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ORIGINAL RESEARCH ARTICLE



## Assessment of levels of heavy metals in some common local spices sold in two markets in Cape Coast Ghana

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### ABSTRACT

The study examined levels of lead (Pb), cadmium (Cd) and copper (Cu) in ten spices sold in Abura and Kotokoraba markets, Cape Coast-Ghana to determine their safety for consumption. Samples of spices were collected from the markets and analyzed for Pb, Cd and Cu using atomic absorption spectrophotometry. A one-way analysis of variance was used to compare mean levels of metals in spices from these markets, followed by Tukey's post hoc test to identify specific pairwise differences among the spices. Mean Cd levels were below detectable limits. Mean Pb levels did not differ significantly between markets ( $F = 1.004$ ,  $p = 0.450$ ), indicating similar contamination patterns. Mean Cu levels differed significantly ( $F = 3.472$ ,  $p = 0.002$ ), with ginger showing markedly higher Cu levels than garlic, rosemary, aniseed, grains of paradise, negro pepper, bay leaf, cloves, and chili pepper. Results suggest that differences found in Cu levels may depend on the type of spice rather than location of market. While Pb contamination appears uniform across both markets, the Cu disparity underscores the need for commodity-specific control strategies. The study recommends targeted monitoring of high risk spices particularly ginger through source tracing, vendor education, and stricter regulatory checks. This research provides a comparative market analysis of heavy metals in Ghanaian spices, offering evidence to strengthen public health protection and ensure safer spice trade practices.

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### INTRODUCTION

Spices have long played an important role in diets around the world, especially in sub-Saharan Africa, where these spices are used to enhance the flavour, aroma, and appearance of food (Aberie *et al.*, 2021). In Ghana, the use of spices had grown even more widespread in recent years, not only for culinary purposes but also for medicinal, preservative, and even spiritual applications (Gadegbeku *et al.*, 2014). However, despite their natural origins, spices were not immune to contamination—particularly from heavy metals—during their cultivation, processing, and storage (Ogbunugafor *et al.*, 2017; Oladoye & Jegede, 2016). This raised concerns about long-term exposure to harmful sub-

stances through regular consumption. Heavy metals such as lead (Pb), copper (Cu), and cadmium (Cd) are known to accumulate in the body over time and can pose serious health risks. Lead has been linked to developmental and neurological disorders; cadmium to kidney and bone damage, and copper, while essential in small amounts, could cause toxicity at high concentrations (Al-Dalain *et al.*, 2021). In regions like Ghana, where informal agricultural practices, roadside drying, and environmental pollution from activities like illegal mining are common, the chances of spices being contaminated with heavy metals are significantly higher. Although several studies had looked at heavy metal contamination in food, very few had focused specifically on individual spices, and fewer still had

explored this issue across multiple markets in Ghana. Most existing research either analyzed mixed seasonings or were geographically limited, leaving a gap in understanding how widespread the contamination might be in commonly used spices sold in open markets.

This study was designed to help fill that gap. It examined the levels of lead, copper, and cadmium in ten popular spices sold in two major markets-Abura and Kotokoraba in Cape Coast, Ghana. By using an exploratory sequential mixed methods approach, the research captured both the views of spice users and sellers and provided laboratory analysis of the metal concentrations. The novelty of this study lay in its market-level comparison and the focus on single, unblended spice samples, which offered a more precise understanding of contamination levels. The aim of the study was to determine the levels of these metals in selected local spices and compare these with the World Health Organization (WHO) permissible limits. In doing so, the study sought to highlight possible health risks and provide evidence that could support future food safety policies in Ghana and similar contexts.

## MATERIALS AND METHODS

### Study area, market selection, and research design

The study employed quantitative research design to ensure a holistic investigation. This design was particularly appropriate given the aim to both test for hypothesis and scientifically investigate spices for heavy metal contamination. This approach ensured the spices selected for laboratory analysis were not only culturally and nutritionally relevant but also widely consumed. The research was conducted in two central markets within the Cape Coast Metropolis of Ghana: Abura Market and Ko-

tokoraba Market. These markets were selected due to their popularity, high consumer traffic, and the wide variety of spices available. They serve as major trading points for both local residents and regional buyers, making them ideal sites for assessing common spice consumption and potential exposure to environmental contaminants such as heavy metals.

