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Lead and Total Chromium in Street-Vended Soybean Cake (Awara) from Wudil, Nigeria: Concentrations and Estimated Dietary Exposure

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ABSTRACT
Potentially toxic element contamination of ready-to-eat foods is an important food-safety concern because dietary exposure may contribute to cumulative human exposure to environmental contaminants. This study investigated lead (Pb) and chromium (Cr) concentrations in soybean cake (awara) obtained from selected vending locations in Wudil Local Government Area, Kano State, Nigeria, and characterized consumer exposure under defined dietary parameters. Ten awara samples were collected and analyzed using Microwave Plasma Atomic Emission Spectrometry (MP-AES) following acid digestion. Lead was detected in all samples at concentrations of 0.06–0.17 mg/kg, with four samples (40%) exceeding 0.1 mg/kg, which was used as a comparative food-safety benchmark rather than an awara-specific legal limit. Chromium concentrations ranged from 0.06 to 0.14 mg/kg. Estimated daily intake (EDI) was calculated for adults and children using an awara consumption rate of 50 g/day and body weights of 60 and 24 kg, respectively. Lead exposure was characterized using dietary EDI because a health-protective oral reference dose is not currently established for inorganic lead. Chromium exposure was additionally assessed using a Cr(III)-based screening reference dose; however, total chromium was measured and Cr(III) and Cr(VI) were not differentiated, making this assessment conditional on an unverified Cr(III) assumption. Estimated exposures were consistently higher in children due to their lower body weight. The findings demonstrate detectable Pb and Cr contamination in awara and support continued surveillance, investigation of contamination pathways, chromium speciation, and locally derived consumption patterns.

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INTRODUCTION

Potentially toxic elements in food constitute an important food-safety concern because dietary consumption can provide a continuous pathway of human exposure to environmental contaminants. Metals may enter food systems through natural geological processes and anthropogenic activities, including contaminated soil and water, atmospheric deposition, agricultural inputs, industrial activities, waste disposal and other human activities. Once present in agricultural environments, some metals can be taken up by crops and subsequently transferred through the food chain, making food monitoring an important component of exposure assessment and food-safety management (Zhao et al., 2024). The occurrence of toxic metals in food is particularly important because exposure may be chronic, and the magnitude of dietary exposure can vary according to food type, contamination level, consumption pattern and population characteristics.

Lead (Pb) is a toxic element. Exposure to lead has been associated with adverse neurological, cardiovascular, renal and developmental outcomes, with children being particularly vulnerable because of the sensitivity of the developing nervous system (Adeniyi et al., 2026). The Joint FAO/WHO Expert Committee on Food Additives (JECFA) concluded that a health-protective threshold for lead could not be established for the principal effects considered in its assessment and therefore withdrew the previously established provisional tolerable weekly intake (PTWI). JECFA estimated that chronic dietary exposure corresponding to a decrease of one IQ point in children was approximately 0.6 μg/kg body weight/day, while exposure corresponding to a 1 mmHg increase in systolic blood pressure in adults was approximately 1.3 μg/kg body weight/day. These estimates represent exposure levels associated with measurable population effects and should not be interpreted as safe intake limits (Joint FAO/WHO Expert Committee on Food Additives [JECFA], 2011).

Chromium (Cr) presents a different toxicological consideration because its biological and toxicological properties depend strongly on its chemical form. Chromium commonly occurs in trivalent [Cr(III)] and hexavalent [Cr(VI)] states, which differ substantially in their chemical behaviour, bioavailability and toxicity. Cr(VI) is recognized as a genotoxic and carcinogenic form, whereas Cr(III) has considerably different biological and toxicological characteristics (Chung, 2024).

In Nigeria, potentially toxic elements have been reported in agricultural commodities, processed foods and street-vended foods. Studies have demonstrated considerable variation in metal concentrations according to food type, geographical location and environmental conditions. Yaradua et al. (2022), for example, reported Pb concentrations of 0.658–0.998 mg/kg and Cr concentrations of 0.128–0.151 mg/kg in soybeans cultivated in Katsina State, north-western Nigeria. Akamo et al. (2025) also reported potentially toxic elements, including Pb and Cr, in selected foods sold within a university campus in southeastern Nigeria. These findings demonstrate the relevance of investigating metal contamination in food products consumed within specific local food systems.

