Research Article

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Heavy metal contaminations in staple spices sold in Yaounde, Cameroon: implications for consumers' health

Abstract

Spices form an essential component of meals worldwide, particularly in Cameroon. Global concerns over spice safety, especially heavy metal contamination and associated consumer health risks continue to escalate. Yet spice safety in Cameroon remains largely uncharacterized. This study assessed heavy metal (mainly, lead Pb, cadmium Cd, and arsenic As) contamination levels in staple spices sold in Yaoundé markets and the associated consumer health risks. An online consumer survey and in-person interviews with spice vendors were conducted at Yaoundé's major markets. Different variety of spices were purchased randomly and analyzed for heavy metals (Pb, Cd, As) using inductively coupled plasma optical emission spectrometry (ICP-OES). The survey showed universal spice consumption (100%), primarily whole forms (79%) from local markets (78%), stored in plastic (43%), and used daily for cooking (100%) and or medicinal purposes (69%). Top consumed spices included garlic (77%), ginger (73%), white pepper (71%), country onion (63%), cloves (54%) and njansang (42%). Awareness of heavy metals was low (25%), though 94% recognized health risks. Mean (range) levels were 1.86 (<LOD-11.15) mg/kg Pb, 1.18 (<LOD-5.07) mg/kg Cd, and 8.83 (<LOD-14.38) mg/kg As. Estimated daily intakes were 0.00029 mg/kg/day Pb, 0.00011 mg/kg/day Cd, and 0.0014 mg/kg/day As. While Pb and Cd exposures appear low risk, As contamination in 92% of spices exceeding THQ of 1 signal significant non-carcinogenic health threat. The estimated cancer risk (ECR) revealed that the ECR linked to Cd exposure from oregano (0.00031708), cardamom (0.00019632) and pepper (0.00016458) and the ECR associated with exposure to As in all the studied spice samples except mustard, exceeded typical thresholds of 0.000001 to 0.0001, emphasizing the need for targeted Cd and particularly As interventions. The ECR from Pb exposure from any of the samples did not pose a concern. This pioneer spice safety study from Cameroon suggests that spices sold in the Mfoundi and Mokolo/8eme markets in Yaounde are tainted with As, and to a lower extent, Cd, with potential cancer risk, that requires urgent attention.

Keywords: lead, cadmium, arsenic, spices safety, consumer health, Yaounde-Cameroon

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Introduction

Food safety, including spices contamination, is a growing issue worldwide, requiring more attention.[1,2] Spices are an essential and dependable component of food and medicine worldwide.[3,4] In Cameroon, spices are widely used for culinary, medicinal, and cultural purposes, and spices production was projected to rise from 106,000 metric tons in 2023 to 111,000 metric tons by 2028.[5] Cameroon engages in international spice trade, exporting key varieties while importing others to meet domestic demand.[6] Notably, Cameroon exports Penja pepper, which holds Protected Geographical Indication (PGI) status for its unique quality. In 2023, spice exports reached an estimated USD 414,000.00.[7,8] Spice consumption in Cameroon has grown steadily at 0.8% annually and is projected to increase from 60,000 metric tons in 2023 (global rank: 23rd) to 63,000 metric tons by 2028.[5] Spices are frequently contaminated with heavy metals and despite being consumed in relatively small quantities, they may significantly contribute to dietary exposure to this toxic contaminant due to their frequent and cumulative intake.[9,10]

Heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), chromium (Cr), and nickel (Ni) are persistent environmental pollutants that can enter spices through contaminated agricultural soils, irrigation water, atmospheric deposition during open-air drying, and poor handling, processing, and storage practices.[10–12] Chronic dietary exposure to the heavy metals Pb, Cd, and As has been associated with serious adverse health effects, including neurotoxicity, renal impairment, cardiovascular disorders, and carcinogenic outcomes.[13,1,14] Lead and cadmium are of particular concern due to their cumulative toxicity and lack of safe exposure thresholds, especially amongst vulnerable populations such as children and pregnant women.[15,16] Consequently, international bodies such as FAO/WHO and national regulatory agencies have established MPLs for heavy metals in foods, including spices.

Several studies have reported elevated levels of heavy metals in spices sold in local markets. Investigations conducted in Nigeria, Ghana, Egypt, Ethiopia and India have documented heavy metal concentrations exceeding recommended limits in commonly consumed spices, with associated non-carcinogenic and carcinogenic health risks indicated by target hazard quotient and carcinogenic risk assessments.[12,17–19] A recent systematic review of spices from global markets further confirmed that spices originating from developing regions often show higher contamination levels, largely due to environmental pollution and inadequate post-harvest practices.[13,3]

Heavy metal investigations on food materials in Cameroon (e.g., lead),[20] are still vague, worst in the case of spices which is an integral part of almost all Cameroonian foods. Despite rising spice consumption, data on heavy metal contamination of spices in

Cameroon remain scarce, and information on dietary exposure and associated health risks is limited. This study evaluated heavy metal (Pb, Cd, As) contamination levels in staple popularly consumed spices sold in the major markets in Yaoundé with the associated consumer health risks.

Materials and methods

Study site and target population

This study was conducted in Yaoundé, Cameroon's capital and largest urban center (population ~3.7 million), focusing on two major markets: Mfoundi and Mokolo (combined with huitième – "8ème") (Figure 1). Target populations included spice consumers (urban households with daily cooking habits) and vendors/sellers operating formal and informal stalls, representing primary exposure pathways for heavy metal-contaminated spices.

Figure 1 Africa, Cameroon, Yaounde map showing the markets from where spices were sampled.

Sample size and justification

A total of 132 spice samples were purchased in this study, although the calculated sample size was 130, as precaution in case of loss of sample. Since no prior research on spice contamination has been reported in Cameroon, the anticipated proportion of contaminated samples was assumed to be 50%((p=0.)) to maximize variability. A 95% confidence level was used, corresponding to a Z-score of 1.96, and the margin of error was set at approximately 8.6% (E≈0.086).