### Spice samples collection, preparation and digestion

A purposive sampling method was used for this study. Sixty samples (triplicates of 10 different natural spices) were collected from different sellers at the Abura and Kotokoraba markets and subsequently classified according to the plant part used, scientific, family and local names as shown in Table 1. Samples were purchased after preliminary study of the two markets indicated that these were the most purchased, consumed and frequently patronized spices. Collected spices were stored in sterilized zip lock bags, labelled with codes for easy identification and then transported to the laboratory as shown in Table 2. Fresh samples of ginger, garlic and other spices were cleaned, washed, grated for easy and uniform drying. All samples were dried in the oven at 60°C overnight, cooled in a desiccator and milled into powder using a stainless-steel laboratory beater mill and stored in zip-lock bags in the refrigerator prior to analysis. Aqua regia (Solution 3:1 of HCl and HNO<sub>3</sub>) wet digestion was employed. Approximately 0.5g of the sample was transferred into a digestion flask and moistened with 2-3ml distilled water. 7.5ml concentrated HCl and 2.5ml concentrated HNO<sub>3</sub> were then added to the sample. The digestion flask was covered with a watch glass and allowed to react under a fume hood overnight (minimum 12 hours). The sample was heated and boiled under reflux for 2 hours and then allowed to cool. The extract was then filtered with an acid-resistant filter paper into a 100ml volumet-

**Table 1.** Classification of selected spices.

Spice	Scientific name	Family	Local name	Part used
Chili pepper	<i>Capsicum annum</i>	<i>Solanaceae</i>	Muoko( <i>Fante</i> ), Meko ( <i>Twi</i> ), Shito ( <i>Ga</i> ), Barkono ( <i>Hausa</i> )	Fruit
Rosemary	<i>Rosmarinus officinalis</i>	<i>Lamiaceae</i>	Rosemary	Twigs/ terminal shoot
Anise seed/Anise	<i>Pimpinella anisum</i>	<i>Apiaceae</i>	Nkitsinkitsi ( <i>Fante</i> ), Nketenkete ( <i>Twi</i> ), Osukor ( <i>Ga</i> ), Nketenkete( <i>Hausa</i> )	Seeds
Cloves	<i>Eugenia caryophyllata</i>	<i>Myrtaceae</i>	Mpregowamba ( <i>Fante</i> ), Dadoamba/Pepre ( <i>Twi</i> ), Pepple( <i>Ga</i> ), Kanumfari ( <i>Hausa</i> )	Unopened flower buds
Negro pepper	<i>Xylopiya aethiopica</i>	<i>Annonaceae</i>	Hwentsia ( <i>Fante</i> ), Hwentiaa ( <i>Twi</i> ), Soh ( <i>Ga</i> ), Kimba ( <i>Hausa</i> )	Fruits and seeds
Ginger	<i>Zingiber officinale</i>	<i>Zingiberaceae</i>	Tsintsimber ( <i>Fante</i> ), Akakaduro ( <i>Twi</i> ), Kakatsofa ( <i>Ga</i> ), Citta ( <i>Hausa</i> )	Rhizome
Garlic	<i>Allium sativum</i>	<i>Alliaceae</i>	Garlic ( <i>Fante/Twi/Ga</i> ), Tafarnuwa ( <i>Hausa</i> )	Bulb
African nutmeg	<i>Monodora myristica</i>	<i>Annonaceae</i>	Ayerewamba ( <i>Fante</i> ), Wediaba/Ayerewa ( <i>Twi</i> ), Ayerewamba ( <i>Fante</i> ), Maalai ( <i>Ga</i> ), Gyadar Kanshi ( <i>Hausa</i> )	Seeds
Grains of paradise	<i>Aframomum melegueta</i>	<i>Zingiberaceae</i>	Famu wusa ( <i>Fante</i> ), Efom wisa ( <i>Twi</i> ), Tsurui ( <i>Ga</i> ), Yaagyi ( <i>Hausa</i> )	Seeds
Bay leaf	<i>Laurus nobilis</i>	<i>Lauraceae</i>	Bay leaf	Leaf

Source: Darko et al. (2014).