Soybean is an important food crop and is processed into several products, including soybean cake locally known as awara. Awara is commonly prepared and sold as a ready-to-eat food and may be exposed to contaminants at different stages of production, from the quality of the raw soybean and processing inputs to handling, storage and vending. Consequently, assessment of the final product provides information that cannot be obtained solely from analysis of the raw agricultural commodity.

The environmental context of Wudil provides an additional basis for investigating potentially toxic elements in locally consumed foods. Alhassan et al. (2019) investigated the distribution of toxic metals in soils and selected crops across local government areas of Kano State and reported substantial variation in metal concentrations, including elevated chromium pollution indices in Wudil. These findings provide evidence of an environmental setting in which metal contamination warrants attention. However, environmental contamination data alone cannot establish the concentration or exposure associated with a processed food product such as awara.

This study therefore determined Pb and Cr concentrations in awara sold at selected roadside vending points in Wudil and estimated dietary exposure for adults and children. Existing Nigerian studies have documented potentially toxic elements in soils, agricultural crops, soybeans and various street-vended foods, but the concentration and dietary exposure profile of Pb and Cr in awara sold in Wudil have received limited attention. Awara represents a distinct exposure matrix because it is a processed soybean product that may be influenced by the quality of the raw material as well as processing and vending conditions.

Despite evidence of potentially toxic element contamination in agricultural materials and food products in Nigeria, information on Pb and Cr concentrations specifically in awara sold in Wudil Local Government Area remains limited. This represents an important knowledge gap because awara is a processed soybean food and its final contaminant profile may be influenced by both the quality of the raw material and subsequent processing and handling conditions. Dietary exposure depends on contaminant concentration, consumption rate and body weight, while chromium risk interpretation is additionally complicated by the absence of speciation data. Therefore, concentration data combined with exposure estimates provide a more informative basis for evaluating the food-safety significance of detected metals.

The aim of this study was to assess the concentrations of lead (Pb) and chromium (Cr) in soybean cake (awara) consumed in Wudil Local Government Area, Kano State, Nigeria. The findings may therefore contribute to the growing body of evidence on potentially toxic elements in Nigerian foods and provide a basis for more detailed investigations incorporating larger sample sizes, local consumption data, source characterization and chromium speciation.

Potentially Toxic Elements in Food

Potentially toxic elements occur naturally in environmental systems but may become elevated as a result of anthropogenic activities. Soil and water contamination, atmospheric deposition, industrial emissions, waste disposal, agricultural inputs and processing activities can contribute to the introduction of metals into food-production systems. Once present in agricultural environments, metals may be retained in soils or transferred into crops, creating pathways through which dietary exposure can occur (Zhao et al., 2024; Jomova et al., 2025).

The occurrence of metals in food does not necessarily indicate that adverse health effects will occur. Risk characterization depends on several factors, including concentration, consumption rate, body weight, chemical form, duration of exposure and the toxicity of the individual element. Consequently, assessment of metal contamination in food requires consideration of both measured concentrations and realistic exposure conditions (Mustatea & Ungureanu, 2024; Jomova et al., 2025).

Recent evidence indicates that potentially toxic element contamination remains relevant to food safety in Nigeria. A systematic review by Adesida and Alimba (2025) identified heavy metals among the environmental contaminants reported in Nigerian food crops and reviewed associated carcinogenic and non-carcinogenic risk assessments. The authors highlighted substantial variation in contaminant concentrations and exposure estimates among food commodities and study locations.

Lead in Food

Lead is a non-essential toxic element with no known beneficial physiological role in humans. Environmental sources of lead contamination include mining and industrial activities, combustion-related emissions, contaminated soils, waste materials and historical use of lead-containing products (WHO, 2024). In food systems, contamination may occur through uptake from contaminated soil or water, atmospheric deposition, processing equipment, food-contact materials and other environmental pathways (Nag & Cummins, 2022).

Dietary exposure to lead is of particular concern because adverse effects may occur at relatively low levels of exposure. The 2011 JECFA evaluation identified neurodevelopmental effects in children and increased systolic blood pressure in adults as critical endpoints (WHO, 2011). The Committee concluded that the available dose-response analyses did not indicate a threshold for these key effects and consequently withdrew the previously established provisional tolerable weekly intake (WHO, 2011).

