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Assessment of toxic trace metal contamination in food spices sold in Nigerian markets

Cornelius Ifeanyi Chime [1, *], Margaret Eze [1], Isaac Egbe Ndukwe [2], Evelyn Ifeoma Abah [3], Olu-Ndukwe Ruth Chinyere [4] and Chukwuma Sabestine Anene [5]

[1] Department of Science Laboratory Technology (Chemistry Option), Institute of Management and Technology, Enugu, Nigeria
[2] Laboratory Technologist, Science Laboratory Technology (Biochemistry Option), Institute of Management and Technology, Enugu, Nigeria
[3] Department of Science Laboratory Technology (Biochemistry Option), Institute of Management and Technology, Enugu, Nigeria
[4] Laboratory Technologist, Department of Science Laboratory Technology (Microbiology Unit), Federal College of Agriculture Ishiagu
[5] Lecturer, Science Laboratory Technology (Biochemistry Option), Institute of Management and Technology, Enugu, Nigeria

Abstract

Spices, although consumed in small quantities, play an essential role in enhancing the flavor, aroma, and acceptability of foods. However, their exposure to environmental contaminants, particularly toxic trace metals, poses serious health risks. This study investigates the concentration of arsenic (As), cadmium (Cd), and lead (Pb) in commonly consumed food spices purchased from New Heaven market in Enugu, Nigeria. Using Atomic Absorption Spectrophotometry (AAS), the findings reveal that all spice samples tested contained cadmium levels far exceeding the FAO/WHO permissible limit of 0.02 µg/g, with values ranging from 2.58 to 6.45 µg/g. Arsenic concentrations in three samples surpassed the safe limit of 0.5 µg/g, while lead levels were above the recommended 2.0 µg/g threshold in two samples. The elevated metal contents observed in this study suggest environmental contamination possibly linked to anthropogenic activities such as improper drying practices, polluted irrigation sources, and poor post-harvest handling. These findings emphasize the urgent need for regulatory enforcement, routine monitoring, and public education on the health risks associated with consumption of contaminated spices.

Keywords: Heavy Metals; Food Spices; Arsenic; Cadmium; Lead; Toxicity; Atomic Absorption Spectrophotometry

1. Introduction

Spices are the dried components of plants primarily utilized to enhance the visual appeal, flavor, aroma, and overall acceptability of foods (1). Historically, spices have played a significant role in shaping global culinary traditions and medicinal practices over thousands of years (2). Unfortunately, substantial levels of toxic heavy metals have been reported in natural food spices, including varieties like pepper and mustard (3,4). The techniques used during the processing and handling of these spices can turn them into vectors of foodborne toxins (5). Owing to their botanical origin, spices can act as conduits for environmental contaminants, especially heavy metals, to enter the human food chain. Contamination often occurs through absorption from polluted soils or deposition from the atmosphere, particularly when spices are sun-dried directly on bare ground or rooftops (6).

Heavy metals, mainly transition and post-transition elements include; commonly reported toxicants such as lead (Pb), cadmium (Cd), vanadium (V), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), arsenic (As), nickel (Ni), manganese

* Corresponding author: Chime Cornelius Ifeanyi

(Mn), tin (Sn), zinc (Zn), and mercury (Hg). Their presence in the environment, whether through natural processes or human activities, poses a persistent global ecological threat (7–9).

Prolonged or repeated exposure to these harmful metals can lead to a range of health complications over time, such as liver and kidney damage, insomnia, neurological impairments, asthma, and depressive symptoms (10,11). Moreover, these toxic elements have been implicated in numerous serious health issues, including developmental and neurobehavioral disorders, hypertension, kidney dysfunction, and certain cancers (12,13,14).

Despite their relatively minimal contribution to total dietary intake, spices are integral to the preparation of common Nigerian dishes such as jollof rice, moimoi, beans, and various local soups, thus raising concern about their safety. Alarmingly, spices have emerged as possible sources of lead exposure in homes that would otherwise be deemed free of traditional lead hazards like paint or gasoline (15).

2. Materials and methods

2.1. Collection and Preparation of Samples

Different brands of spices were purchased from New Heaven market Enugu and then labelled sample A, sample B, sample C, sample D, sample E and sample F respectively. The scent leaves used in this study was collected from a nearby garden at Ugwuaji, washed under running water dried at room temperature for two week and was packaged together with the other solid samples and was send to the lab for analysis.

2.2. Sample Digestion

2g of the samples each were weighed into a digestion flask and 20ml of aqua regia acid mixture (65ml conc HNO_3; 8ml perchloric acid; 2ml conc H_2SO_4) was added into it and sealed with a cork. The flask is placed under fume cupboard and heat applied with the aid of electric hot plate at temperature of 600C and allowed to heat until clear digest is obtained. The clear digest is diluted to 100ml with distilled water and filtered into reagent bottle for analysis of heavy metal with atomic adsorption spectrophotometer (AAS).

2.3. Analysis of Heavy metals

Elemental analysis was conducted using Agilent FS240AA Atomic Absorption Spectrophones according to the method of APHA 1998 (American Public Health Association)

2.4. Working principle

Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

2.5. Preparation of reference solutions

A series of standard metal solutions in the optimum concentration range are prepared, the reference solutions were prepared by diluting the single stock element solutions with water containing 1.5 ml concentrated nitric acid/liter. A calibration blank was prepared using all the reagents except for the metal stock solutions. Calibration curve for each metal was prepared by plotting the absorbance of standards versus their concentrations.