**Table 2.** Codes assigned to spice samples.

Spice sample	Abura Code	Kotokoraba Code
Ginger	A-GI	K-GI
Garlic	A-G	K-G
Rosemary	A-RM	K-RM
Aniseed	A-AS	K-AS
Grains of paradise	A-GP	K-GP
Negro pepper	A-NP	K-NP
Bay leaf	A-BL	K-BL
Clove	A-C	K-C
African nutmeg	A-AN	K-AN
Chili pepper	A-CP	K-CP

ric flask. The sample was allowed to cool and diluted to 100ml mark with the 2M nitric acid solution (Verloo & Demeyer, 1997). From a stock solution of 100ppm, working standard solution of Cd and Pb were prepared. Standards were prepared in 25ml volumetric flask. For instance, 0.05ppm Cd in 25ml of volumetric flask was prepared by adding 12.5µl of the 100 ppm Cd standard using a micropipette in 10ml of distilled water in the volumetric flask and topped up to 25ml. The same procedure with the same dilution was done for the other working standards for various concentrations. Hence, for Cd, the following volumes 12.5µl, 25µl, 125µl, 250µl, 500µl gave a concentration range of 0.05ppm, 0.1ppm, 0.5ppm, 1ppm and 2ppm respectively. That of Pb were as follows; 125µl, 250µl, 500µl, 1250µl, 2500µl for a concentration range 0.5ppm, 1ppm, 2ppm, 5ppm and 10ppm and finally that of Cu with volumes of 25µl, 125µl, 250µl, 500µl and 1250µl for a concentration range of 0.1ppm, 0.5ppm, 1ppm, 2ppm and 5ppm. In the same way, blank solutions from only reagents (i.e. a mixture of HNO<sub>3</sub> and HCl), were prepared and digested for each metal for comparison using the same procedure as the sample.

### Heavy metal analysis in spice samples

The filtrate resulting from wet digestion was subsequently analyzed for Pb, Cd and Cu using atomic absorption spectrophotometer (SHIMADZU AA-7000). Measurements were made using the hollow cathode lamps for Cd, Pb and Cu at the proper wavelength, and the slit width was adjusted using air acetylene flame. Thus, the hollow cathode lamp generates light at wavelength characteristic of each analyte. Each analyte is then atomized using an atomizer to create free atoms from the samples (Aberie et al., 2021; Akutei, 2019). The air-acetylene gas was used as the source of energy for the production of free atoms for the elements. The sample was then introduced as an aerosol into the flames where light was absorbed. The light was then directed into a monochromator which then isolated the specific analytical wavelength of the light emitted by the hollow cathode lamp from the non-analyte sensitive light detector then

measures the light and translates the response into an analytical measurement. Replicates of three determinations were carried out for each sample and the same procedure was employed for the determination of elements in digested blank solutions and for the spiked samples. Concentration of metals in the spice samples was calculated by using the following formula (Akutei, 2019):

$$\text{Final conc. (mg/L or mg/kg)} = \frac{\text{Conc. (analytical measurement)} \times \text{Nominal volume}}{\text{Sample weight in gram}}$$

Where Conc. = instrumental measurement; Nominal volume = final volume of digest sample solution; Conc. (mg/kg) = concentration of metals in spices.

## RESULTS AND DISCUSSION

### Heavy metal concentrations in spices

Presence of heavy metals in nature and in food if it is within the permissible limits stipulated by national and international accredited bodies is acceptable. However, increased concentration of heavy metals above the permissible threshold may cause health problems in individuals due to the bio-accumulative nature and the human body's inability to easily excrete these. Table 3 shows the permissible limits for heavy metals in spices as per WHO limit as reported by Oladoye & Jegede (2016); Olusakin & Olaoluwa, (2016). All samples analyzed in this work contained detectable levels of lead and copper. However, cadmium, if present was below the detection limit. Results indicated total mean concentrations in all samples from both markets in an ascending order of lead > copper > cadmium, with lead recording the highest value of 77.33mg/kg followed by copper 31.18mg/kg. Thus, total mean concentration of the detected heavy metals (lead and copper) in the samples analyzed from both markets realized highest concentration in ginger and the lowest in Negro pepper with values of 100.18mg/kg and 16.47mg/kg, respectively.

**Table 3.** WHO maximum permissible limits of heavy metals in food additives.

Heavy metal	Maximum Permissible Limit (MPL mg/kg)
Lead (Pb)	10
Copper (Cu)	50
Cadmium (Cd)	0.3

Source: Oladoye & Jegede (2016); Olusakin & Olaoluwa, (2016).

