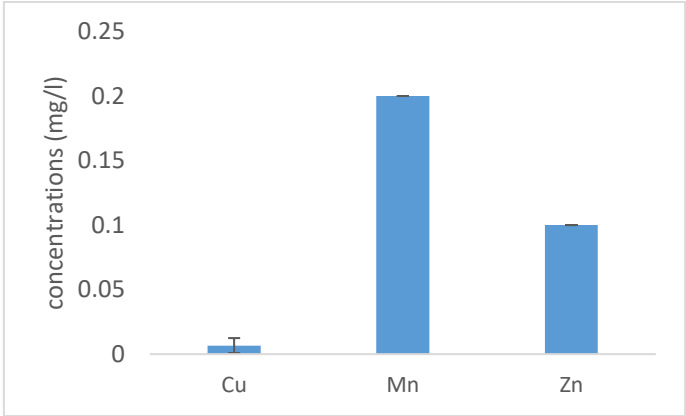


Figure 2: Concentrations of heavy metals in Chivita exotic

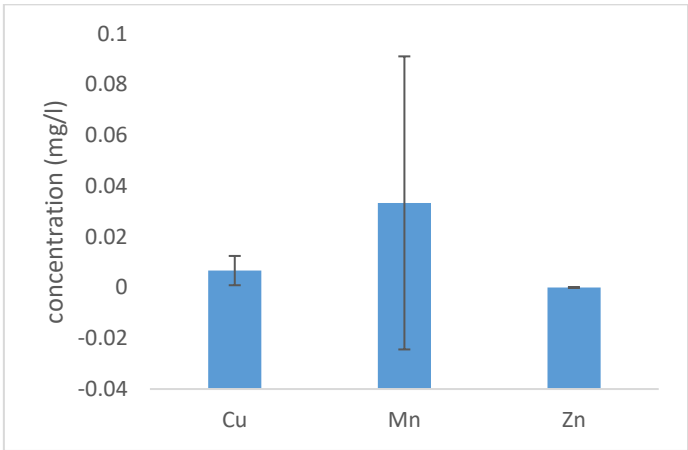


Figure 3: Concentrations of Heavy Metals in Caprison

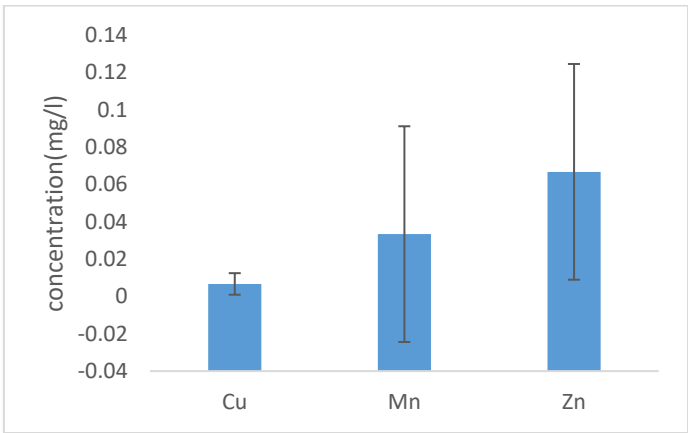


Figure 4: Concentrations of Heavy Metals in Ribena

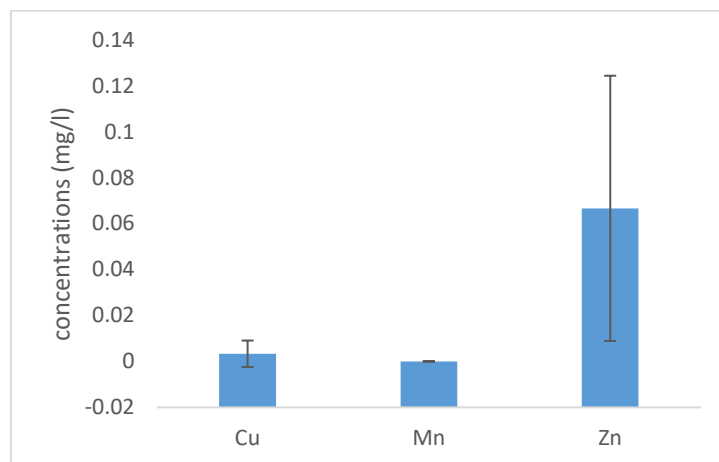


Figure 5: Concentration of Heavy Metals in Mr.Fruit

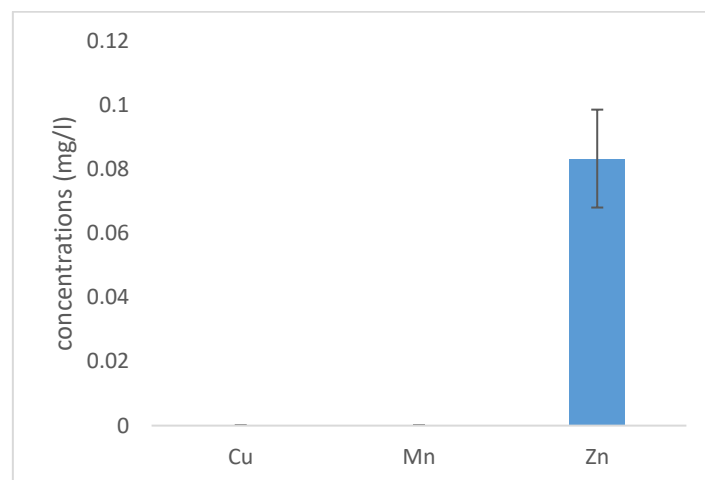


Figure 6: Concentrations of Heavy Metals in Chivita Active.