The sample size was calculated using the method described by,[21] for estimating a proportion in a cross-sectional survey, based on the formula:

$$n_0 = \frac{Z^2 * P(1-P)}{E^2}$$

Where: n_o = required sample size; Z = Z-score (based on confidence level, 1.96); P = estimated proportion of contamination (0.5); and E = margin of error (0.086)

Sample collection

In November 2024, different varieties of spices were systematically purchased from vendors at two major Yaoundé markets: Mfoundi and Mokolo/8ème. In each market studied, the section where spices are sold was divided into three sub-sections and one variety or type of each spice sample was purchased at random from a vendor in each of the three sub-sections. Approximately 100 g of each unground (unmilled) spice was collected per vendor. Altogether, 132 samples were collected, stored in separate clean, labelled zip-lock plastic bags to prevent cross-contamination and transported to the Laboratory of Pharmacology and Toxicology of the University of Yaounde 1, Cameroon, under cold chain conditions where they were stored at 4°C until analysis at the Global Health System Laboratory in Douala, Cameroon.

Sample preparation and acid digestion

On the eve of analysis, 3 samples of each type per market were pooled into a single composite sample, resulting to a total of 44 pooled samples representing 27 different varieties of spices. Twenty-six different spices varieties were purchased from Mfoundi, while 18 were purchased from Mokolo/8ème. Of these, 17 spice varieties were identical between the two markets, and one spice, "herbs of province" ("herbes de province"), was purchased only in Mokolo/8ème and was not found in Mfoundi. Each sample was milled into fine powder in the market directly by the vendor, immediately after purchase, using a clean market blender (Hoffmans Electronics – Powder grinder, Model No: HM-9085, 220V-50HZ:2500W). A one-gram subsample was weighed using an analytical balance (Mettler Toledo AL104) and transferred into a digestion beaker. To this, 6 mL concentrated HNO_3 (69%, trace metal grade) and 2 mL H_2O_2 (30%, trace metal grade) were added into each beaker. The mixture was heated at 200°C until digestion was complete (clear or pale-yellow solution). The digest was evaporated to ~5 mL without boiling, cooled, filtered using qualitative filter paper 100, and diluted to 50 mL with ultra-pure water in a volumetric flask.

Heavy metal analysis using the inductively coupled plasma – optical emission spectroscopy (ICP-OES)

Instrument setting and quality control: The ICP-OES instrument (ICP-OES 7100) was operated under the following conditions: a plasma gas flow rate of 15 L/min, an auxiliary gas flow rate of 0.2 L/min, and a nebulizer gas flow rate of 0.6 L/min, with an RF power set at 1450 kW. The peristaltic pump speed was maintained at 1.5 mL/min, and a cyclonic nebulizer/spray chamber was used. The torch cassette position was set at -3, with purge and resolution both adjusted to normal settings. The integration time ranged from 2 - 5 sec, wit a read time of 1 minute and a wash time of 30 seconds. Each measurement was performed in triplicate (three replicates). For quality control, the QC standard (ID: AASE) had a certified concentration of 1000 ± 10 mg/L and was prepared to a working concentration of 1 mg/L (1000 µg/L); the measured concentration obtained was 0.98 mg/L (980 µg/L), indicating good analytical accuracy.

Recovery test: Recovery tests were performed by spiking triplicate subsamples with known concentrations (100 and 500 ppb) of Pb, Cd, and As standards. In brief, triplicate sub-samples (1 g) of a representative spice matrix were spiked with certified standards at 100 and 500 ppb for Pb, Cd, and As before digestion. Samples underwent complete acid digestion (HNO_3/H_2O_2), dilution, and ICP-OES analysis alongside unspiked controls. The percentage recovery was calculated as:

$$\text{Recovery (\%)} = \left(\frac{\text{Measured} - \text{Background}}{\text{Spike Added}}\right) \times 100$$

Heavy metal quantitation: Aliquots of the digest were diluted and analyzed using an Optima 7100 DV Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP-OES) (PerkinElmer). Calibration curves were prepared with standard solutions (10, 50, 100, 500, 1000 ppb) for Pb, Cd, and As. Quality control included method blanks, sample replicates, and certified reference material analysis.

Health risk assessment

Health risks from spice consumption were estimated using Estimated Daily Intake (EDI) for each heavy metal. EDI was calculated with the following formula:

$$\text{Estimated DailyIntake(EDI)}=\frac{\text{Concentration of heavy metal(mg/kg)X Ingestion Rate(kg/day)}}{\text{Body weight(kg)}}$$

Where:

Concentration of heavy metal (C) is the level of a specific heavy metal in the studied raw spice (mg/kg), ingestion rate (IR) is the mean amount of spices injected (assumed 0.01 Kg/day as used by[22] in South Africa and [23] in Bangladesh), and body weight (BW) is the mean adult body weight (assumed to be 60.7 kg,). [24]

Target Hazard Quotient (THQ) and Hazard Index (HI) were calculated following US Environmental Protection Agency (US EPA) (2011) guidelines to assess non-carcinogenic health risk. The calculations were done using the formula:

$$\text{Target Hazard Quotient (THQ)}=\frac{\text{Estimated Daily Intake (EDI)}}{\text{Reference Dose (RfD)}}$$

Where:

RfD = reference dose values for each heavy metal of interest (mg/kg/day). The RfD values for Pb, Cd and As were 0.004, 0.001 and 0.0003 mg/kg per day, respectively, according to the US EPA.[25]

The Hazard Index (HI) was calculated as the sum of individual THQs as follows:

$$HI = THQ_{Pb} + THQ_{Cd} + THQ_{As}$$

Values of THQ or HI greater than 1 indicate that the population may experience potential adverse health effects, whereas values below 1 suggest that the population is unlikely to suffer noticeable adverse effects.

Cancers risk which is an individual's increased likelihood of developing cancer due to contact with hazardous carcinogenic compounds such as Pb, Cd, and As was calculated as follows

$$\text{Cancer Risk} = EDI \times CSF$$

Where:

CSF (Cancer Slope Factor) is presented in mg/kg/day. Cancer risk according to the US EPA ranges from 1×10^{-6} (1 in 1,000,000) to 1×10^{-4} (1 in 10,000) for appropriate risk management purposes[2]

Statistical analysis

Data was analyzed using descriptive statistical methods, including frequencies, percentages, means, and standard deviations, to summarize and characterize the variables measured in the study. These statistics were used to describe the distribution, central tendency, and variability of the data, thereby providing an overview of the baseline characteristics and observed patterns within the dataset. All statistical analyses were performed using Microsoft Excel 2016 and the Statistical Package for the Social Sciences (SPSS) version 22.0 (IBM Corp., Chicago, USA).