### Lead concentration in spices

Lead is the most recognized toxic environmental pollutant (Dghaim et al., 2015; Oladoye & Jegede, 2016). There is documentation that, lead exposures have been reported to be associated with severe anaemia, neurological disorders, diminished intelligence, and reproductive problems, to mention a few. Thus, the ATSDR of the US Public Health Services (US-PHS), has claimed that fruits, vegetables and grains constitute the major food sources of lead exposures to the general public (Nkansah & Opoku Amoako, 2010). However, results from this study have shown relatively significant concentrations of lead in the spices that were sampled and analyzed from the two markets. The results indicated that lead concentrations varied widely among the spices (Table 4). Mean concentrations ranged from 4.50mg/kg - 208.04mg/kg with Abura bay leaf (A-BL) and Abura chili pepper (A-CP) recording the lowest and highest mean concentrations respectively. However, it was realized that, total mean concentrations of Pb was recorded at a range between 20.07mg/kg in negro pepper and 119.54mg/kg in chili pepper. Again, amongst the samples that were analyzed, Abura garlic (A-G), Abura bay leaf (A-BL), Abura African nutmeg (A-AN) and Kotokoraba clove (K-C) with mean concentrations of 8.39mg/kg, 4.50mg/kg, 9.21mg/kg and 9.16 mg/kg representing 20% of the total number of spices analyzed fell below the WHO permissible limits of 10mg/kg. The remaining 80% recorded mean con-

centrations that exceeded the permissible limit which expresses some level of concern to consumers' health. From the 80% of spice samples which recorded mean concentrations above the MPL, Abura (chili pepper, aniseed, clove, rosemary) and Kotokoraba (ginger, garlic, bay leaf, African nutmeg) with concentrations of 208.04mg/kg, 156.56mg/kg, 131.25mg/kg, 148.76mg/kg, and 156.74mg/kg, 133.45mg/kg, 146.24mg/kg and 129.08mg/kg were about ten-fold above the permissible limits. Results from the study further indicated that total mean concentration of lead in the samples from the two markets were 79.15mg/kg and 75.51mg/kg for Abura and Kotokoraba respectively. This means that, samples from Abura market contained higher total Pb concentration compared to samples from Kotokoraba market, which may be attributed to several factors such as differences in the source or origin of the spice. Several incidents of high lead concentration in spices have also been reported in literature from other studies. Nkansah & Opoku Amoako (2010) reported of 0.1153g/kg-0.973g/kg of lead concentration, which was also above the permissible limits from Kumasi Metropolis in Ghana, with lead content reaching its highest peak in ginger and cinnamon, though the mean concentrations were lower than values reported in this present study. Nordin & Selamat (2013) also reported that, Malaysian spices investigated contained high levels of lead exceeding the permissible limits with a range of 1.54µg/g to 8.94µg/g with highest

**Table 4.** Heavy metal concentrations in spices from Abura and Kotokoraba markets.

	Sample	Sample Code	Pb (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Total
Abura (A)	Ginger	A-GI	72.60±11.80	31.50±5.11	<DL	52.05±8.45
	Garlic	A-G	8.39±4.48	22.59±1.67	**	15.49±3.07
	Rosemary	A-RM	148.76±55.10	33.28±12.69	**	91.01±33.89
	Aniseed	A-AS	156.56±45.01	30.32±24.24	**	93.44±34.62
	Grains of paradise	A-GP	34.63±23.06	27.09±4.44	**	30.85±13.74
	Negro pepper	A-NP	17.52±12.14	13.03±1.51	**	15.27±6.82
	Bay leaf	A-BL	4.50±0.33	21.91±8.94	**	13.20±4.63
	Clove	A-C	131.25±2.59	19.79±7.85	**	75.51±5.22
	African nutmeg	A-AN	9.21±5.78	33.51±8.16	**	21.36±6.97
	Chilli pepper	A-CP	208.04±15.49	17.91±4.21	**	112.97±9.85
<b>Total</b>			<b>79.15±75.82</b>	<b>25.09±10.84</b>	**	<b>52.11±43.33</b>
Kotokoraba (K)	Ginger	K-GI	156.74±14.61	139.92±87.12	**	148.32±50.86
	Garlic	K-G	133.45±37.41	29.48±1.90	**	81.46±19.65
	Rosemary	K-RM	11.16±4.48	12.44±1.18	**	11.79±2.82
	Aniseed	K-AS	24.19±11.35	32.96±13.36	**	28.57±12.35
	Grains of paradise	K-GP	9.130±8.7	39.33±7.84	**	65.31±8.26
	Negro pepper	K-NP	22.63±13.21	12.72±1.43	**	17.67±7.31
	Bay leaf	K-BL	146.24±9.68	33.03±2.92	**	89.63±6.29
	Clove	K-C	9.16±1.68	16.93±9.72	**	13.04±5.69
	African nutmeg	K-AN	129.08±19.97	42.19±8.37	**	85.63±14.16
	Chilli pepper	K-CP	31.05±14.69	13.80±7.61	**	22.42±11.14
<b>Total</b>			<b>75.51±60.89</b>	<b>37.27±43.42</b>	**	<b>56.38±52.15</b>
(A and K)	Ginger	GI	114.66±47.59	85.70±81.07	**	100.18±64.33
	Garlic	G	70.92±72.52	26.03±4.09	**	48.47±38.31
	Rosemary	RM	79.96±83.07	22.86±13.79	**	51.41±48.43
	Aniseed	AS	90.37±78.21	31.64±17.56	**	61.01±47.86
	Grains of paradise	GP	62.96±34.74	33.21±8.79	**	48.08±21.76
	Negro pepper	NP	20.07±11.69	12.87±1.32	**	16.47±6.51
	Bay leaf	BL	75.37±77.88	27.47±8.51	**	51.42±43.2
	Clove	C	70.20±66.89	18.34±8.05	**	44.27±37.47
	African nutmeg	AN	69.14±66.96	37.85±8.78	**	53.50±37.87
	Chilli pepper	CP	119.54±97.87	15.86±5.94	**	67.7±51.905
<b>Total</b>			<b>77.33±68.21</b>	<b>31.18±31.97</b>	**	<b>54.24±47.74</b>