3. Result

Table 1 shows the level of selected toxic metals in food spices. It also shows their standard limit in food

Sample	Arsenic ug/g	Cadmium ug/g	Lead ug/g
Sample A	0.165	6.45	2.16
Sample B	0.3	4.71	2,19
Sample C	1.68	3.675	1.71
Sample D	0.315	2.835	1.305
Sample E	1.26	2.835	1.26
Sample F	0.075	3.21	1.53
Scent Leaves	0.18	2.58	1.71
Permissible limit	0.1-0.5	0.02	2.00

4. Discussion

The presence of toxic trace metals in food items, particularly spices, poses a significant public health concern, especially in regions with lax environmental control and food safety regulations. The results presented in Table 1 indicate worrying levels of arsenic (As), cadmium (Cd), and lead (Pb) across multiple spice samples (A to F and scent leaves), with all cadmium values far exceeding the permissible limit of 0.02 µg/g as recommended by FAO/WHO. For example, Sample A records the highest cadmium level at 6.45 µg/g, which is over 322 times above the permissible limit, while all other samples range between 2.58 and 4.71 µg/g. Arsenic levels also exceed the permissible range (0.1–0.5 µg/g) in samples C (1.68 µg/g), E (1.26 µg/g), and D (0.315 µg/g), indicating excessive contamination that could be due to polluted soil or water sources. Furthermore, lead levels surpass the recommended maximum of 2.0 µg/g in Sample A (2.16 µg/g) and Sample B (2.19 µg/g), while remaining elevated but below this threshold in other samples. The implications of such exposure include carcinogenic, nephrotoxic, neurotoxic, and developmental disorders, consistent with documented toxicological profiles of these metals (16, 17).

When compared to the findings of Chukwujindu et al. (18), who reported cadmium levels between 0.2 and 0.7 mg/kg in spices and 4.5 mg/kg in vegetables, the present study's cadmium levels are significantly higher. This indicates a likely escalation in environmental contamination, possibly due to irrigation with polluted water or increased atmospheric deposition from urban or industrial activities. A similar pattern is evident in arsenic concentrations. Veronica and Chukwuma (19) reported negligible arsenic levels in their spice samples, contrasting sharply with the present findings where three samples exceed 1.0 µg/g. This suggests a site-specific contamination possibly linked to anthropogenic inputs such as fertilizers or pesticide residues. Nnaji et al. (20) reported cadmium levels of 0.001 mg/kg across all spices studied, much lower than in this analysis, indicating more controlled or less contaminated agricultural practices in their study area. Similarly, the lead concentrations recorded by Nnaji et al. (maximum of 15.91 mg/kg in basil but generally low in others) reflect variability in sample sourcing and handling, yet only two samples in this study exceed the threshold, implying moderately high exposure risks.

Amin et al. (21) and Beauty et al. (22) also recorded generally lower concentrations of Pb and Cd in most spices. Beauty et al., for instance, observed lead levels ranging from 0.15 to 1.80 mg/kg and cadmium between 0.002 and 0.5 mg/kg, markedly lower than the current report. The elevated values in the present dataset may be associated with regional differences in industrialization, environmental hygiene, or agricultural practices. Makanjuola et al. (23) discussed the transfer of metals from soil to edible parts of plants, and high levels of metals such as Cd and As in this context could indicate the use of contaminated soils or agrochemicals. Likewise, Gaya and Ikechukwu, (24) emphasized the role of anthropogenic pollution from vehicular emissions and industrial waste as primary contributors to lead and cadmium contamination in food crops and herbs. Their findings resonate with the present data where spices, often sun-dried along roadsides, may adsorb airborne pollutants directly.

In alignment with Aigberua et al. (25) and Zubairu and Zegge (26), who found that contamination levels in spices often exceeded international safety limits, the present results further validate the ongoing risk posed by poorly regulated spice production and marketing in Nigeria. Aigberua et al. (25) noted that Pb concentrations in some spice brands

reached 3.9 mg/kg, and Cd levels were also above threshold. Aniobi et al. (27) additionally stressed that such contamination could be influenced by the utensils used in processing and packaging, which might leach trace metals. The potential for additive or synergistic toxic effects from concurrent exposure to multiple metals is particularly critical here, as samples such as C and E show elevated levels of all three metals. Chronic exposure to such mixtures, even at marginally elevated levels, can lead to cumulative health damage including carcinogenesis, nephrotoxicity, and neurological deficits. Therefore, considering the severity of the contamination observed and its comparison to earlier literature, there is an urgent need for continuous monitoring, stricter enforcement of food safety standards, and public awareness on the dangers of consuming contaminated spices.

5. Conclusion

This study reveals alarming levels of toxic trace metals, particularly cadmium, arsenic, and lead in a range of food spices sold in New Heaven market, Enugu. The concentrations of cadmium in all analyzed samples grossly exceeded international safety limits, with several samples also surpassing thresholds for arsenic and lead. The likely sources of contamination include environmental pollution, soil and water quality, and substandard post-harvest processing and handling methods. Chronic exposure to these metals poses a serious threat to public health, including risks of carcinogenesis, neurotoxicity, and organ damage. These findings necessitate immediate intervention by food safety authorities to regulate spice quality, enforce contamination limits, and conduct public sensitization campaigns to mitigate exposure risks.

Future Perspectives

Future research should aim to expand the geographical scope of spice contamination studies across various Nigerian markets to capture regional variations in toxic metal levels. It is crucial to identify the precise sources of contamination, whether from soil, irrigation water, atmospheric deposition, or processing equipment to inform targeted interventions. Additionally, assessing the cumulative dietary intake of heavy metals through spice consumption among different population groups will help evaluate potential health risks. Efforts should also be directed toward developing cost-effective purification or decontamination methods to reduce metal content in spices prior to market distribution. Finally, there is an urgent need to advocate for stricter government regulations on permissible metal limits and to establish standardized monitoring frameworks to ensure consumer safety.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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