Results

Survey results

The socio-demographic variables of participants, the handling, uses, storage and sources from where consumers obtain the spices they consume are presented on Table 1. The majority (52%) of participants were of the age range 19-29 years old. They store the spices in plastic containers (43%), and used daily, both for cooking 100% and medicinal (69%) purposes. Participants purchased most of the spices they consume from local markets (78%), while some are from local producers/farmers (33%). While heavy metals were poorly known (only 25% awareness), most participants acknowledged their health risks.

Table 1 Socio-demographic variables and sources of foods.

Parameter	Description	Frequency	Percentage
Age range (years)	19-29	52	52
	30-39	28	28
	40-49	15	15
	50-59	2	2
	≥60	2	2
	Missing data	1	1
Sex	Female	55	55
	Male	45	45
Occupation	Student	34	34
	Merchant	38	38
	Others	25	25
	Missing data	3	3
Marital situation	Single	64	64
	Married	28	28
	Missing data	8	8
Level of education	High school	6	6
	Undergraduate	22	22
	Masters	25	25
	Doctorate	1	1
	Missing data	46	46
Transportation of spices to the market	Car	34	34
	Truck	5	5
	Others	6	6
	Missing data	55	55
Storage duration of the spices while selling	Years	4	4
	Months	21	21
	Weeks	19	19
	Days	1	1
	Missing data	55	55
Number of cups used to measure the spices in the market	One for each spice type	40	40
	One for every spice	8	8
	Missing data	52	52
Preferred spices storage method	Glass jars	31	29
	Plastic containers	45	43
	Spice ranks	9	9
	Other	21	20
Use spices for medical purposes	Yes	69	69
	No	28	28
	Missing data	3	3
Awareness of heavy metals in spices	Yes	25	25
	No	72	72
	Missing data	3	3
Source of spices sold	Local producers/ fields	17	33
	Market	36	69
	Others	5	10

Table 1 Continued...

The preferred form to buy spices	Whole spices	55	79
	Pre-packaged spice blend	2	3
	Ground spices	15	21
	Other	3	4
Source of spices you consume	Market	88	78
	Super market	9	8
	Stores	7	6
	Grocery stores	9	8
Do you think heavy metals represent a danger to man	Yes	30	94
	No	2	6

The sales rate of the various spices in local markets in Yaounde are presented in (Figure 2). Country onion, white pepper, and njansang had the highest sales rate (>70% each). Cloves, garlic, ginger and African nutmeg with sales frequency of 50-50% each. On the one hand, lentils, saffron, coriander, cumin, mustard and paprika had the lowest sales rate (<3%).

The consumption frequency of the different spices studied is provided in (Figure 3). Garlic, ginger and white pepper were the most consumed spices consumed by more than 70% of the studied population. Cloves, onion, pepper, and country onion had consumption frequency between 50% and 65%. The consumption rate of the African nutmeg, njansang and black pepper were higher than 30% but lower than 50%. The remainder of spices had intake frequencies higher than 9% but below 30%.

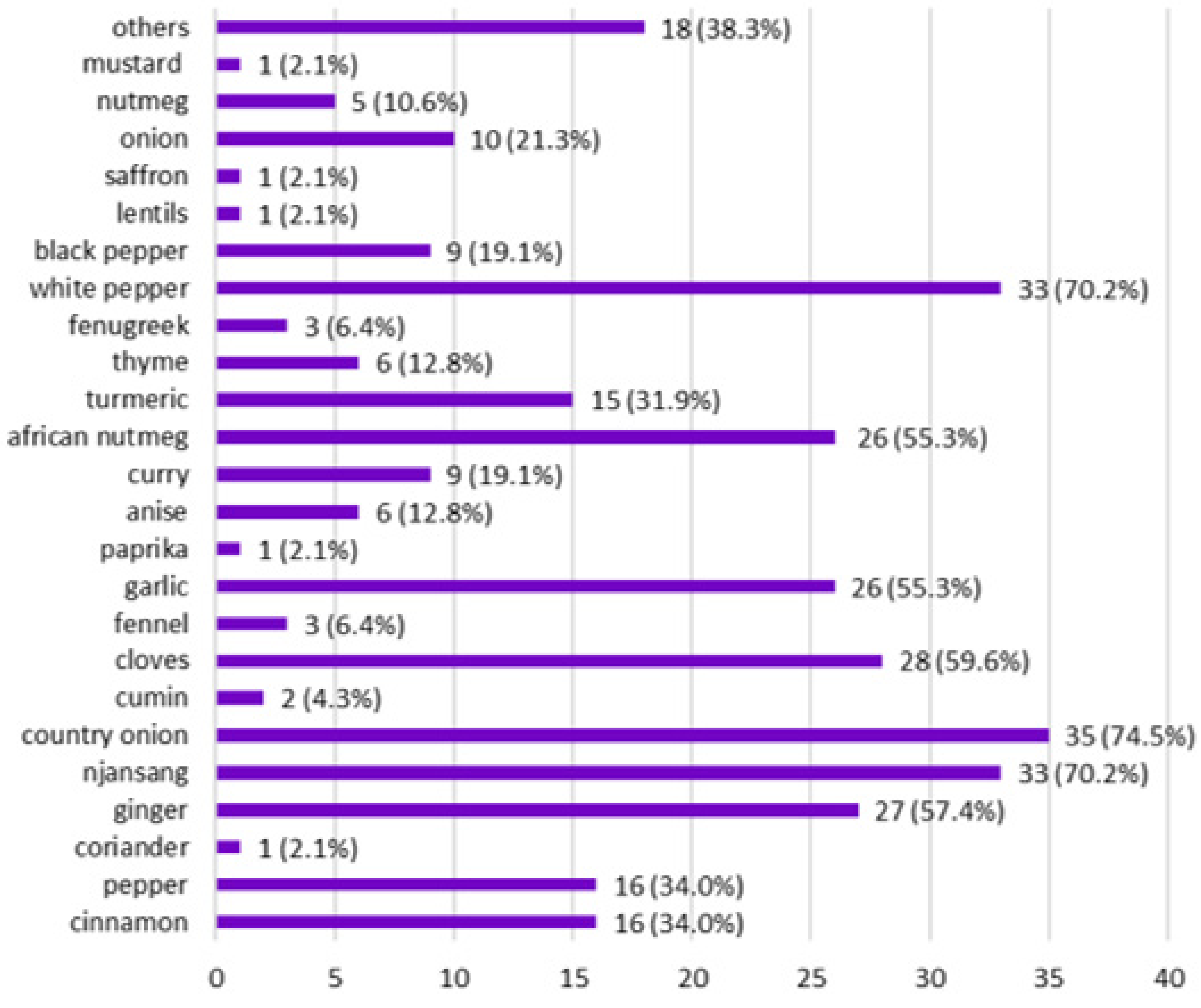

Figure 2 Representation of the sales of different spice in local markets in Yaounde, Cameroon.