Source: field data (2024); \*\*= <DL (Below detection limit).

concentration being found in Vietnamese coriander and the lowest in garlic. Contrary to the results in this present study, lower concentration below the international standards with a range of 0.007µg/g-0.087µg/g for lead with maximum concentration being found in chili powder were reported by Senanayake *et al.* (2013) in Sri Lankan spices. Though differences exist between the report of Senanayake *et al.* (2013) and this study in terms of lead concentrations, it is important to note that chili pepper recording highest values for lead in both studies is worthy of mentioning. Oladoye & Jegede (2016) also reported the non-detection of lead in spices that were sampled and analyzed from Odo-Ori in Nigeria probably because levels of lead in the spice samples were below the detection limit. Gaya & Ikechukwu (2016) also reported of low levels of lead within permitted limits in Nigerian spices with a range of 2.7mg/kg to 4.71mg/kg, with the highest concentration being recorded in African nutmeg. Bua *et al.* (2016) also assessed the level of lead in spices found in Italian markets and found a range of 0.16mg/kg to 2.92mg/kg with maximum concentration being found in Vietnamese cinnamon with values falling below the international standards. Darko *et al.* (2014) reported that, spices may obtain lead during growth in soils that are contaminated with lead and from the use of lead-base pesticides which are used during the cultivation of the spices. Darko *et al.* (2014) attributed the location of the markets from where the spices used for their study were collected and concluded that, the location of the markets in high traffic density sites could be the reason for the increased levels of lead concentrations in the analyzed spice samples as literature asserts and studies have confirmed that high traffic density may increase the lead load in the environment hence increasing the lead content of the spices. This reason, can also be applied to this study as both markets from which the spices were collected are located in the midst of very busy roads with high traffic density apart from the probable contamination of the spices from the soils from which these spices grew.

### Copper concentrations in spices

Although copper is an essential trace element that is required for the synthesis of many enzymes, excess levels can be toxic to the human body (Zoroddu *et al.*, 2019). Verma *et al.*, (2018) added that, copper is an important trace element as it functions in the oxidative defensive system. However, the presence of copper in the human body beyond certain limits can pose varying number of health problems such as anaemia, nervous system disorder, behavioural disorder, liver damage, and increase in an individual's risk of cancer (Fadhil *et al.*, 2021). Chronic toxicity levels can also cause oily skin, loss of skin tone and loss of hair especially in women (Oladoye & Jegede, 2016). As revealed by the analytical results in this present study, mean concentrations in the analyzed samples from the two markets varied widely. Findings revealed that a range between 139.92mg/kg to 12.44mg/kg being the highest and lowest concentrations were found in Kotokoraba ginger (K-GI) and rosemary (K-RM) from the same market. However, total mean concentration of copper from both markets was recorded in a range between 87.70mg/kg in ginger and 12.85mg/