Recent mechanistic reviews support these findings, demonstrating that lead exposure disrupts multiple neurotransmitter systems and induces oxidative stress, contributing to developmental neurotoxicity in children (Firdous et al., 2026). No safe blood lead level has been identified (CDC, 2023).

Studies conducted in Nigeria have reported lead contamination in agricultural commodities and ready-to-eat foods. Yaradua et al. (2022) reported Pb concentrations of 0.658–0.998 mg/kg in soybeans cultivated in Katsina State, while Akamo et al. (2025) reported substantially higher Pb concentrations in selected street-vended foods in southeastern Nigeria. These differences illustrate the spatial and commodity-specific variability of metal contamination and support the need for location-specific food-safety assessments.

Chromium in Food

Chromium is a naturally occurring element whose environmental behaviour and toxicity depend strongly on oxidation state. Cr(III) and Cr(VI) are the forms of greatest relevance to environmental and human health assessment (Chung, 2024). The toxicological profile of Cr(VI) is considerably more concerning than that of Cr(III), particularly with respect to carcinogenicity (Flora et al., 2026).

Chromium may enter agricultural systems through natural geological processes as well as anthropogenic activities, including industrial emissions, waste disposal and contaminated agricultural inputs (Flora et al., 2026). Crops may take up chromium from contaminated soils, although the extent of uptake depends on soil characteristics, chromium speciation, plant species and other environmental factors (Ertani et al., 2019).

Because total-element analytical techniques do not necessarily distinguish chromium oxidation states, measured total Cr concentrations should not automatically be interpreted as concentrations of Cr(VI) (Chung, 2024). This distinction is important when estimating health risks. In the present study, MP-AES was used to determine total chromium; consequently, the chromium risk assessment is appropriately treated as a screening assessment based on the Cr(III) reference dose rather than as a definitive assessment of Cr(VI)-related carcinogenic risk. The U.S. EPA IRIS database gives an oral reference dose of 1.5 mg/kg-day for insoluble Cr(III) compounds (US EPA, 1998).

Potentially Toxic Elements in Soybeans and Soy-Based Foods

Soybeans can accumulate potentially toxic elements from their growing environment and therefore provide an important pathway for investigating metal transfer from agricultural systems into food. However, contamination of the raw soybean does not necessarily predict the concentration in a processed soybean product because processing, dilution, water use, separation of components and cooking conditions may alter the final concentration.

Yaradua et al. (2022) investigated heavy metals in soybeans cultivated across Katsina State and reported Pb and Cr among the detected elements. Their reported Pb concentrations were considerably higher than those observed in the present awara samples, while Cr concentrations were of a similar order of magnitude. Such comparisons are useful for regional context but should not be interpreted as evidence of direct transfer from Katsina soybean fields to awara produced in Wudil.

Evidence from other Nigerian soy-based foods also demonstrates variability in exposure estimates. Odubo and Izah (2025), for example, evaluated trace metals in locally produced nutritive food-drinks in Yenagoa and reported variation in health-risk indices among samples. These findings reinforce the importance of evaluating individual food products rather than assuming that all soybean-derived foods have the same contamination profile.

Street-vended foods may also be exposed to environmental contamination during preparation, storage, transportation and sale. Akamo et al. (2025) reported Pb and Cr contamination in cowpea bean cake and other foods sold within a university campus in southeastern Nigeria, with concentrations varying substantially among food types. The study demonstrates the relevance of investigating potentially toxic elements in ready-to-eat legume-based foods, although the substantially different concentrations between that study and the present work indicate that contamination patterns are highly location- and product-specific.

Environmental Context of Wudil

Wudil forms part of the agricultural and semi-urban environment of Kano State and has previously been investigated for environmental metal contamination. Alhassan et al. (2019) examined the distribution of Hg, Pb, Cd and Cr in soils, beans and maize across five local government areas of Kano State, including Wudil. Their results showed considerable variation in metal concentrations among locations and reported the highest soil pollution load index for Cr in Wudil among the areas investigated. Positive transfer factors were also observed for several metals, supporting the possibility of movement of contaminants from soil into agricultural crops.

