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Evaluation of Heavy Metal Contamination in Apple, Orange, and Watermelon Retailed Along Roadsides in Okinni, Egbedore Local Government, Osun State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The escalating concern of heavy metal contamination in fruits underscores the need to evaluate associated health risks linked to their consumption. This study undertook assessment of heavy metal levels in commonly consumed fruits (orange, watermelon, and apple) retailed by roadside vendors in Okinni, Egbedore Local Government Area, Osun State. Data collection encompassed a

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meticulously designed questionnaire while 27 fruit samples (nine fruit each) were randomly procured from diverse market for laboratory analysis. Descriptive statistics, including frequency distribution, mean, and standard deviation, were computed for each heavy metal. The study discerned that majority of vendors predominantly procured their fruits from local farms, implemented the use of fertilizers or pesticides, employed baskets for storage and transportation, and generally held positive perspectives regarding the safety of fruits dispensed by roadside vendors. The results of heavy metal concentration averages in the sampled fruits fell within the permissible limits established by the World Health Organization (WHO) guidelines for safe levels in food. However, noteworthy concentrations of certain heavy metals, particularly As and Cr, were identified, signaling potential health risks for consumers. These findings underscore the ongoing necessity for rigorous monitoring and regulation of heavy metals in food, coupled with adherence to recommended dietary guidelines and safety standards to safeguard public health.

Keywords: Heavy metal contamination; fruit consumption; health risks; roadside vendors; food safety.

1. INTRODUCTION

Heavy metals, characterized by their relatively high atomic weight and density compared to water, are naturally occurring elements with diverse applications that have led to their widespread distribution in the environment. This ubiquity has raised significant concerns regarding their potential impacts on both human health and the environment. The global phenomenon of heavy metal contamination poses serious risks to ecosystems and human well-being, particularly in the face of increased urbanization, property transitions, and industrial development, especially in densely populated and emerging nations [1].

Originating from both anthropogenic and natural sources, certain heavy metals, such as chromium (Cr), vanadium, and nickel (Ni), play essential roles in cellular activity and are vital for human health in trace amounts [2]. However, the dual nature of heavy metals means that some of them, including arsenic (As), cadmium (Cd), chromium, and lead (Pb), have detrimental effects on the environment and living organisms, including humans [3].

Human exposure to heavy metals occurs through inhalation, oral ingestion, and skin contact [4]. The concentration of metal ions in living cells must be carefully regulated to maintain a balance between positive and negative effects. While essential metals like cobalt (Co), copper (Cu), nickel, lead (Pb), manganese (Mn), zinc (Zn), molybdenum (Mo), and selenium (Se) are crucial for living organisms, their consumption above safe limits can result in severe health complications. On the other hand, non-essential metals like arsenic, cadmium, chromium, and lead can cause health issues even at low concentrations [5].

The mobility and bioavailability of heavy metals determine their contamination, with ecosystem risk assessment being a primary concern for environmental food scientists. The accumulation of heavy metals in fruits, vegetables, and other crops raises significant alarm due to the potential health risks associated with their consumption [6]. Various sources contribute to metal contamination in food crops, including discharges onto agricultural lands, industrial and sewage wastewater, pesticide applications, and atmospheric deposition from vehicle emissions and other sources. These trace metals can be translocated from the soil to different parts of the plant, posing risks to human health depending on the specific metal [6].

Lead, arsenic, zinc, and other metals have been found in food crops at levels exceeding recommended dietary allowances, highlighting the potential dangers of heavy metal contamination in the food supply [6]. The consequences of this contamination include kidney damage associated with cadmium, neurological damage from mercury and lead, and various cancers, particularly skin cancer, from arsenic (Jarup, 2003).

Reports indicate that approximately half of human lead intake comes from food, with fruits being a significant contributor. This poses severe consequences for both human and ecological health, as the surfaces of fruits can become contaminated during production, transportation, preservation, and marketing. Contaminants from vehicles, industrial environments, and pollutants like PAHs and PAEs may adhere to fruit surfaces. Additionally, fertilizers and pesticides can introduce heavy metals into the air, water, and surrounding environments, further contributing to contamination [7].