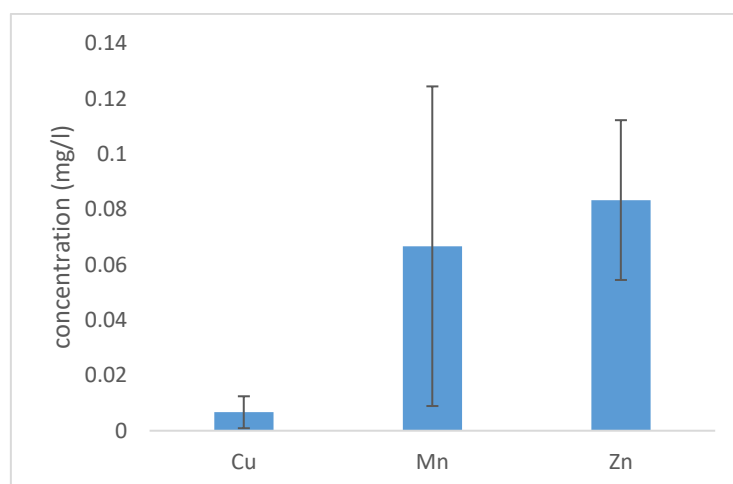


Figure 7: Concentrations of heavy Metals in Frutta.

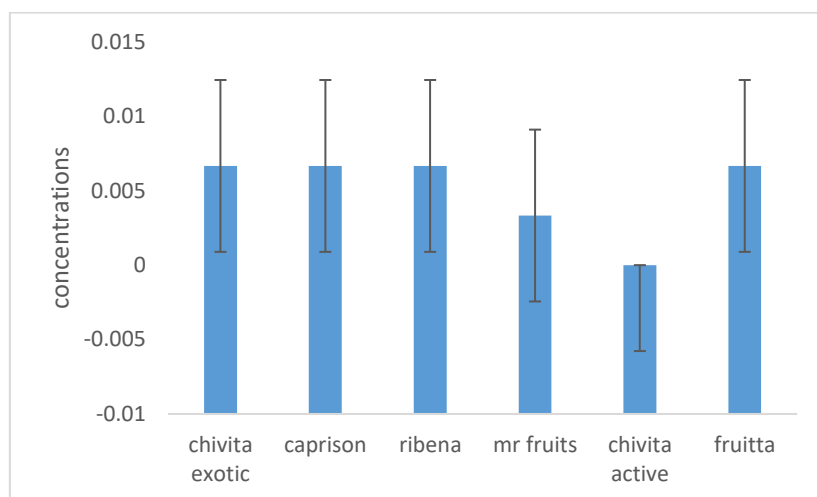


Figure 8: Concentrations of Copper in Fruit Juice.

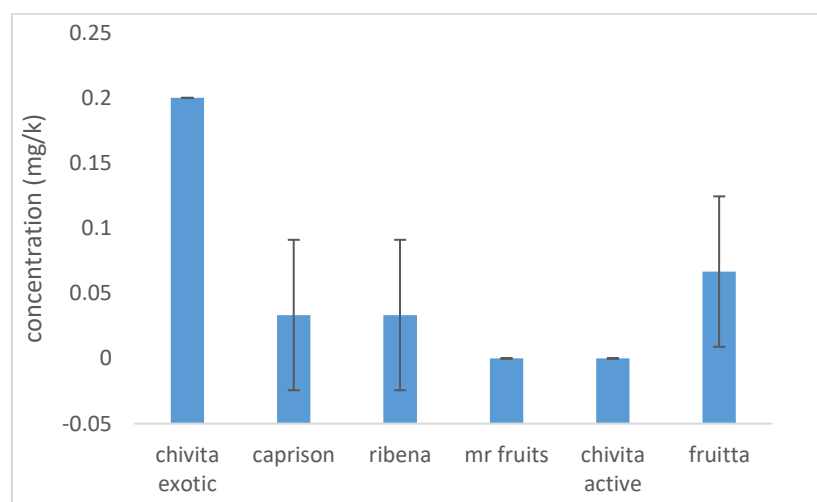


Figure 9: Concentrations of Manganese in Fruit Juice.