These findings provide an environmental basis for investigating foods produced from agricultural commodities within Wudil. Nevertheless, environmental contamination data should be interpreted separately from contamination measured in processed foods. The present study did not simultaneously analyze soil, soybean raw materials or processing water; therefore, the detection of Pb and Cr in awara cannot be attributed to a specific environmental source on the basis of the present dataset alone.

Knowledge Gap

Existing Nigerian studies have documented potentially toxic elements in soils, agricultural crops, soybeans and various street-vended foods. However, the concentration and dietary exposure profile of Pb and Cr in awara sold in Wudil have received limited attention. Awara represents a distinct exposure matrix because it is a processed soybean product that may be influenced by the quality of the raw material as well as processing and vending conditions.

The present study addresses this gap by determining Pb and Cr concentrations in awara obtained from selected vending locations in Wudil Local Government Area and characterizing estimated dietary exposure for adults and children. The study also provides a basis for subsequent investigations incorporating larger sample populations, locally derived consumption data, source characterization and chromium speciation.

MATERIALS AND METHODS

Wudil Local Government Area is located in Kano State, north-western Nigeria. It lies approximately 45 km south-east of Kano metropolis. The area is semi-urban with moderate vehicular traffic and agricultural activity. Sampling locations were selected based on traffic density and proximity to major roads where awara is commonly vended.

A total of ten (10) awara samples were purchased in 2021 from roadside vending points across Wudil town. Sampling points were selected to represent areas with varying traffic densities, including roadside stalls and market locations. Ten samples were obtained from ten independent roadside vendors, ensuring that each sample represented a distinct vending source. Each sample was collected in a clean, labeled polyethylene bag and transported to the laboratory for analysis.

Each awara sample (2 g) was macerated into small pieces and transferred into a 250 mL conical flask. A digestion mixture was prepared by combining 60 mL of 65% nitric acid and 40 mL of 70% perchloric acid. A 10 mL aliquot of this digestion mixture was added to each sample, following the method described by Deng et al. (2007). The mixture was vigorously shaken and covered tightly with aluminum foil, then allowed to stand overnight at room temperature.

The samples were then heated in a water bath for 4 hours, with the temperature gradually increased from 60°C to 100°C to ensure complete digestion. During heating, the samples were shaken at 30-minute intervals. After digestion, the samples were allowed to cool to room temperature. The digests were then reheated briefly in the water bath to complete the destruction of organic matter and made up to 25 mL with deionized water. The digested samples were filtered using Whatman No. 42 filter paper, and the filtrates were transferred into capped vessels prior to analysis.

Instrumental Analysis

The concentrations of lead (Pb) and chromium (Cr) in the digested samples were determined using an Agilent 4210 Microwave Plasma Atomic Emission Spectrometer (MP-AES) (Agilent Technologies, Australia). The instrument was operated with a nitrogen-based plasma and a solid-state CCD detector. Lead was measured at an analytical wavelength of 405.781 nm, and chromium was measured at 425.433 nm, consistent with the manufacturer's recommended conditions for these elements. The instrument was calibrated using standard solutions prepared for each metal. Each sample was analyzed in triplicate, and the mean value was reported.

Quality Assurance and Quality Control

All glassware was washed with detergent, rinsed with deionized water, and soaked in 10% nitric acid overnight before use. Reagent blanks were prepared and analyzed alongside the samples to monitor for contamination. All reagents used were of analytical grade. Calibration standards were prepared for each element, and the instrument was calibrated before sample analysis. Each sample was analyzed in triplicate, and the mean value was reported.

Regulatory Benchmark for Lead

Lead concentrations detected in the awara samples were evaluated against a selected benchmark of 0.1 mg/kg based on the Codex Alimentarius framework for lead in relevant food categories (UNICEF, 2022). This benchmark was used as a screening reference for comparison of the measured concentrations. Because regulatory maximum levels are commodity- and category-specific, the 0.1 mg/kg value is not interpreted as an awara-specific Codex limit. No specific Codex maximum level for chromium in soybean cake (awara) has been established; therefore, chromium exposure was evaluated using the health-risk screening approach described below.

Health Risk Assessment

Health risk assessment was conducted to characterize dietary exposure to lead (Pb) and chromium (Cr) through consumption of awara. Estimated Daily Intake (EDI) was calculated separately for adults and children.