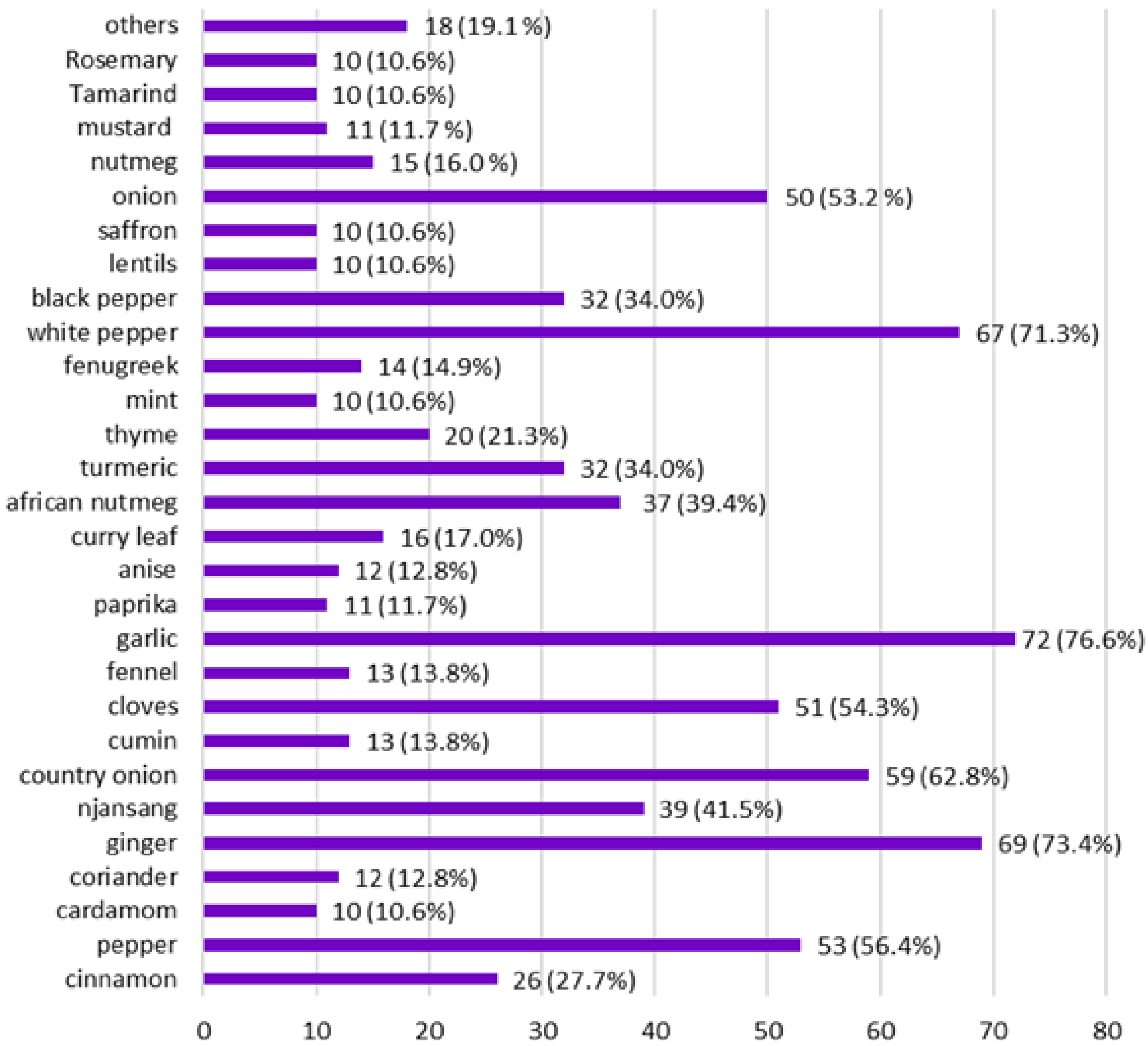

Figure 3 Frequency of consumption of the different spices sold in local markets in Yaounde

Heavy metal concentrations in spices sold in Yaounde

The levels of lead (Pb), cadmium (Cd) and arsenic (As) in each of the 44 pooled samples (that originated from 132 samples of 27 different varieties of spices) are presented in (Table 2).

Cadmium levels in spice samples from markets ranged from below limit of detection (LOD) to 5.065 mg/kg overall. Over 50% of samples were <LOD (Aidan fruit, Anise, Coriander, cumin, curry, ginger, African nutmeg, white pepper, black pepper, village black pepper, rosemary), but detected levels often exceeded the WHO/FAO Codex Alimentarius (2006) MPL of 0.2 mg/kg for cadmium in spices,[26] notably Oregano (5.065 mg/kg, 25.33 times), Cardamom (3.136 mg/kg, 15.68 times), Pepper (2.629 mg/kg, 13.15 times), Fennel (1.473 mg/kg, 7.37 times), Turmeric (1.367 mg/kg, 6.84 times), Mustard (1.347 mg/kg, 6.74 times), herb of province (0.927 mg/kg, 4.64 times), Njansang (0.345 mg/kg, 1.725 times), Paprika (0.315 mg/kg, 1.575 times), Cloves (0.307 mg/kg, 1.54 times). Overall, these spices had Cd levels exceeded the MPL in a range of 1.27 (fenugreek) – 4.46 (oregano) times. The ranking of Cd levels in spice was highest in Oregano > Cardamom > Pepper > Fennel > Turmeric > Mustard > herb of province > Njansang > Paprika > Cloves > Garlic > Fenugreek > Nutmeg > thyme > Country onion > Cinnamon

Lead (Pb) levels in spice samples from markets in Yaoundé ranged from below the limit of detection (LOD) in mustard to 11.15 mg/kg in oregano. Several spices exceeded the WHO/FAO Codex Alimentarius (2025) MPL of 2.5 mg/kg for lead in spices,[27] including oregano (11.15 mg/kg), cardamom (7.785 mg/kg), turmeric (3.29 mg/kg), nutmeg (3.225 mg/kg), and fenugreek (3.186 mg/kg). Overall, these spices had Pb levels that exceeded the MPL by a factor of 1.27 (fenugreek) to 4.46 (oregano) times. The ranking of Pb levels in spices was as follows: oregano > cardamom > turmeric > nutmeg > fenugreek > fennel > anise > herb of province > cinnamon > pepper > Aidan fruit > cloves > curry > paprika > country onion > African nutmeg > rosemary > garlic > cumin > black pepper > white pepper > thyme > ginger > village black pepper > coriander > njansang.