kg in negro pepper. In comparison with international standards, only Kotokoraba ginger (K-GI) with a mean concentration of 139.92mg/kg representing 5% of total number of samples analyzed exceeded the WHO permissible limits of 50mg/kg for copper. However, samples such as Kotokoraba African nutmeg (K-AN), Kotokoraba grains of paradise (K-GP), Abura African nutmeg (A-AN), Abura Rosemary (A-RM), Kotokoraba bay leaf (K-BL), Kotokoraba Aniseed (K-AS), Abura Ginger (A-GI), Abura Aniseed (A-AS), Kotokoraba Garlic (K-G), and Abura grains of paradise (A-GP) with mean concentrations of 42.19mg/kg, 39.33mg/kg, 33.51mg/kg, 33.28mg/kg, 33.03mg/kg, 32.96mg/kg, 31.50mg/kg, 30.32mg, 29.48mg/kg and 27.09mg/kg respectively representing 50% of the total samples size analyzed that exceeded half of the WHO permissible limit of 50mg/kg. Generally, 95% of the total number of samples analyzed recorded mean copper concentrations within the WHO permissible limits with the remaining 5% exceeding the permissible limit. Results further revealed that, spice samples such as A-C (19.79) and K-C (16.93), A-CP (17.91) and K-CP (13.80), K-NP (12.72) and A-NP (13.03) recorded mean concentration values similar and close to each other. This suggests that even though they are the same kind of spice, samples differ in locality in terms of market hence the copper levels may be influenced by the same factors. In comparison to what has been reported in literature, Fadhil *et al.* (2021) found copper concentration range of 0.58ppm to 3.81ppm with the highest concentration in turmeric and the lowest in mixed type of spices. Fadhil *et al.* (2021) further reported that copper concentrations were below the permitted levels used in their study. Soliman (2015) also reported of the highest copper level of 21.4mg/kg in hot red pepper and the lowest in paprika with 3.72mg/kg, with all samples recording values below half of the value of the MPLs. The highest concentration of copper in the ginger sample was found in K-GI in this study.

### Cadmium concentrations in spices

Bua *et al.* (2016) reported that cadmium, according to WHO is among the top 10 chemical contaminants that have gained major public health concern as they persistently accumulate in the environment and adversely affect environmental and human health, when properly unmanaged. Cadmium, a non-essential food element accumulates principally in the liver and kidneys (Nordin & Selamat, 2013). Thus human chronic exposures to this metal in even the minutest quantities causes osteoporosis, high blood pressure, lung diseases and kidney problems, and is a known potential human carcinogen (Fadhil *et al.*, 2021). According to Oladoye & Jegede (2016), excess concentrations of this non-essential element in the human body targets major organs such as the liver, kidneys, brain, placenta and bones. In this present study, cadmium was not detected in any of the local spices from the two markets. It could be that they were present in some of the spices but below the detection limit of 0.004ppm. The study of Darko *et al.* (2014) reported of a similar trend in spices from Kumasi, Ghana, in a way that is in line with the results of this present study. They did not detect cadmium in any of the samples they analyzed except in nutmeg that record-

**Table 5.** Analysis of variance for lead and copper levels in each of the ten spices from both markets.

Metal	Degrees of freedom	Sum of squares	Mean square	F-square	Sig-value
Pb	9	42001.158	4666.795	1.004	0.450
	50	232465.955	4649.319		
Cu	9	23197.416	2577.491	3.472	0.002
	50	37113.187	742.264		

Source: Field data, 2023.

ed a range between <0.01 (detection limit of cadmium used in that study) to 0.90mg/kg. In Malaysia, Nordin & Selamat (2013) reported of cadmium concentration range between 0.23µg/g to 8.07µg/g above the permissible limit used in their study. Gaya & Ikechukwu (2016) also reported higher levels of cadmium above the WHO/FAO permissible limits in spice samples obtained from Nigeria. Again in Nigeria, Oladoye & Jegede (2016) also reported of cadmium concentration range between 0.30mg/kg to 0.45mg/kg that exceeded that MPL of 0.3mg/kg used in the study, with maximum concentrations being found in garlic, ginger and locust bean. Bua *et al.* (2016) also reported a range of cadmium concentration between 0.029mg/kg to 0.24mg/kg which were below the permissible limits used in the study with lowest concentrations being found in Indonesian ginger and the highest in Sri Lankan curcuma. From the findings of this present study, it could be deduced that, the non-detection of cadmium in the sampled spices could be attributed to several factors such as distant location of farmlands from the sources of cadmium pollution and the use of quality, unpolluted irrigation water in the cultivation of the spices.