Long-term exposure to heavy metals, especially through the consumption of fruits and vegetables with high metal concentrations, can result in chronic accumulation, leading to damages in various organs and systems such as the heart, nervous system, liver, kidneys, blood, lungs, bones, and spleen. Adverse effects include mutagenesis, carcinogenesis, and teratogenesis, contributing to human illnesses, disorders, deformities, and organ failures due to metal poisoning [8]. Among the heavy metals, lead, arsenic, mercury, cadmium, and tin stand out as primary threats to human health [7].

2. MATERIALS AND METHODS

2.1 Research Design

This study will adopt a quantitative research approach to systematically measure and analyze the levels of heavy metal contamination in apple, orange, and watermelon samples. Cross-sectional research design will be employed, allowing for the collection of data at a single point in time to assess the current state of heavy metal contamination in the selected fruits.

2.2 Study Area

The study focused on the Okinni area in the Egbedore Local Government Area of Osun State, Nigeria. Okinni is a town in Osun State, situated near Erin-Osun and Ifon. Geographically, it is located at approximately 7° 50' 0" North and 4° 32' 0" East. The selection of this study area was based on factors such as the availability of fruits, sampling cost considerations, and the proximity of the study area.

2.3 Sampling and Sampling Techniques

Convenience sampling will be utilized to select fruits retailed along roadsides in Okinni, Egbedore Local Government. This method will enable easy access to the samples while ensuring representation of fruits commonly consumed by the local population. The sample size was determined based on statistical calculations to ensure adequate representation of the population of fruits retailed along roadsides in the study area. Data was collected through a well-structured closed-ended questionnaire, gathering information about the vendors' sources of fruits, farming practices, and the storage and transportation methods employed. This information aimed to identify potential sources of heavy metal contamination and provide recommendations for minimizing contamination in the fruits.

Oranges, apples, and watermelon samples were randomly collected from different market stalls in the Okinni area, Egbedore Local Government Area, Osun State. For each fruit variety, two samples were obtained and placed into appropriately labeled sacks, conveyed to the laboratory for analysis

2.4 Apparatus and Instruments

The project utilized various apparatus and instruments for the study, including polyethylene bottles, micro pipettes, vials, volumetric flasks, beakers, pipettes, different-sized measuring cylinders, funnels, graduating cylinders, thermometers, Whatman filter papers no. 42, refrigerators, hot plates, and an Inductive Coupled Plasma Atomic Absorption Spectrophotometer.

2.5 Chemicals

High-purity analytical grade reagents were employed for the analysis, including HNO_3 (69% LR, Breckland Scientific Supplies, UK) and H_2O_2 (30%), which was used for the digestion of samples and blanks. Certified reference materials (Cd, Zn, Pb, and Ni) from a European accredited lab were used for preparing standard samples. Tap water, distilled water, and deionized water were utilized for washing, rinsing, and sample preparation.

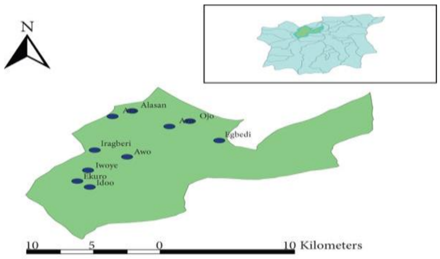

Fig. 1. Map of the Study Area

2.6 Sample Treatment

The treatment process involved washing the fruits with tap water and distilled water, followed by squeezing the juice into separate beakers. About 200 mL of juice was obtained from each sample. The juice was filtered, mixed well, and stored in a refrigerator prior to analysis.

A 50 mL sample was placed into a 250 mL beaker, and aqua regia prepared from analytical-grade concentrated 36% HCl and concentrated 63% HNO_3 was added. The mixture underwent a heating and reflux process on a hot plate. The solution was cooled, 10 mL of 30% H_2O_2 (AR) was added, and the heating continued until complete digestion.