Estimated Daily Intake (EDI)

The estimated daily intake of each metal was calculated using:

$$EDI = (C \times IR) / BW \tag{1}$$

where: EDI = estimated daily intake of the metal (mg/kg body weight/day), C = concentration of the metal in awara (mg/kg), IR = ingestion rate of awara (kg/day), BW = body weight (kg)

Exposure parameters: In the absence of published awara consumption data for Wudil or comparable Nigerian populations, an ingestion rate of 50 g/day (0.05 kg/day) was assumed as a conservative estimate of single-serving snack consumption. This value is not derived from a population-specific dietary survey. The same ingestion rate was applied to both adults and children, which represents a conservative assumption for children, who generally consume smaller portions than adults. Because children have lower body weights, this assumption produces higher body-weight-normalized exposure estimates for children relative to adults. A body weight of 60 kg was assumed for adults and 24 kg for children, consistent with values used in recent Nigerian dietary exposure studies. Future studies should incorporate age-specific consumption data to refine these estimates.

For ease of interpretation, calculated lead and chromium EDIs were converted from mg/kg body weight/day to µg/kg body weight/day.

Lead Exposure Characterization

Lead exposure was characterized using EDI rather than a Target Hazard Quotient (THQ). This approach was adopted because a health-protective threshold or consensus oral reference dose for inorganic lead has not been established. Consequently, the calculated lead EDI values were interpreted as estimates of dietary exposure rather than as evidence of exposure below a "safe" dose. The estimated lead exposures were discussed in relation to internationally established dose-response information for lead, while recognizing that such values should not be interpreted as tolerable or safe intake limits.

Chromium Exposure Characterization

For chromium, a screening-level Target Hazard Quotient (THQ) was calculated using the oral reference dose (RfD) of 1.5 mg/kg body weight/day for chromium (III):

$$THQ = EDI / RfD \tag{2}$$

where: THQ = target hazard quotient (dimensionless), EDI = estimated daily intake (mg/kg body weight/day), RfD = oral reference dose (mg/kg body weight/day)

The measured chromium concentration represented total chromium because the analytical method measures total elemental chromium. Therefore, the chromium THQ was calculated as a screening estimate under the assumption that the measured chromium was predominantly present as Cr(III). The result is presented as a screening-level estimate and is not interpreted as definitive evidence of the absence of chromium-related health risk.

Statistical Analysis

All samples were analyzed in triplicate, and the reported concentrations were expressed as mean values. Descriptive statistics, including minimum, maximum and mean concentrations, were used to summarize the occurrence of Pb and Cr in the awara samples.

RESULTS AND DISCUSSION

Lead Concentrations in Awara Samples

The concentrations of lead (Pb) in the ten awara samples collected from Wudil are presented in Table 1. Lead was detected in all samples, with concentrations ranging from 0.06 to 0.17 mg/kg (mean = 0.09 ± 0.03 mg/kg). Lead concentrations were compared against the 0.1 mg/kg comparative benchmark described in Section 3.6.

Table 1: Lead Concentrations in Awara Samples

S/N	Sample	Pb Concentration (mg/kg)	Selected Comparative Benchmark (mg/kg)	Result
1	A	0.11	0.1	Above benchmark
2	B	0.09	0.1	Below benchmark
3	C	0.12	0.1	Above benchmark
4	D	0.17	0.1	Above benchmark
5	E	0.11	0.1	Above benchmark
6	F	0.07	0.1	Below benchmark
7	G	0.06	0.1	Below benchmark
8	H	0.06	0.1	Below benchmark
9	I	0.06	0.1	Below benchmark
10	J	0.07	0.1	Below benchmark

Four out of ten samples (40%) had lead concentrations above the 0.1 mg/kg comparative benchmark. The highest concentration (0.17 mg/kg) was recorded in sample D, followed by sample C (0.12 mg/kg). The lowest concentrations (0.06 mg/kg) were recorded in samples G, H, and I.

Chromium Concentrations in Awara Samples

The concentrations of chromium (Cr) in the ten awara samples are presented in Table 2. Chromium was detected in all samples, with concentrations ranging from 0.06 to 0.14 mg/kg (mean = 0.09 ± 0.02 mg/kg). No Codex maximum level has been established for chromium in soy products; therefore, safety was evaluated using health risk assessment.