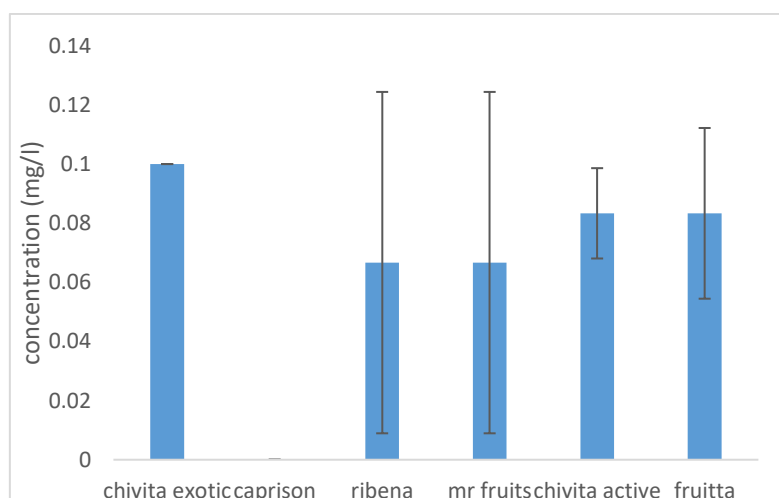


Figure 10: Concentrations of Zinc in Fruit Juice.

Health Risk Assessment in Heavy Metals

The health risks linked with consuming the samples analyzed in this study were evaluated using the Target Hazard Quotient (THQ), Estimated Daily Intake (EDI), and Carcinogenic Risk (CR).

Estimated Daily Intake (EDI)

The Estimated Daily Intake of heavy metals is based on both the quantity of metals and the average consumption of the samples. The EDI is computed using the following equation:

$$EDI = \frac{\text{concentration} \times \text{Daily food intake}}{\text{Average body weight}} \quad (1)$$

Where;

EDI is estimated daily intake

Average body weight is 60kg as reported by Di Leo et al. (2010)

Assumed average daily food intake is 200ml (children) and 500ml (adult)

Table 3: Estimated Daily Intake of Fruit Juices.

	Cu		Mn		Zn	
	Children	Adult	Children	Adult	Children	Adult
Chivita exotic	0.02	0.06	0.67	1.67	0.33	0.83
Caprison	0.02	0.06	0.11	0.28	0.00	0.00
Ribena	0.02	0.06	0.11	0.28	0.22	0.56
Mr fruit	0.01	0.03	0.00	0.00	0.22	0.56
Chivita active	0.00	0.00	0.00	0.00	0.28	0.69
Frutta	0.02	0.06	0.22	0.56	0.28	0.69