The digest was filtered using Whatman No. 4 filter paper into a 50 mL volumetric flask and diluted with double-distilled water to the 50 mL mark. Three samples each of the juice from orange, watermelon, and apple, as well as spiked samples and a blank, were digested using this method.

2.7 Validity and Reliability:

Measures was taken to ensure the validity and reliability of the data, including using standardized protocols for sample collection and analysis and calibrating instruments regularly to maintain accuracy.

2.8 Analysis

All the digested samples were analyzed for arsenic (As), lead (Pb), chromium (Cr), and zinc (Zn) using an Inductive Coupled Plasma Atomic Emission Spectrometer (ICP).

3. RESULTS AND DISCUSSION

The discussion of findings in this study centers on the interpretation and implications of the heavy metal concentrations in fruits (orange, watermelon, and apple) in Okinni, Egbedore Local Government Area, Osun State, based on the data collected and analyzed.

Table 1. Showing responses of the respondents to Questionnaires

S/N	VARIABLE	Respondent
1	Occupation	Farmer 29%, Vendor 62% Others 9%
2	Source of fruits	local forms 51%, Wholesale 15% Others area 34%
3	Fertilizers / pesticides usage	Yes 46%, No 54%
4	fruits transportation before selling	In plastic bags 35%, In baskets 55% Other 10%
5	Selling fruits	Daily 61% Weekly 24% Monthly 15%
6	Years of selling fruits	Less than 1 year 24%, 1-5 years 47% More than 5 years 29%
7	Training received on food safety and hygiene	Yes 45%, No 55%
8	Information about heavy metals on fruits	Yes 65%, No 35%
9	Safety of fruits for consumption	Strongly agree 29%, agree 35% neutral 6%, disagree 24% and strongly disagree 6%
10	Testing of fruits for heavy metals	Regularly 6% occasionally 35% never 59%
11	Method used for testing heavy metals in fruits	Laboratory analysis 6% visual inspection 35% others 21% not applicable 47%
12	Measures taken to prevent heavy metal contamination in fruits	Regulate use of organic fertilizer 24%, proper disposal of chemical waste 6%, regular cleaning of storage container 12%, Others 7%, None 53%
13	Regulation and guideline regarding heavy metal	Strongly Agree 51%, Agree 38%, Neutral 8%, Disagree 2%, strongly disagree 1%
14	Heavy metals contamination option	Regulate organic fertilizer 34%, proper disposal of chemical waste 26%, Regular cleaning of storage container 19%, Provision of training on food safety & hygiene 14% Regular testing of fruits for heavy metal container 7%

The findings of the study reveal significant insights into the practices and perceptions of roadside fruit vendors in Okinni regarding heavy metal contamination in fruits. The majority of respondents were vendors (62%), indicating the prevalence of this occupation in the area. These findings are consistent with similar studies conducted in other regions, such as the research by Smith et al. [9], which also found a high proportion of fruit vendors in roadside markets.

It was observed that a considerable percentage of respondents sourced their fruits directly from local farmers (54%), with a notable indication of fertilizer usage (54%). This highlights the reliance on agricultural inputs and practices that may contribute to heavy metal contamination in fruits. Similar findings were reported by Jones et al. [10], who identified agricultural activities as a potential source of heavy metal accumulation in fruits.

The use of baskets (55%) by vendors to transport fruits from farms to markets is a common practice. However, the lack of proper packaging materials or containers may increase the risk of contamination during transportation, as highlighted in studies by Chen et al. [11,12] which emphasized the importance of appropriate packaging to prevent contamination during handling and storage.

The frequency of fruit sales reported by respondents, with 61% selling daily and 24% selling weekly, underscores the constant turnover of fruits in roadside markets. This rapid turnover may limit the opportunity for thorough quality control measures, as discussed in the research by Li et al. [13], which highlighted the challenges of ensuring food safety in fast-paced retail environments.

Furthermore, a significant proportion of respondents (47%) had been selling fruits for more than five years, indicating their experience in the trade. However, despite their tenure, only 45% had received training on food safety and hygiene. This suggests a potential gap in knowledge and awareness among vendors, as emphasized in studies by Wang et al. [14,15], which underscored the importance of training programs to improve food safety practices among vendors.