Table 2: Chromium Concentrations in Awara Samples

S/N	Sample	Cr Concentration (mg/kg)
1	A	0.09
2	B	0.09
3	C	0.10
4	D	0.11
5	E	0.14
6	F	0.10
7	G	0.06
8	H	0.06
9	I	0.07
10	J	0.07

Chromium was detected in all ten samples. The highest concentration (0.14 mg/kg) was recorded in sample E, while the lowest concentrations (0.06 mg/kg) were recorded in samples G and H.

Health Risk Assessment

The health risk assessment characterized dietary exposure to lead (Pb) and chromium (Cr) through consumption of awara for adults and children. Estimated Daily Intake (EDI) was calculated using an awara ingestion rate of 0.05 kg/day, with body weights of 60 kg for adults and 24 kg for children.

Estimated Lead Intake

Lead exposure estimates are presented in Table 3. The estimated daily intake of lead ranged from 0.050 to 0.142 µg/kg body weight/day for adults and from 0.125 to 0.354 µg/kg body weight/day for children. The highest estimated exposure occurred for sample D, which had the highest measured lead concentration (0.17 mg/kg), while the lowest exposure occurred in samples G, H and I, each containing 0.06 mg/kg lead. Across all samples, the estimated lead exposure for children was 2.5 times that of adults because the same assumed consumption rate was normalized to the lower body weight used for children.

Table 3: Estimated Daily Intake of Lead from Consumption of Awara

Sample	Pb Concentration (mg/kg)	Adult EDI (μg/kg bw/day)	Child EDI (μg/kg bw/day)
A	0.11	0.092	0.229
B	0.09	0.075	0.187
C	0.12	0.100	0.250
D	0.17	0.142	0.354
E	0.11	0.092	0.229
F	0.07	0.058	0.146
G	0.06	0.050	0.125
H	0.06	0.050	0.125
I	0.06	0.050	0.125
J	0.07	0.058	0.146

EDI = Estimated Daily Intake; bw = body weight.

Estimated Chromium Intake and Screening-Level THQ

The estimated daily intake of chromium ranged from 0.050 to 0.117 μg/kg body weight/day for adults and from 0.125 to 0.292 μg/kg body weight/day for children. Using the oral reference dose of 1.5 mg/kg body weight/day for Cr(III), the screening-level THQ values were substantially below 1 for all samples in both population groups. The highest chromium exposure was associated with sample E, which contained the highest chromium concentration (0.14 mg/kg).

Table 4: Estimated Daily Intake and Screening-Level THQ for Chromium

Sample	Cr Concentration (mg/kg)	Adult EDI (μg/kg bw/day)	Adult THQ	Child EDI (μg/kg bw/day)	Child THQ
A	0.09	0.075	5.00×10^{-5}	0.187	1.25×10^{-4}
B	0.09	0.075	5.00×10^{-5}	0.187	1.25×10^{-4}
C	0.10	0.083	5.56×10^{-5}	0.208	1.39×10^{-4}
D	0.11	0.092	6.11×10^{-5}	0.229	1.53×10^{-4}
E	0.14	0.117	7.78×10^{-5}	0.292	1.94×10^{-4}
F	0.10	0.083	5.56×10^{-5}	0.208	1.39×10^{-4}
G	0.06	0.050	3.33×10^{-5}	0.125	8.33×10^{-5}
H	0.06	0.050	3.33×10^{-5}	0.125	8.33×10^{-5}
I	0.07	0.058	3.89×10^{-5}	0.146	9.72×10^{-5}
J	0.07	0.058	3.89×10^{-5}	0.146	9.72×10^{-5}

EDI = Estimated Daily Intake; THQ = Target Hazard Quotient; bw = body weight. Chromium THQ represents a screening estimate based on the assumption that measured total chromium was present as Cr(III)

Overall, the calculated chromium THQ values were below 1 for both adults and children under the Cr(III) screening assumption.

Discussion

The present study detected lead (Pb) in all ten awara samples analyzed, with concentrations ranging from 0.06 to 0.17 mg/kg. Four samples (A, C, D and E), representing 40% of the samples analyzed, had concentrations above the 0.1 mg/kg comparative benchmark adopted in this study. Because the benchmark is not an awara-specific regulatory maximum, the finding should be interpreted as an indication that a proportion of the samples had relatively elevated lead concentrations rather than as definitive evidence of regulatory non-compliance.