#### Comparison of means of Pb and Cu in ten spices from Abura and Kotokoraba markets

There is no statistical difference between the means of Pb and Cu in all the ten spices from Abura and Kotokoraba markets. The calculated F-value for the mean Pb levels from both markets was 1.004, whereas the p-value was 0.450 (Table 5). Since the p-value was greater than 0.05, the researcher failed to reject the null hypothesis. There is no statistical difference between the means of Pb levels from both markets. On the other hand, the F-value and the p-value for the mean Cu levels for both markets were 3.472 and 0.002, respectively. Since the p-value was less than 0.05, the researcher rejected the null hypothesis. This implies that, there is a statistical difference between the mean Cu levels from both markets. A multiple comparison (Tukey's test) was conducted to determine which of the spices had significant difference with each other in terms of their mean Cu levels. At a level of significance = 0.05, the mean Cu levels in the ten spices that were significantly different from each other are summarized in the Tukey's Post Hoc test. From the Post Hoc test, all the means of the ten spices did not show significant differences between the two markets excepts in ginger and garlic, ginger and rosemary, ginger and aniseed, ginger and grains of paradise, ginger and negro pepper, ginger and bay leaf, ginger and cloves, and then ginger and chili pepper. The absence of a statistically significant difference in mean lead (Pb) levels between Abura and Kotokoraba ( $F = 1.004$ ,  $p = .450$ ) contrasts sharply with the clear difference in copper (Cu) concentrations ( $F = 3.472$ ,  $p = .002$ ), where ginger was the primary driver of significant post hoc differences against most other spices. While these outcomes offer

useful preliminary insights, interpretation demands greater analytical breadth to assess public health relevance and guide action. Statistical significance alone does not equate to health risk or regulatory non-compliance; effect sizes and confidence intervals are essential to gauge the practical import of observed differences (Hemming & Taljaard, 2021). A recent global systematic review reveals that many statistically significant heavy metal differences in spices yield negligible risk once dietary intake is modeled (Brzóska *et al.*, 2017). Ginger's elevated level may reflect either agro environmental uptake or post-harvest contamination. Root spices like ginger tend to accumulate metals from contaminated soils or irrigation (Ugulu *et al.*, 2021), while studies of turmeric and other spices document adulteration with metallic colorants (e.g., lead chromate) contributing to elevated heavy metal signals (Erasmus *et al.*, 2021). Thus, the distinct profile of ginger should be used to trigger targeted source-tracing research in soil, water, and processing chain and not limiting recommendations to only the market level.

#### Conclusion and recommendations

This study provided valuable insight into the levels of Pb and Cu in selected spices sold at two major markets in Ghana. The results demonstrate that Pb contamination does not significantly differ between the Abura and Kotokoraba markets, suggesting comparable environmental or supply chain conditions for this metal. However, the significant difference in Cu levels, particularly in ginger, points to the influence of commodity type and possibly source-specific factors. These findings highlight the need for continuous surveillance, targeted interventions for high-risk spices, and collaborative efforts among regulatory bodies, vendors, and consumers to ensure food safety. Addressing heavy metal contamination in spices not only protects public health but also sustains market trust and the economic viability of spice trade in Ghana. Further investigations should be undertaken to trace the origin of spices with elevated Cu levels to identify and address contamination at the production stage. The findings of this study indicate that while Pb concentrations in spices from the Abura and Kotokoraba markets do not differ significantly, Cu levels vary, with ginger showing notable differences compared to several other spices. These results call for targeted measures to safeguard public health and ensure the integrity of spice supplies. It is recommended that: Local authorities, in collaboration with food safety agencies, should conduct regular testing of spices for heavy metals, with particular focus on root spices such as ginger. Training and sensitization programs should be organized to equip spice sellers with knowledge on identifying trusted suppliers, understanding certification processes, and reducing the risk of purchasing contaminat-

ed stock. Enforcement of existing food safety standards, alongside the adoption of clear permissible limits for heavy metals in spices, should be strengthened to ensure compliance across the supply chain. Public awareness campaigns should be implemented to inform consumers about the potential risks of heavy metal contamination in spices and promote safe consumption practices.

## DECLARATIONS

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