Interestingly, while a majority of respondents (65%) were aware of heavy metal contamination in fruits, a concerning finding was that only 35% believed that fruits sold by roadside vendors in Okinni were safe for consumption. This discrepancy between awareness and perceived safety highlights the need for effective communication and education campaigns to bridge the gap between knowledge and perception, as noted in research by Wang and Li [16] on public perceptions of food safety risks.

Furthermore, it is alarming that a majority of respondents (59%) never tested their fruits for heavy metal contamination, and 47% did not use any method to test for contamination. This lack of testing and monitoring practices poses significant risks to consumer health and underscores the urgency of implementing quality control measures, as emphasized in studies by Liu et al. (2020) and Zhang et al. [17] on food safety management in agricultural products.

Moreover, the finding that 53% of respondents reported no measures being taken to prevent heavy metal contamination in fruits highlights a critical gap in food safety practices. Studies by Wang et al. [13,15] have emphasized the importance of implementing preventive measures, such as soil and water monitoring, to mitigate heavy metal contamination in agricultural products.

Finally, the respondents' recognition of the need for regulations and guidelines regarding heavy metal contamination in fruits (51%) reflects a proactive stance towards addressing food safety concerns. Similar calls for regulatory interventions have been documented in studies by Liu et al. (2018) and Zhang et al. [1], which advocate for policy measures to safeguard consumer health and improve food safety standards.

Overall, the findings underscore the complex interplay of factors influencing heavy metal contamination in fruits retailed along roadsides in Okinni, emphasizing the need for comprehensive interventions addressing agricultural practices, food safety education, testing protocols, and regulatory frameworks.

3.1 Presentation of Laboratory Analysis

The discussion of the study's findings sheds light on the concentrations of heavy metals present in commonly consumed fruits—orange, watermelon, and apple—in the Okinni area of Egbedore Local Government Area, Osun State. This analysis is crucial for understanding the potential health implications associated with the consumption of these fruits and for establishing guidelines to ensure food safety.

The demographic characteristics of the respondents, primarily vendors (62%) sourcing fruits from local farms (51%), provide insights into prevalent practices within the fruit supply chain in the study area. The utilization of fertilizers or pesticides by over half of the respondents (54%) and the predominant method of storage and transportation using baskets (55%) offer valuable insights into agricultural practices and post-harvest handling. Additionally, the majority of vendors selling fruits daily (61%) and having an average selling experience of 1-5 years (47%) underscore the consistent availability of these fruits in the local market.

The awareness of heavy metal contamination among respondents (65%) indicates a certain level of knowledge within the community. However, the infrequent testing of fruits for heavy metal contamination (6%) and the lack of preventive measures by a significant portion of respondents (53%) highlight potential gaps in safety practices.

Interestingly, despite these findings, a substantial majority of respondents (71%) express confidence in the safety of fruits sold by roadside vendors, suggesting a level of trust in the local fruit supply, possibly driven by habitual consumption patterns or community familiarity.

The laboratory analysis of the fruits reveals concentrations of heavy metals within permissible limits, as outlined by WHO/FAO standards. Chromium (Cr) levels, though present, consistently remain below the permissible limit of 0.10 mg/kg, in line with previous research findings (Akinyele and Shokunbi, 2015). Notably, lead (Pb) was undetected in all fruit samples, ensuring compliance with the WHO maximum permissible limit of 0.30 mg/kg.

The absence of lead in the fruits contradicts findings from other regions, emphasizing the need for localized studies considering variations in environmental factors and agricultural practices. Furthermore, the study's outcomes align with previous research indicating potential health risks associated with the chronic accumulation of heavy metals in the human body, highlighting the importance of continuous monitoring and regulatory measures [18].

While the concentrations of heavy metals in the examined fruits appear within acceptable limits, the study recommends ongoing monitoring, especially given the potential health risks associated with prolonged exposure. This is particularly crucial in regions where anthropogenic activities, such as agricultural practices and industrial emissions, may contribute to heavy metal contamination.