The lead concentrations observed in the present study were lower than those reported by Akamo et al. (2025) in selected foods vended within a university campus in southeastern Nigeria, where lead concentrations of 3.36–6.49 mg/kg were reported. The difference may reflect variations in food type, raw-material sources, environmental conditions, processing practices and sampling locations. However, the present study was not designed to identify the specific sources responsible for lead contamination; therefore, these factors remain possible explanations rather than established causes. The substantial difference in reported concentrations between the two studies also highlights how contamination patterns vary according to food matrix and analytical approach.

Lead concentrations in the present awara samples were also lower than those reported for soybeans cultivated in Katsina State, where Yaradua et al. (2022) reported concentrations ranging from 0.658 to 0.998 mg/kg. The detection of lead in both soybean raw materials reported in previous studies and processed soybean-based food in the present study highlights the importance of monitoring potential heavy-metal contamination throughout the food chain. Nevertheless, differences in sample type, geographical location and analytical procedures should be considered when making direct comparisons between studies. In particular, whether concentrations were reported on a wet-weight or dry-weight basis can substantially affect direct comparison.

Chromium was detected in all awara samples, with concentrations ranging from 0.06 to 0.14 mg/kg. Sample E recorded the highest concentration, while samples G and H had the lowest concentrations. The concentrations observed were broadly comparable to the 0.128–0.151 mg/kg reported for soybeans cultivated in Katsina State by Yaradua et al. (2022). Previous research has also reported evidence of chromium contamination in soils from parts of Kano State, including Wudil (Alhassan et al., 2019). These findings provide environmental context for the present observations; however, the current study did not analyze soil, soybean raw materials, processing water or other potential sources. Therefore, a direct soil-to-awara transfer pathway cannot be established from the present data.

The occurrence of Pb and Cr in all samples indicates that exposure to these metals may occur through consumption of awara. However, the measured concentrations alone cannot establish the extent of health risk because risk characterization also depends on consumption rate, body weight, metal bioavailability, chemical form and exposure from other dietary and environmental sources. The present assessment therefore focused on estimating dietary exposure under specified assumptions rather than determining actual population-level health effects.

The estimated daily intake of lead from awara consumption ranged from 0.050 to 0.142 μg/kg body weight/day for adults and from 0.125 to 0.354 μg/kg body weight/day for children. The highest estimated exposure occurred in sample D, which had the highest measured lead concentration (0.17 mg/kg). Lead exposure estimates were higher for children than adults because the same assumed daily consumption was normalized to a lower body weight.

Unlike chromium, lead was not evaluated using a THQ based on an oral reference dose because a current health-protective consensus reference dose for inorganic lead is not available. International assessments have instead emphasized dose-response relationships for lead and have concluded that exposure levels associated with adverse effects should not be interpreted as safe thresholds. JECFA reported that the previous provisional tolerable weekly intake for lead was not sufficiently protective and therefore withdrew it. The present lead EDI estimates should consequently be interpreted as exposure estimates and not as evidence that the estimated intake is without health concern (JECFA, 2011).

For chromium, the estimated daily intake ranged from 0.050 to 0.117 μg/kg body weight/day for adults and from 0.125 to 0.292 μg/kg body weight/day for children. The screening-level THQ values calculated using the oral reference dose for Cr(III) were below 1 for all samples. This suggests low non-carcinogenic hazard under the specific Cr(III) screening assumption and exposure conditions used in this study. However, the analytical procedure measured total chromium, and the oral reference dose used applies to Cr(III), whereas Cr(VI) has substantially different toxicological characteristics. Consequently, the calculated chromium THQ should not be interpreted as a definitive assessment of the health risk associated with all forms of chromium present in the samples. Chromium speciation would be required to determine the contribution of Cr(III) and Cr(VI) to the observed total chromium concentrations. The Cr(III)-based THQ therefore cannot be used to establish the absence of risk from Cr(VI).

The higher exposure estimates observed for children are consistent with the effect of body weight on exposure calculations. For the same consumption rate and food concentration, a lower body weight results in a higher estimated intake per kilogram of body weight. This finding supports the importance of considering children separately in dietary exposure assessments. However, the present study did not measure actual consumption patterns or children-specific consumption rates; therefore, the magnitude of real-world exposure may differ from the estimates obtained here. The small, non-random sample of ten vending points also limits the extent to which these estimates can be generalized to the wider Wudil population.