Table 2 Levels of Cd, Pb and As in 27 different varieties of spices sold in some popular markets in Yaounde, Cameroon.

Variety of Spice	Mfoundi market (n=26)			Mokolo/8eme market (n=18)			Mean levels in both markets (n=27) vs MPL					
							Cd		Pb		As	
	Cd (mg/kg)	Pb (mg/kg)	As (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	As (mg/kg)	Cd (mg/kg)	Number of times > MPL 0.2 mg/kg	Pb (mg/kg)	Number of times > MPL 2.5 mg/kg	As (mg/kg)	Number of times > MPL 0.2 mg/kg
Aidan fruit	<LOD	2.213	13.36	<LOD	0.054	9.415	<LOD	n/a	1.134	n/a	11.388*	56.95
Garlic	0.103	0.642	2.064	n.s.	n.s.	n.s.	0.103	n/a	0.642	n/a	2.064*	10.32
Anise	<LOD	2.911	12.685	<LOD	0.656	10.795	<LOD	n/a	1.784	n/a	11.740*	58.7
Cinnamon	0.055	1.923	11.78	<LOD	0.604	1.024	0.03	n/a	1.264	n/a	6.402*	32.01
Cardamom	3.136	7.785	2.827	n.s.	n.s.	n.s.	3.136*	15.68	7.785*	3.11	2.827*	14.14
Cloves	0.608	1.448	1.278	<LOD	0.604	1.024	0.307*	1.54	1.026	n/a	1.151*	5.75
Coriander	<LOD	0.067	11.63	<LOD	0.055	9.415	<LOD	n/a	0.061	n/a	10.523*	52.6
Cumin	<LOD	0.624	13.155	<LOD	0.624	1.024	<LOD	n/a	0.624	n/a	7.090*	35.5
Turmeric	2.357	2.049	14.855	0.377	4.53	5.8	1.367*	6.84	3.290*	1.32	10.328*	51.65
Curry	<LOD	1.021	12.29	n.s.	n.s.	n.s.	<LOD	n/a	1.021	n/a	12.29*	61.45
Ginger	<LOD	0.148	9.355	<LOD	0.148	9.355	<LOD	n/a	0.148	n/a	9.355*	46.8
Fennel	<LOD	2.083	0.118	2.941	2.178	14.355	1.473*	7.37	2.131	n/a	7.237*	36.2
Fenugreek	0.189	3.186	9.255	0.188	3.186	9.255	0.189	n/a	3.186*	1.27	9.255*	46.3
Mustard	1.347	<LOD	<LOD	n.s.	n.s.	n.s.	1.347*	6.74	<LOD	n/a	<LOD	
Njansang	0.684	0.048	8.565	<LOD	0.055	10.065	0.345*	1.725	0.052	n/a	9.315*	46.6
Nutmeg	<LOD	0.555	15.71	0.299	5.895	6.565	0.152	n/a	3.225*	1.29	11.138*	55.7
Oregano	5.065	11.15	10.68	n.s.	n.s.	n.s.	5.065*	25.33	11.15*	4.46	10.68*	53.4
Paprika	0.315	0.976	2.928	n.s.	n.s.	n.s.	0.315*	1.575	0.976	n/a	2.928*	14.64
African nutmeg	<LOD	1.436	12.515	<LOD	0.271	12.405	<LOD	n/a	0.854	n/a	12.460*	62.3
Pepper	2.629	1.219	14.38	n.s.	n.s.	n.s.	2.629*	13.15	1.219	n/a	14.380*	71.9
White pepper	<LOD	1.022	14.625	<LOD	<LOD	7.715	<LOD	n/a	0.514	n/a	11.170*	55.85
Black pepper	<LOD	0.547	13.73	n.s.	n.s.	n.s.	<LOD	n/a	0.547	n/a	13.730*	68.65
Village Black pepper	<LOD	0.205	13.35	<LOD	<LOD	11.305	<LOD	n/a	0.105	n/a	12.328*	61.65
Rosemary	<LOD	0.767	11.44	<LOD	0.767	11.44	<LOD	n/a	0.767	n/a	11.440*	57.2
Country onion	<LOD	1.882	11.19	0.226	<LOD	5.11	0.116	n/a	0.944	n/a	8.150*	40.75
thyme	0.118	0.498	3.738	n.s.	n.s.	n.s.	0.118	n/a	0.498	n/a	3.738*	9.35
herd of province	n.s.	n.s.	n.s.	0.927	1.786	6.35	0.927*	4.64	1.786	n/a	6.350*	31.75
Number of contaminated samples above MPLs	8	4	24	5	3	18	10	n/a	5	n/a	26	n/a

n.s.: no sample. Note: All non-detected samples were assigned to have an LOD value of 0.005 mg/kg irrespective of the heavy metal. n: number of spice varieties. *: concentrations greater than maximum permissible limits (MPLs) for each heavy metal (Pb: 2.5mg/kg, Cd and As: 0.2mg/kg). Recovery rate: 98%. n/a: not applicable.

Note: The percentage recovery was 98% with a mean recovery ranged from 80-120% (RSD <5%), confirming method accuracy and precision for trace metal quantitation in spice matrices.

Arsenic was detected in nearly all samples (except mustard from Mfoundi), with levels ranging from <LOD to 14.38 mg/kg (pepper). All samples far exceeded the WHO/FAO Codex Alimentarius (2006) MPL of 0.2 mg/kg for arsenic in spices[26] making As the predominant heavy metal contaminant. The most contaminated spices were pepper (14.38 mg/kg), black pepper (13.73 mg/kg), African nutmeg (12.46 mg/kg), village black pepper (12.33 mg/kg), and curry (12.29 mg/kg). And the least contaminated were Paprika (2.928 mg/kg), Cardamom (2.827 mg/kg), Garlic (2.064 mg/kg), thyme (1.869 mg/kg), Cloves (1.151 mg/kg). Overall, these spices had As levels that exceeded the MPL from 5.75 times (cloves) to 71.9 times (pepper). The ranking was as follows Pepper > Black pepper > African nutmeg > Village Black pepper > Curry > Anise > Rosemary > Aidan fruit > White pepper > Nutmeg > Oregano > Coriander > Turmeric > Ginger > Njansang > Fenugreek > Country onion > Fennel > Cumin > Cinnamon > herd of province > Paprika > Cardamom > Garlic > thyme > Cloves.