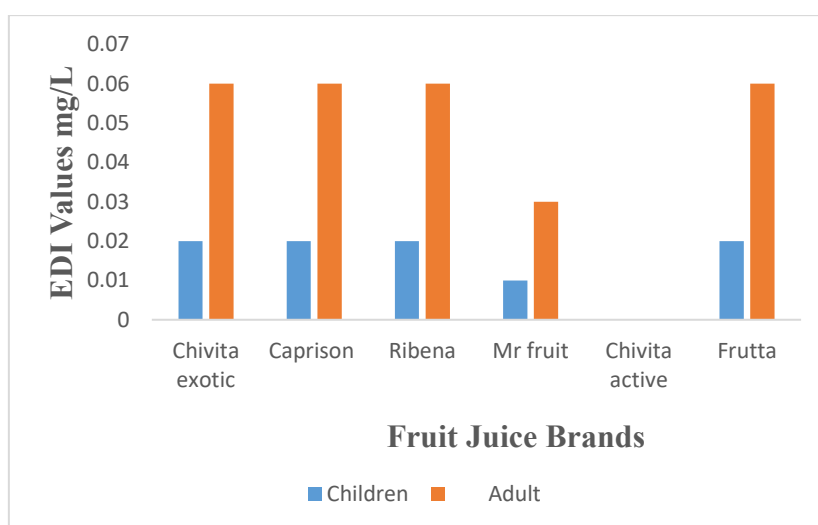


Figure 11: Estimated Daily Intake (EDI) of Cu for Children and Adults

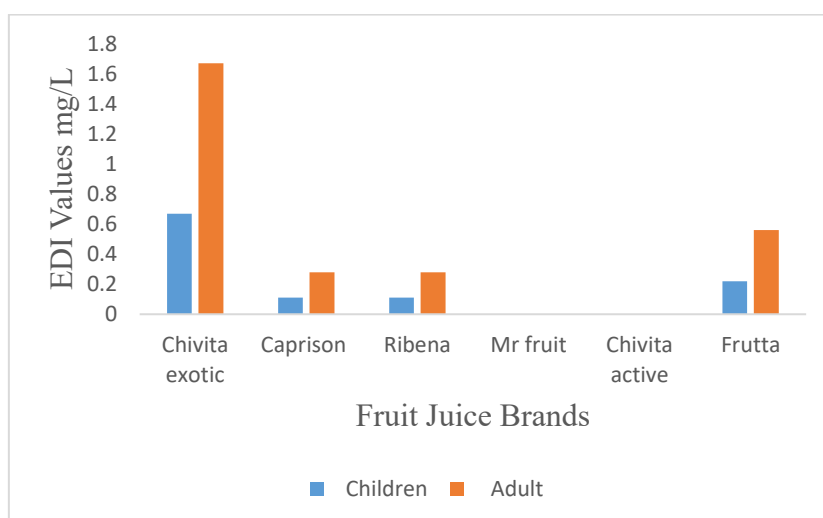


Figure 12: Estimated Daily Intake (EDI) of Mn for Children and Adults

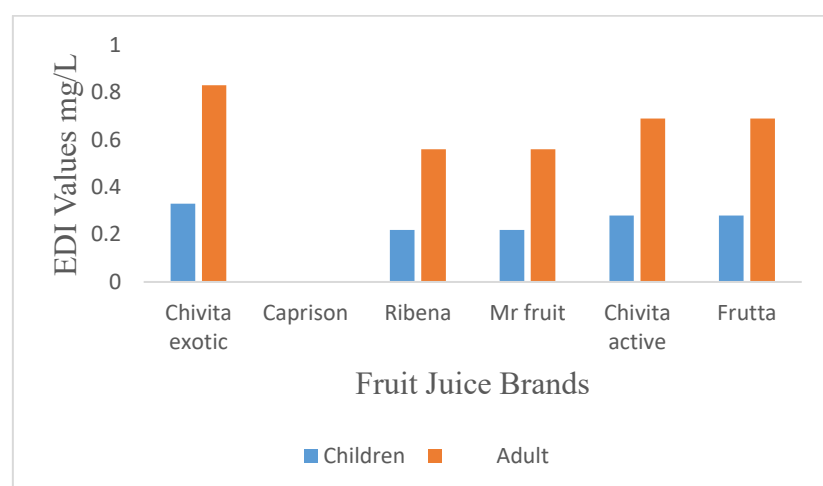


Figure 13: Estimated Daily Intake (EDI) of Zn for Children and Adults

Target Hazard Quotient (THQ)

The Target Hazard Quotient represents the ratio between exposure and the reference oral dose (RfD) and is commonly utilized to indicate the risk of non-carcinogenic effects. According to this ratio, populations exposed to a value equal to or greater than 1 are considered to have a non-carcinogenic risk. Conversely, values below 1 suggest no health risk from the metals for the exposed population. The following reference doses were utilized (Cu=0.040mg/l, Mn=0.014mg/l, Zn=0.300mg/l) to calculate the target hazard quotient.

$$THQ = \frac{\text{concentration of metals} \times \text{Daily juice intake}}{RfD \times \text{Average body weight}} \quad (2)$$

Where;

THQ is Target Hazard Quotient

RfD is reference oral dose as reported by Emmanuel *et al.*, (2022).

Average body weight is 60kg as reported by Di Leo *et al.*, (2010).

Assumed average daily juice intake is 200ml (children) and 500ml (adult).

Table 4: Target Hazard Quotient for Fruit Juices.

	Cu		Mn		Zn		TTHQ	TTHQ
	Children	Adult	Children	Adult	Children	Adult	Children	Adult
Chivita exotic	0.56	1.39	47.62	119.05	1.11	2.78	49.29	123.21
Caprison	0.56	1.39	7.94	19.84	0	0	8.49	21.23
Ribena	0.56	1.39	7.94	19.84	0.74	1.85	9.23	23.08
Mr fuit	0.28	0.69	0	0	0.74	1.85	1.02	2.55
Chivta active	0	0	0	0	0.93	2.31	0.93	2.31
Frutta	0.56	1.39	15.87	39.68	0.93	2.31	17.35	43.39