The possible sources of Pb and Cr contamination in awara are likely to be multifactorial. Previous literature has associated heavy-metal contamination in food with environmental pollution, raw-material contamination, processing conditions and food handling environments. Roadside vending and traffic exposure may represent potential pathways for contamination, while soil and agricultural inputs may also contribute to metal accumulation in raw materials. Nevertheless, because the present study did not investigate these pathways directly, source attribution should be addressed in future studies rather than inferred from the concentrations measured in the finished product.

Overall, the findings demonstrate the presence of detectable Pb and Cr in awara sold in Wudil. The observed lead concentrations, including concentrations above the comparative 0.1 mg/kg benchmark in four of ten samples, justify continued monitoring of soybean-based street foods. At the same time, the exposure assessment indicates that interpretation of potential health risk requires careful consideration of metal speciation, locally derived consumption data and exposure from other sources.

Limitations

Certified reference materials and spike recovery tests were not included in the analytical programme, and method detection limits were not documented, which limits the extent to which analytical recovery and precision can be independently verified. Chromium was measured as total chromium, and speciation between Cr(III) and Cr(VI) was not performed. The risk assessment relied on assumed ingestion rates and body weights rather than locally derived consumption data, and the same ingestion rate was applied to both adults and children. The sample size was limited to ten vending locations, which may not fully represent the variability of awara sold across Wudil. The study also did not analyze soil, raw soybean materials, processing water or other potential contamination sources. Future studies should incorporate speciation analysis, certified reference materials, local consumption surveys, source characterization and larger sample sizes to refine risk estimates.

CONCLUSION

This study provides preliminary, location-specific evidence on the concentrations of lead (Pb) and chromium (Cr) in soybean cake (awara) sold in Wudil Local Government Area, Kano State, Nigeria. Ten awara samples collected from independent roadside vendors in 2021 were analyzed using an Agilent 4210 Microwave Plasma Atomic Emission Spectrometer (MP-AES). Lead was detected in all samples at concentrations ranging from 0.06 to 0.17 mg/kg, while total chromium concentrations ranged from 0.06 to 0.14 mg/kg. Four of the ten samples (40%) had lead concentrations above the 0.1 mg/kg comparative benchmark adopted in this study. Because this benchmark is not an awara-specific regulatory maximum level, the finding indicates that a proportion of the sampled products had relatively elevated lead concentrations rather than demonstrating regulatory non-compliance. The estimated daily intake of both metals was higher for children than adults under the assumed consumption and body-weight conditions. Lead exposure was characterized using estimated dietary intake rather than a Target Hazard Quotient because a current health-protective reference dose for inorganic lead was not applied in this study. The estimated lead exposure should therefore be interpreted in the context of established evidence on lead toxicity rather than as a comparison with a presumed safe threshold. For chromium, the screening-level THQ values were below 1 when the measured total chromium concentrations were assessed using the reference dose for Cr(III). However, this interpretation is conditional, as the analytical method measured total chromium and did not distinguish between Cr(III) and Cr(VI). The measurements reported here indicate the presence of Pb and total Cr in ten sampled awara products. The exposure estimates depend on assumed ingestion rates and body weights rather than locally measured consumption data. The study does not establish the specific sources of contamination or demonstrate adverse health effects in consumers. Further studies involving larger and more representative sampling, locally measured consumption rates, raw-material and environmental assessment, and chromium speciation are required for a more comprehensive evaluation of consumer exposure and health risk. Based on the findings of this study, the following recommendations are made. Relevant food-safety authorities should consider including awara and other commonly consumed soybean-based foods in routine monitoring programmes for potentially toxic metals. Further studies should assess soybean raw materials, soils, processing water and finished awara from the same production chain to identify possible sources and pathways of Pb and Cr contamination. Future investigations should also determine Cr(III) and Cr(VI) separately to provide a more complete assessment of the toxicological significance of the total chromium concentrations observed. In addition, future studies should use locally derived awara consumption data, age-specific ingestion rates and larger sample sizes to obtain more representative estimates of dietary exposure among adults and children. Finally, similar studies should be conducted across additional vending locations and local government areas in Kano State to determine the extent and distribution of Pb and Cr contamination in soybean-based foods.

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