Furthermore (Table 2), summarizes the distribution of Pb, Cd and As contamination in the studied spice samples. The mean levels of As in all As-contaminated spice (96.3%, 26/27) exceeded the MPLs of As 0.2 mg/kg fixed by Codex Alimentarius (2006). Meanwhile, only 18.52% (5/27) of Pb-contaminated samples had mean Pb levels higher than the MPL for Pb 2.5 mg/kg fixed by WHO/FAO Codex Alimentarius (2025). Likewise, 37.04% (10/27) of Cd-contaminated spices had mean levels higher than the MPL for Cd 0.2 mg/kg fixed by Codex Alimentarius (2006).

Exposure and health risk assessment

Table 3 provides the estimated daily intake (EDI), target hazard quotient (THQ) and total hazard index (HI) for cadmium (Cd), lead (Pb), and arsenic (As) across the 27 studied spices. Cd exposures were negligible/tolerable, with EDI values ranging from 0.0000008 mg/kg bw/day (several spices, e.g. Aidan fruit, Anise, Coriander) to 0.000834 mg/kg bw/day in oregano, and a mean EDI of 0.000108 mg/kg bw/day; all THQ values for Cd were < 1 (mean: 0.108, range: 0.0008-0.834). Pb EDI ranged from 0.0000008 mg/kg bw/day (mustard) to 0.00184 mg/kg bw/day in oregano, with a mean of 0.000285 mg/kg bw/day, and corresponding THQ values between 0.0002 and 0.459 (mean 0.071), which remained < 1. As shown, the highest non-carcinogenic risk, with EDI values spanning from 0.0000008 mg/kg bw/day (mustard) to 0.00237 mg/kg bw/day in pepper, and a mean EDI of 0.0014 mg/kg bw/day. The THQ values for As ranged from 0.003 (mustard) to 7.897 in pepper, with a mean of 4.667. The cumulative non-carcinogenic risk (HI) across Cd, Pb and As varied from 0.225 (mustard) to 8.380 (pepper), with a mean HI of 4.890, indicating that for several spices, particularly pepper, oregano, African nutmeg, village black pepper, white and black pepper, the combined exposure exceeded the safe limit of 1.

Table 3 Mean Estimated Daily Intake (EDI) (mg/kg BW/day), Target Hazard Quotient (THQ) and Hazard Index (HI) values of heavy metals in all the different studied spices from Yaounde.

Spices	Cd		Pb		As		HI
	EDI	THQ	EDI	THQ	EDI	THQ	
Aidan fruit	0.0000008	0.0008237	0.0001867	0.0466845	0.0018760	6.2534322	6.3009404
Garlic	0.0000170	0.0169687	0.0001058	0.0264415	0.0003400	1.1334432	1.1768534
Anise	0.0000008	0.0008237	0.0002938	0.0734555	0.0019341	6.4470071	6.5212864
Cinnamon	0.0000049	0.0049423	0.0002082	0.0520387	0.0010547	3.5156507	3.5726318
Cardamom	0.0005166	0.5166392	0.0012825	0.3206343	0.0004657	1.5524437	2.3897172
Cloves	0.0000505	0.0504942	0.0001690	0.0422570	0.0001896	0.6320703	0.7248215
Coriander	0.0000008	0.0008237	0.0000100	0.0025124	0.0017335	5.7784185	5.7817545
Cumin	0.0000008	0.0008237	0.0001028	0.0257002	0.0011680	3.8931906	3.9197144
Tumeric	0.0002252	0.2252059	0.0005419	0.1354819	0.0017014	5.6713344	6.0320222
Curry	0.0000008	0.0008237	0.0001682	0.0420511	0.0020247	6.7490390	6.7919138
Ginger	0.0000008	0.0008237	0.0000244	0.0060956	0.0015412	5.1372872	5.1442065
Fennel	0.0002427	0.2426689	0.0003510	0.0877471	0.0011922	3.9739154	4.3043314
Fenugreek	0.0000311	0.0310544	0.0005249	0.1312191	0.0015247	5.0823723	5.2446458
Mustard	0.0002219	0.2219110	0.0000008	0.0002059	0.0000008	0.0027457	0.2248627
Njansang	0.0000568	0.0567545	0.0000085	0.0021211	0.0015346	5.1153213	5.1741969
Nutmeg	0.0000250	0.0250412	0.0005313	0.1328254	0.0018348	6.1161450	6.2740115
Oregano	0.0008344	0.8344316	0.0018369	0.4592257	0.0017595	5.8649094	7.1585667
Paprika	0.0000519	0.0518946	0.0001608	0.0401977	0.0004824	1.6079077	1.7000000
African nutmeg	0.0000008	0.0008237	0.0001406	0.0351524	0.0020527	6.8423943	6.8783704
Pepper	0.0004331	0.4331137	0.0002008	0.0502059	0.0023690	7.8967600	8.3800796
White pepper	0.0000008	0.0008237	0.0000846	0.0211491	0.0018402	6.1339923	6.1559651
Black pepper	0.0000008	0.0008237	0.0000901	0.0225288	0.0022619	7.5398133	7.5631658
Village black pepper	0.0000008	0.0008237	0.0000173	0.0043245	0.0020309	6.7696321	6.7747803
Rosemary	0.0000008	0.0008237	0.0001264	0.0315898	0.0018847	6.2822625	6.3146760
Country onion	0.0000190	0.0190280	0.0001554	0.0388591	0.0013427	4.4755629	4.5334500
thyme	0.0000194	0.0194399	0.0000820	0.0205107	0.0006158	2.0527183	2.0926689
Herd of province	0.0001527	0.1527183	0.0002942	0.0735585	0.0010461	3.4870950	3.7133718
Mean	0.0001078	0.1078284	0.0002852	0.0712879	0.0014001	4.6669209	4.8896013

The estimated cancer risk (ECR) linked to intake of each spice is presented in (Table 4). Across the studied 27 spice sample brands, the mean ECRs were 0.00004097 for Cd, 0.00000242 for Pb and 0.00210011 for As, with only that of As exceeding the acceptable cancer risk range (0.000001 to 0.0001), indicating cancer risk. However, outliers like ECR of Cd in oregano (0.00031708), cardamom (0.00019632) and pepper (0.00016458) and ECR of As in all the samples except mustard, exceeded typical thresholds of 0.000001 to 0.0001, emphasizing the need for targeted Cd and particularly As interventions. The ECR from Pb exposure through any of the studied spice samples did not pose a concern.