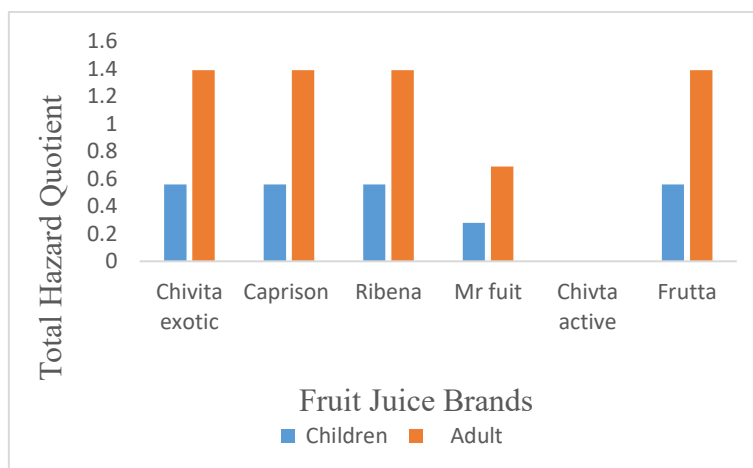


Figure 14: Total hazard quotient for Cu in Children and Adults

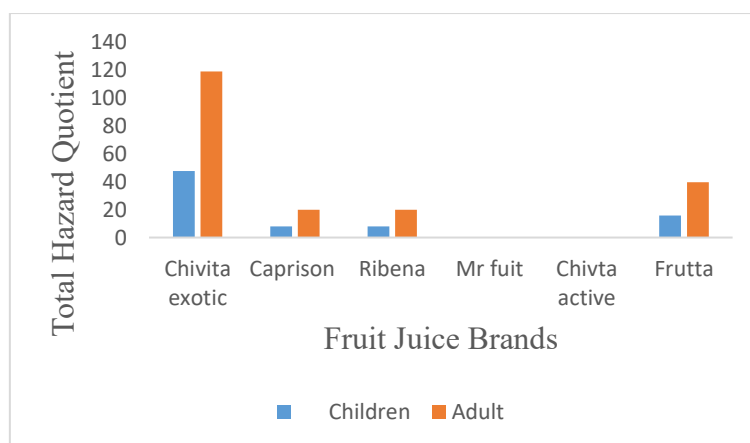


Figure 15: Total hazard quotient for Mn in children and adults

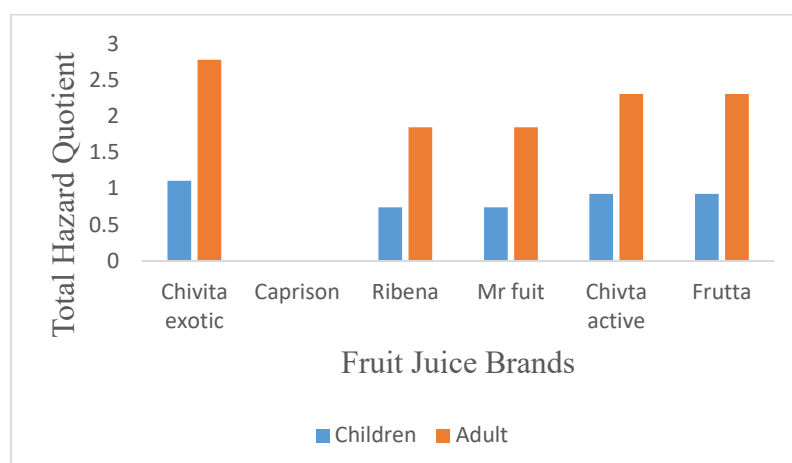


Figure 16: Total hazard quotient for Zn in Children and Adults

Discussion

Heavy Metal Concentrations in Fruit Juices

The concentrations of heavy metals in fruit juices decreased in the order $Mn > Zn > Cu$. The mean concentration of copper and manganese have p-values greater than 0.05, suggesting no significant difference, however zinc has a p-value less than 0.05, indicating a significant difference. The concentration of heavy metals in carbonated beverages is influenced by the efficacy of purifying techniques used during manufacture and the possibility of metal migration from packaging materials into the packed food or beverage (Bora *et al.*, 2020). The raw materials used, the quality of the water used in production, the conditions of plant growth influenced by soil metal levels and irrigation water, environmental pollutants like fertilizers and pesticides, the purity of added sugar and possible contamination during industrial processing and packaging are some of the factors that could cause differences in metal levels among the different juice samples (Abdel-Rahman *et al.*, 2019).

Copper and zinc are crucial trace metals. Copper concentrations in this study had values lower than those reported by Fatima *et al.*, (2020) who conducted a study on the evaluation of heavy metals content in the canned/packed fruit juices from local and imported origin in Lahore, Pakistan with concentration levels that ranged from 11.50 ± 1.11 to 95.00 ± 1.71 ppm. This study's results were also lower than those of Al-Mayaly (2013) who carried out a study on heavy metals in some artificial fruit juices in Iraqi local markets with values ranging from 0.04 ± 0.00 to 0.08 ± 0.03 ppm and Adegbola *et al.*, (2015) who conducted a study on the evaluation of some heavy metal contaminants in biscuits, fruit drinks, concentrates, candy, milk products and carbonated drinks sold in Ibadan, Nigeria with concentration levels ranging from 0.01 ± 0.001 to 0.04 ± 0.002 mg/L. The highest copper content determined in this study was 0.007 mg/L, while the lowest was 0.000 mg/L. According to World Health Organization (WHO) guidelines, the permissible level of copper in fruit juice is 2.0 mg/l

(Mahugija, 2018). The concentration of copper in all of the fruit juice samples examined in this study were below the WHO's permitted limits.

The concentrations of zinc in this study were compared to those reported by Mohamed *et al.*, (2020) who conducted a study on the ICP-OES assisted determination of the metal content of some fruit juices from Yemen's market with mean concentration levels ranging from 0.02 ± 0.01 to 5.38 ± 0.23 mg/l in Yemen and Ajai *et al.*, (2014) determination of trace metals and essential minerals in selected fruit juices in Minna, Nigeria with concentration levels ranging from 0.00 ± 0.00 to 0.40 ± 0.01 mg/l in Nigeria. The World Health Organization (WHO) has set a range of 10 to 75 mg/L. The highest concentration of zinc found in this study was 0.1 mg/l while the lowest concentration was 0.0 mg/l. These values pose no carcinogenic risk to the public who consumed these drinks.