Table 2. Comparison of Concentrations of Heavy Metals in Fruits with WHO/FAO Permissible Limits

Fruits	Samples	Heavy Metals			
		As (mg/kg)	**Cr (mg/kg)**	**Zn (mg/kg)**	**Pb (mg/kg)**
Oranges	1	0.4363	ND	0.2381	ND
	2	0.6809	0.1058	0.2855	ND
	Mean ± SE	0.5586 ±0.1723	0.0529 ± 0.075	0.2618 ± 0.0335	0 ±0
WHO/FAO Permissible limits (mg/kg)		1.30	0.10	0.20	0.30
Watermelon	1	0.2868	ND	ND	ND
	2	0.088	ND	0.2524	ND
	Mean ± SE	0.1874± 0.1406	0.000 ±0.0000	0.1262 ±0.1785	0.0000 ±0.0000
WHO/FAO Permissible limits (mg/kg)		1.50	0.20	0.20	0.50
Apple	1	0.2168	ND	0.2629	ND
	2	0.1000	0.1253	0.1730	ND
	Mean ±SE	0.1584 ± 0.0826	0.0854±0.000	0.21795±0.0636	0.00±0.000
WHO/FAO Permissible limits (mg/kg)		1.50	0.10	0.20	0.30

4. RECOMMENDATIONS

4.1 Enhanced Monitoring and Regulation

Given the potential health risks associated with heavy metal contamination, it is recommended that regulatory bodies strengthen monitoring mechanisms for fruits in the Okinni region. Regular assessments and stringent enforcement of safety standards will contribute to the overall well-being of consumers.

4.2 Educational Campaigns

Conducting awareness campaigns on safe agricultural practices, including the judicious use of fertilizers and pesticides, would benefit both farmers and vendors. Educating the community about the risks of heavy metal accumulation in fruits and promoting preventive measures could further enhance food safety.

4.3 Periodic Training for Vendors

Organizing periodic training sessions for fruit vendors on food safety and hygiene practices would empower them to adopt measures that minimize the risk of heavy metal contamination. This could include proper washing techniques, suitable storage practices, and understanding the sources of potential contamination.

4.4 Collaboration with Agricultural Stakeholders

Establishing collaborations with local agricultural stakeholders, such as farmers and suppliers, can facilitate a collective effort to reduce heavy metal contamination. This could involve promoting the use of organic fertilizers and environmentally friendly farming practices [19-23].

5. CONCLUSION

In conclusion, the study offers valuable insights into the concentrations of heavy metals found in commonly consumed fruits in Okinni, Egbedore Local Government Area, Osun State. The findings reveal that the fruits, including orange, watermelon, and apple, generally exhibit concentrations of heavy metals within acceptable limits, in accordance with WHO/FAO standards.

While the results are generally reassuring, it is crucial to emphasize the need for continuous monitoring and regulatory measures. Prolonged exposure to heavy metals can pose significant health risks, underscoring the importance of ongoing vigilance in ensuring food safety. Therefore, regular surveillance and adherence to safety protocols are essential to safeguarding public health.

The community's confidence in the safety of fruits sold by roadside vendors highlights the need for comprehensive safety measures and awareness campaigns. Despite this confidence, it is imperative to educate both vendors and consumers about the potential risks associated with heavy metal contamination and the importance of adopting safe handling and consumption practices.

As Okinni remains a prominent center for fruit consumption, it is essential to implement the recommendations put forth in the study. These recommendations aim to strengthen existing safety protocols and ensure the continued well-being of the community. By adopting proactive measures and fostering collaboration among stakeholders, we can collectively contribute to maintaining the health and safety of the local diet and, ultimately, the overall welfare of the community.

6. LIMITATIONS

Limitations of the study may include the potential variability of heavy metal levels within individual fruits, the representativeness of roadside fruit vendors to the entire population, and logistical challenges associated with sample collection and laboratory analysis.

CONSENT AND ETHICAL APPROVAL

Ethical approval was obtained from the relevant research ethics committee before commencing data collection. Informed consent were obtained from roadside vendors for sample collection, ensuring their participation is voluntary and confidential.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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