Table 4 Estimated cancer risk (ECR) of heavy metals (Cd, Pb and As) through consumption of each of the studied spice.

Spices	Estimated Cancer Risk (ECR)		
	Cd	Pb	As
Aidan fruit	0.00000031	0.00000159	0.00281404
Garlic	0.00000645	0.00000090	0.00051005
Anise	0.00000031	0.00000250	0.00290115
Cinnamon	0.00000188	0.00000177	0.00158204
Cardamom	0.00019632	0.00001090	0.00069860
Cloves	0.00001919	0.00000144	0.00028443
Coriander	0.00000031	0.00000009	0.00260029
Cumin	0.00000031	0.00000087	0.00175194
Turmeric	0.00008558	0.00000461	0.00255210
Curry	0.00000031	0.00000143	0.00303707
Ginger	0.00000031	0.00000021	0.00231178
Fennel	0.00009221	0.00000298	0.00178826
Fenugreek	0.00001180	0.00000446	0.00228707
Mustard	0.00008433	0.00000001	0.00000124
Njansang	0.00002157	0.00000007	0.00230189
Nutmeg	0.00000952	0.00000452	0.00275227
Oregano	0.00031708	0.00001561	0.00263921
Paprika	0.00001972	0.00000137	0.00072356
African nutmeg	0.00000031	0.00000120	0.00307908
Pepper	0.00016458	0.00000171	0.00355354
White pepper	0.00000031	0.00000072	0.00276030
Black pepper	0.00000031	0.00000077	0.00339292
Village Black pepper	0.00000031	0.00000015	0.00304633
Rosemary	0.00000031	0.00000107	0.00282702
Country onion	0.00000723	0.00000132	0.00201400
Thyme	0.00000739	0.00000070	0.00092372
Herd of province	0.00005803	0.00000250	0.00156919
Mean	0.00004097	0.00000242	0.00210011

Discussion

Patterns of spice consumption and public health implications

The high frequency of spice consumption indicated by survey participants in Yaoundé—especially among adults aged 19–66 years and daily use for both culinary and medicinal purposes amplify the potential for chronic exposure to contaminants present in these products. This observation is consistent with findings from other African contexts, where spices are integral to food culture and often consumed regularly.[18] Despite general recognition of health risks from heavy metals, the low awareness among consumers in Yaoundé (25.8%) suggests an important gap between risk perception and behaviour, a gap that has also been noted in other regions of Africa where food safety education is limited.

Heavy metal contamination of spices in African markets

Our study documents widespread contamination of spices with Pb, Cd, and particularly As, often exceeding the MPLs established by WHO/FAO. Similar patterns have been reported across African countries, although the magnitude and metal profile vary by geographic location and spice type. For example, a recent study in Accra, Ghana reported detectable levels of arsenic and lead in locally sold spices, with some samples slightly above Codex limits, although these did not uniformly pose clear health risks at typical consumption rates.[18] This underscores a continental trend of spice contamination by heavy metals, albeit at varying intensities. In Nigeria, assessments of heavy metal contamination in local spices have also identified elevated metal levels.[28] Pb was detected in significant concentrations in spices such as African nutmeg and *Prosopis africana* from markets in northern and southeastern parts of Nigeria,[29] sometimes exceeding WHO recommended limits. Alongside the observed high As levels in studied spice samples, the observed Cd (0.152 mg/kg) and Pb (3.225 mg/kg) levels in the pooled nutmeg sample in this present study were similar to the high Cd, Pb and As levels in unrevealed market spice samples from Nigeria.[17] Though some studies reported Pb concentrations below normative toxic thresholds in certain spices, they nevertheless highlighted the potential for chronic exposure and the need for continued surveillance.

Comparative studies in South Africa, by contrast, reported generally lower concentrations of Pb and Cd in spice samples, with hazard quotients and total hazard indices below unity, indicating minimal immediate risk under typical consumption patterns.[22] This suggests regional differences in agricultural practices, soil contamination profiles, and food safety systems that influence heavy metal burdens in spices across African markets. Studies show African spices have higher metals than Middle East or Indian ones, and Yaoundé's urban farming pollution is a big factor.[13,30]

The levels of arsenic was higher than the levels obtained in Poland by Kowalska in 2021[31] which was in the range of 0.102–0.863 mg/kg. The study did by Nana in 2022[30] indicates that the the high As levels in the samples may stem from irrigated groundwater, pesticide residues, or industrial pollution uptake in spice plants, amplified during drying or grinding. This can lead to some health implications such as chronic inorganic As exposure drives skin lesions, cancers (skin, lung, bladder), cardiovascular disease, and neurotoxicity, posing acute risks in spice-dependent diets.

Exposure and health risk assessment

Across the 27 spice samples, most individual THQ values for Cd, Pb, and As were well below 1, indicating that daily exposure to each metal from a single spice is unlikely to cause adverse non-cancer health effects under typical consumption. For example, the Mean Cd THQ was 0.1078, Pb THQ was 0.0713, and As THQ was 4.667, with the resulting Mean HI of 4.89. This pattern shows that As driven THQ dominates the overall risk, while Cd and Pb contribute only modestly to the HI. The overall HI of 4.89 is much higher than the safe level of 1 seen in South Africa,[22] Ghana[18] and Morocco studies.[15]

Several spices, however, approach or exceed concern thresholds. For example, the HI values of Cardamon (2.39) and of pepper (8.38) stand out as the highest-risk items, driven mainly by the THQ values of As (6.75-7.89) and of Cd (0.43-0.52). The HI value of Oregano (7.16) and turmeric (6.03) also show elevated indices, with As THQ remaining the main contributor.

Even relatively "low-risk" spices such as coriander, cumin, and garlic have HI values near or slightly above 1, mainly due to the THQ of As alone, rather than Cd or Pb.