The concentrations of manganese in this study were lower than those obtained by Abdel-Rahman *et al.*, (2019) who conducted a study on the heavy metals content in some non-alcoholic beverages (carbonated drinks, flavored yogurt drinks, and juice drinks) of the Egyptian markets with concentration values ranging from 0.12 ± 0.02 to 1.24 ± 0.04 mg/kg. This study found that manganese had the highest mean concentration in all of the fruit juices tested. Mn levels may have been notably influenced by the acidic soil conditions under which the fruits were cultivated. However, further research is needed to accurately correlate the content of this element with soil characteristics in diverse growth areas.

Comparing findings from this study with earlier Nigerian studies revealed that metal levels found here are substantially lower. For instance, Ajai *et al.* (2014) reported Mn concentrations up to 0.27 mg/L and Zn up to 0.09 mg/L in juices from Minna, while Nwanya *et al.* (2023) measured Cu between 1.67–2.18 mg/L and Zn between 1.37–5.62 mg/L in non-alcoholic beverages from Enugu. The lower concentrations observed in Benin City likely reflect improved manufacturing hygiene, water-quality monitoring and packaging standards adopted in recent years. Internationally, the findings also align with reports by Godebo *et al.* (2023), who found trace levels of As, Cd, and Pb in U.S. mixed-fruit beverages often below regulatory limits confirming that fruit-based drinks worldwide commonly contain residual metal traces from natural or industrial sources but rarely at levels posing acute toxicity.

Health Risk Assessment

The risk linked with the exposure to contaminants present in food items has aroused concerns in human health. Improvements in food production and processing technology have brought about the increased chances of food contamination with various environmental pollutants, such as heavy metals. Health risk assessment revealed that Estimated Daily Intake (EDI) and Total Hazard Quotient (THQ) were below 1 in children while above 1 in adult. When the value of THQ is less than 1, there is no non-carcinogenic risk. When it exceeds 1, there may be concerns about the non-carcinogenic health risks linked with excessive exposure.

For Cu, THQ values for adults were greater than one except Mr. Fruit (0.69). However, for children, all THQ values for Cu were less than one, with Chivita active having no THQ values for either adults or children. For Mn, all THQ values for both adults and children were greater than one, with Mr. Fruit and Chivita active having no values for either adults or children.

For Zn, THQ values for children were all less than one, except Chivita exotic (1.11), whilst THQ values for adults were all greater than one, with Caprison having no values for both children and adults. Target Hazard Quotient (THQ) and Total Target Hazard Quotient (TTHQ) results highlight manganese as the major contributor to cumulative exposure. For example, the TTHQ in *Chivita Exotic* was 49.29 for children and 123.21 for adults, compared with < 2.0 for Cu and Zn which implies that even though absolute Mn concentrations are low, its relatively small RfD value magnifies its contribution to risk indices. This pattern agrees with earlier studies showing Mn as the dominant element in total hazard assessment of fruit juices (Adegbola *et al.*, 2015; Weldegebriel *et al.*, 2025).

THQ and TTHQ values exceeding unity do not necessarily predict clinical toxicity but rather signal potential concern if exposure is chronic and additive from multiple dietary sources. In this study, the THQ values for most brands were above 1 for adults but near 1 for children, suggesting that frequent adult consumers may accumulate higher relative exposure due to greater intake volumes. However, since absolute metal concentrations remain low, the real-world health risk is expected to be minimal.

The predominance of Mn in the hazard indices necessitates the need for periodic surveillance of trace metals in fruit juices and their raw materials. Continuous monitoring will ensure compliance with WHO and NAFDAC limits and help trace sources of contamination where exceedances occur. Given the large consumer base in Benin City, maintaining strict quality-control standards is essential to prevent gradual accumulation of trace metals in the population.

Limitation of the Study

This study was limited by its small sample size (six brands) and analysis of only three metals. Future work should include additional toxic metals such as Pb, Cd, and Ni, expand sample representation across multiple Nigerian cities and assess seasonal variation. Furthermore, biomonitoring of trace-metal exposure among regular juice consumers would strengthen risk-assessment validity.

Conclusion

This study assessed the concentrations of copper (Cu), manganese (Mn), and zinc (Zn) in six popular brands of packaged fruit juices sold in Benin City, Nigeria and evaluated potential health risks associated with their consumption. All measured metal concentrations were below the World Health Organization (WHO) and NAFDAC permissible limits, indicating

that the analyzed juices are generally safe for consumption. However, manganese exhibited slightly higher levels in some brands and contributed most to the total hazard indices (TTHQ), suggesting the need for continued surveillance of Mn content in beverages. This study is the first of its kind to document heavy metal concentrations in fruit juices in Benin City. Unlike earlier investigations that reported higher contamination in other regions, this study provides recent evidence of improved compliance with international safety standards, reflecting progress in manufacturing hygiene, water treatment and packaging practices. However, the study recommends the following;

- NAFDAC and the Edo State Ministry of Health should conduct periodic surveillance of trace-metal levels in packaged beverages, particularly focusing on manganese and other potentially toxic metals (Pb, Cd, Ni).
- Regulatory bodies should issue public advisories encouraging moderate consumption of packaged juices, particularly among children and ensure that labeling clearly indicates compliance with national and WHO safety guidelines.

Conflicts of Interest

All authors have no conflicts of interest to declare.

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References

- Abdel-Rahman, G. N., Ahmed, M. B., Sabry, B. A., & Ali, S. S. (2019). Heavy metals content in some non-alcoholic beverages (carbonated drinks, flavored yogurt drinks, and juice drinks) of the Egyptian markets. *Toxicology Reports*, 6, 210–214. <https://doi.org/10.1016/j.toxrep.2019.02.010>
- Ackah, M., Anim, A. K., Zakaria, N., Osei, J., Saah-Nyarko, E., Gyamfi, E. T., & Bentil, N. O. (2014). Determination of some heavy metal levels in soft drinks on the Ghanaian market using atomic absorption spectrometry method. *Environmental Monitoring and Assessment*, 186(12), 8499 – 8507. <https://doi.org/10.1007/s10661-014-4019-8>.
- Adegbola, R. A., Adekanmbi, A. I., Abiona, D. L., & Atere, A. A. (2015). Evaluation of some heavy metal contaminants in biscuits, fruit drinks, concentrates, candy, milk products, and carbonated drinks sold in Ibadan, Nigeria. *International Journal of Biological and Chemical Sciences*, 9(3), 1691-1696. <https://doi.org/10.4314/ijbcs.v9i3.47>
- Ajai, A. I., Ochigbo, S. S., Abdullahi, Z., & Anigboro, P. I. (2014). Determination of trace metals and essential minerals in selected fruit juices in Minna, Nigeria. *International Journal of food science*, 2014(1), 462931. <https://doi.org/10.1155/2014/462931>.
- Al-Mayaly, K. I. (2013). Determination of some heavy metals in some artificial fruit juices in Iraqi local markets. *International Journal of Research and Development in Pharmacy and Life Sciences*, 2(4), 507-510. <http://www.doi/ijrdpl.com/docs/june13/8.pdf>.
- Anastácio, M., Dos Santos, A. M., Aschner, M., & Mateus, L. (2018). Determination of trace metals in fruit juices in the Portuguese market. *Toxicology Reports*, 5, 434-439. <https://doi.org/10.1016/j.toxrep.2018.03.010>

- Bora, F. D., Calugar, A., Bunea, C. L., & Racz, I. (2020). Determination of trace and heavy metals in fruit juices in the Romanian market. *Horticulture*, **77**(2):125 – 128. <https://doi.org/10.15835/buasvmcn-hort:2020.0022>
- Di Leo, A., Cardellicchio, N., Giandomenico, S., & Spada, L. (2010). Mercury and methylmercury contamination in *Mytilus galloprovincialis* from Taranto Gulf (Ionian Sea, Southern Italy): risk evaluation for consumers. *Food and Chemical Toxicology*, **48**(11), 3131-3136. <https://doi.org/10.1016/j.fct.2010.08.008>.
- El-zwaey, R. S., Towier, N. H., Ahmida, N. H., Busaadia, M. A. S., & Amer, S. M. (2022). The level of some heavy metals in canned fruit juices collected from some Benghazi city markets. *Journal of Environmental Science, Toxicology and Food Technology*, **16**(2), 13-20. <https://doi.org/10.9790/2402-1602011320>.
- Emmanuel, U. C., Chukwudi, M. I., Monday, S. S., and Anthony, A. I. (2022). Human health risk assessment of heavy metals in drinking water sources in three senatorial districts of Anambra State, Nigeria. *Toxicology Reports*, **15**(9), 869-875. <https://doi.org/10.1016/j.toxrep.2022.04.011>
- Enuneku, A., Ogbomida, E., Edomwande, S., & Izebere, B. (2025). Heavy Metals and Health Risk Assessment of Topsoil in Primary School Playgrounds in Edo State, Nigeria. *African Journal of Environmental Sciences and Renewable Energy*, **20**(1), 173-194. <https://doi.org/10.62154/ajesre.2025.020.01021>
- Fatima, N., Khan, M., & Kabeer, M. S. (2020). Evaluation of heavy metals content in the canned/packed fruit juices from local and imported origin in Lahore, Pakistan. *Journal of Food Safety and Hygiene*, **6**(4), 183 – 197. <https://doi.org/10.18502/jfsh.v6i4.7564>.
- Godebo, T. R., Stoner, H., Pechilis, M., Taylor-Arnold, H., Ashmead, J., Claman, L., & Heard, E. (2023). Toxic metals and essential elements contents in commercially available fruit juices and other non-alcoholic beverages from the United States. *Journal of Food Composition and Analysis*, **119**, 105230. <https://doi.org/10.1016/j.jfca.2023.105230>.
- Godebo, T. R., Stoner, H., Pechilis, M., Taylor-Arnold, H., Ashmead, J., Claman, L., & Heard, E. (2023). Toxic metals and essential elements contents in commercially available fruit juices and other non-alcoholic beverages from the United States. *Journal of Food Composition and Analysis*, **119**, 105230. <https://doi.org/10.1016/j.jfca.2023.105230>.
- Gomaa N Abdel-Rahman, G. N., Ahmed, M. B. M., Sabry, B. A. & Ali, S. S. M. (2019). Heavy metals content in some non-alcoholic beverages (carbonated drinks, flavored yogurt drinks, and juice drinks) of the Egyptian markets. *Toxicology Reports*, **25**(6), 210–214. <https://doi.org/10.1016/j.toxrep.2019.02.010>.
- Jayakumar, M., Surendran, U., Raja, P., Kumar, A., & Senapathi, V. (2021). A review of heavy metals accumulation pathways, sources and management in soils. *Arabian Journal of Geosciences*, **14**(20), 2156. <https://doi.org/10.1007/s12517-021-08543-9>.
- Khan, I., Mehmood, Z., Khan, M., & Fatima, T. (2016). Analysis and detection of heavy metals present in fruit juices of Lahore. *International Journal of Engineering Science*, **6**, 3536 – 3539. <https://doi.org/10.4010/2016.819>.
- Mahugija, J. A. (2018). Levels of heavy metals in drinking water, cosmetics and fruit juices from selected areas in Dar es salaam. *Tanzania Journal of Science*, **44**(1), 1-11. <https://doi.org/10.4314/tjs.v44i1>.
- Mohamed, F., Guillaume, D., Abdulwali, N., Al-Hadrami, K., & Al-Maqtari, M. A. (2020). ICP-OES assisted determination of the metal content of some fruit juices from Yemen's market. *Heliyon*, **6**:1-6. <https://doi.org/10.1016/j.heliyon.2019.e0313>.
- National Agency for Food and Drug Administration and Control (NAFDAC) (2019). *Fruit Juice and Nectar Regulations, Nigeria*. Abuja: Federal Republic of Nigeria. Retrieved from