From a health-risk perspective, the data indicates that As is the primary driver of non-carcinogenic health risk in the spice basket, consistent with its high chronic toxicity and relatively low oral reference dose. Cd-enriched spices (cardamom, oregano, turmeric, fennel, pepper) contribute secondary but non-negligible risk, especially under high-frequency or high-dose usage. Pb related THQ remains low in almost all spices (mostly < 0.150), suggesting that, at least in this dataset, Pb does not significantly increase the HI burden, although chronic neurotoxic effects at low doses are still a concern.[16,29] Compared with other studies on heavy metals in spices and herbs, the HI pattern in the present work is similar (as spices do not exceed HI value of 1 for most items), but As and Cd rich spices may elevate cumulative risk, particularly for high-consumption subgroups.[3] While some African studies reported negligible or tolerable risk from Cd and Pb (e.g., South Africa), others observed exceedances that might contribute to long-term toxicological concerns when spiced diets are habitual. This heterogeneity underscores the influence of local environmental contamination sources, such as industrial activities, mining, and agricultural inputs, on spice safety.

The estimated cancer risks obtained in this study were low to moderate when compared with internationally reported ranges for heavy metals in spices and herbs. In regulatory and risk assessment practice, incremental lifetime cancer risk (ILCR) values below 0.000001 are typically considered negligible, values between 0.000001 and 0.0001 are regarded as acceptable or tolerable, and values above 0.0001 are interpreted as indicating a significant health concern.[2,30,31] In the present work, the mean cancer-risk estimates were 0.000041 for Cd, 0.0000024 for Pb, and 0.0021 for As. These values lie within or slightly above commonly reported ranges from global spice-monitoring studies. Compared to other works,[3] for instance, reported carcinogenic risk values for Pb in the order of 0.000034 to 0.00019 for male consumers, with similar or higher ranges for As-related risk depending on metal concentration and consumption level; in this context, the mean Cd and Pb risk values in my dataset fall at the lower end of these ranges, whereas the mean As-related risk is higher than many of the As-based values reported in the same review, particularly for spices such as pepper, curry, black and white peppers, and African nutmeg. Also, Kowalska in 2021[30] reported As mean as being below 10^{-4}. It's similar to Hanoi Vietnam spices that reached around 10^{-3}[1] and much higher than safe levels in South African studies.[22] The outliers in Cd match high-risk patterns seen in Nigerian market spices[17] and exceed Australian levels that stayed below 10^{-5}.[9]

In the present study, it was noticed that only one spice sample (mustard) in As was within the acceptable cancer risk range. These levels signal lifetime cancer risk (skin, lung, bladder) from routine cooking especially concerning for high-spice users (pregnant women, children, elders). While mean Cd is safe, oregano (0.000317), cardamom (0.000196), and pepper (0.000164) exceed the acceptable cancer range, users of these specific spices might face kidney/cancer risks.

Several recent investigations on heavy metals in spices from North America and Europe have shown that spices can contribute to total dietary metal intake, yet total cancer risk from spices alone is often estimated to be close to or below 0.0001 when mean across the spice basket.[3,1] In contrast, As-driven cancer-risk values for individual spices such as pepper (0.00355) in my dataset exceed 0.001, suggesting that for Cameroonian consumers, particularly those living in Yaoundé with high-spice diets may experience a larger contribution of spices to lifetime cancer risk than is typically observed under Western market spice intake scenarios. Cadmium-related risk in this study is generally higher than that reported in some spice-monitoring programs, where Cd-based carcinogenic or hazard indices are often below 0.00001 for most products,[3,32] although values for spices such as oregano (0.00031708), cardamon (0.00019632), fennel (0.00009221), and pepper (0.00016458) are comparable to those reported for Cd-enriched spices and herbs in other regions. Lead-related cancer risk in my dataset is notably lower than the upper-end Pb-based ILCR values reported in some spice-monitoring surveys, where Pb-driven risk occasionally exceeded 0.0001 in certain herbs and spices,[3,13] indicating that Pb is relatively well-controlled in the sampled spices, whereas As and Cd merit focused attention.

From a public-health perspective, the findings are consistent with broader evidence that spices are not a major driver of overall population-level cancer risk under typical intake patterns, but As and Cd rich spices act as hot spots that can elevate individual risk, particularly among high-consumption subgroups.[3,32] The present results align with global means for Cd and Pb cancer risk yet exceed many international reports for As related risk in specific spices, particularly pepper type spices and curry related blends.[3,13] This supports the need for region-specific monitoring, soil and irrigation management, and post-harvest processing controls in Cameroon and similar settings, where local growing conditions and traditional spice-use patterns may amplify As-driven cancer risk compared with Western-style spice-intake scenarios.

Altogether, considering the evidence from this present study relative to the other African studies, it may be speculated that regular monitoring of spice contamination levels, enforcement of Codex standards, and improved supply chain traceability are essential to mitigate risks associated with heavy metal-contamination of spices. The low consumer awareness observed in this study mirrors findings across African settings and points to the need for targeted heavy metals risk communication (including spice safety education campaigns tailored to local contexts) and risk management.

Limitations and future research

While this study provides important baseline data on heavy metal contamination in spices in Yaoundé, limitations include the reliance on pooled samples and market origins without direct analysis of agricultural sources. Future research will investigate contamination sources (e.g., soil and water analysis) and extend to a wider geographic scope across Cameroon and neighbouring countries to better understand spatial patterns of heavy metal exposure from spices.

Conclusion

This study which evaluated contamination by lead, cadmium, and arsenic in commonly consumed spices sold in the Mfoundi and Mokolo/8eme markets in Yaoundé, Cameroon is the pioneer spice safety study from Cameroon. The results indicate widespread exceedance of FAO/WHO MPLs, particularly for As, highlighting a significant spice safety concern amongst consumers in Yaounde. White pepper, njansang, cloves, country onion, garlic, and ginger were the most frequently consumed spices. Despite limited awareness of heavy metal contamination among vendors and consumers, most respondents recognised the associated health risks. Analytical findings showed that all analysed spices were unsafe for consumption due to elevated As levels. Additionally, cardamom, oregano, and nutmeg exceeded permissible limits for Pb, while cloves, turmeric, oregano, mustard, njansang, pepper, and fennel showed Cd concentrations of potential concern. Health risk assessment revealed low non-carcinogenic risk for Pb and Cd with regards to the THQ which was < 1. In contrast, As posed a substantial health risk, with average (range) THQ value of 4.667 (0.0027-7.897) in the studied samples, far exceeding safety thresholds. Likewise, the cancer-risk estimates further indicate that As-rich spice samples such as white pepper, pepper-type spices, and njansang as well as a few Cd-rich spice samples (oregano, cardamom and pepper) with ECR values exceeding the acceptable cancer range constitutes a public health risk to consumer populations, requiring attention.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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