- https://www.nafdac.gov.ng/wpcontent/uploads/Files/Resources/Regulations/FOOD_REGULATIONS/Fruit-Juice-and-Nectar-Regulations-2019.pdf. Accessed 25th September, 2025.
- Nwanya, K. O., Aniobi, C. C., Okeke, M. U., Okeke, O. R., & Ezeagwu, P. C. (2023). Risk assessment of the intake of heavy metals in locally and foreign packaged non-alcoholic beverages consumed by adults living within Emene in Enugu, State, Nigeria. *Journal of Current Research in Food Science*, 4(2), 08-13. No DOI Available
- Ofori, H., Owuau, M. & Anyebuno, G. (2013). Heavy metals analysis of fruit juice and soft drinks bought from retail market in Accra, Ghana. *Journal of Scientific Research and Reports*, 2(1): 423–428. DOI: <https://csirspace.foodresearchgh.site/handle/1/359>
- Ogidi, O. I., Enenebeaku, U. E., Okara, E., & Elumelu, S. A. (2021). Toxic metal profiles, carcinogenic and non-carcinogenic human health risk assessment of some locally produced beverages in Nigeria. *Journal of Toxicology and Risk Assessment*, 7(1), 1-8. <https://doi.org/10.23937/2572-4061.1510039>
- Ogoko, E. C., Aletan, U. I., Osu, C. I., Kelle, H. I., Iroegbulem, I., Emeziem, D., & Adams, A. E. (2024). Hazard and health risk assessment of heavy metals in non-alcoholic beverage consumed in Abia State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 28(9), 2575-2583. <https://10.4314/jasem.v28i9.1>
- Okafor, V. N., Omokpariola, D. O., Okabekwa, C. V., & Umezina, E. C. (2022). Heavy metals in alcoholic beverages consumed in Awka, South-East Nigeria: Carcinogenic and non-carcinogenic health risk assessments. *Chemistry Africa*, 5(6), 2227-2239. <https://doi.org/10.1007/s42250-022-00477-3>.
- Ozen, A. E., Pons, A., & Tur, J. A. (2012). Worldwide consumption of functional foods: a systematic review. *Nutrition reviews*, 70(8), 472-481. <https://doi.org/10.1111/j.1753-4887.2012.00492.x>
- Subedi, S., Adhikari, D., & Poudel, B. R. (2022). Determination of heavy metals in varieties of fresh and packaged fruit juices along with powdered fruit drink mixes in Kathmandu Valley. *Journal of Balkumari College*, 11(1), 63-69. <https://doi.org/10.3126/jbkc.v11i1.53024>.
- Timothy, N. A., & Williams, E. T. (2019). Environmental pollution by heavy metal: an overview. *International Journal of Environmental Chemistry*, 3(2), 72-82. <https://10.11648/j.ijec.20190302.14>
- Weldegebriel, F., Gizaw, Z., Gebrehiwot, M., Yohannes, L., Azanaw, J., Genet, M., & Ahlawat, Y. (2025). Toxic metal contamination and health risk assessment of packaged fruit juices for children in Gondar city, Ethiopia. *Scientific Reports*, 15(1), 1-12. <https://doi.org/10.1038/s41598-025-20789-x>.
- World Health Organization (WHO). (2022). *Chemical Fact Sheets: Copper, Manganese, and Zinc*. Geneva: World Health Organization. Available at <https://cdn.who.int/media/docs/default-source/wash-documents/wash-chemicals>. Accessed 25th September, 2025.