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Evaluation of nutritional and chemical profiles in tuber crops from mining and non-mining areas in Ahafo, Ghana

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Abstract

*The environmental repercussions of mining in sub-Saharan Africa, predominantly in Ghana, have raised precarious concerns about food safety and public health. This study evaluated the effect of mining on the nutritional and chemical composition of two staple tuber crops namely cassava (*Manihot esculenta*) and cocoyam (*Xanthosoma sagittifolium*), collected from mining-induced and non-mining communities in the Asutifi North District. A total of 120 tuber samples were sampled from twelve farms across four communities, including three mining-impacted sites (Kenyasi No. 1, Kenyasi No. 2, and Ntotroso) and one non-mining site (Wamahinso). Samples were analysed for concentrations of heavy metals (Pb, Cd, As, Hg) and essential nutrients (P, K, Ca, Mg, Na.) Results revealed significantly elevated levels ($p < 0.05$) of toxic metals in tubers from mining areas, with cocoyam and cassava from Kenyasi and Ntotroso exhibiting high levels of arsenic, cadmium, and lead. Contrariwise, nutrient levels, particularly phosphorus and potassium, were markedly higher in crops from Wamahinso, which served as the non-mining site. The results unveiled serious consequences for food safety, public health, and agricultural sustainability in the mining communities. The study therefore suggest policy actions such as routine monitoring of food crops,* *environmental education, spatial zoning, and the integration of agricultural impact assessments into mining regulations. Protecting staple food crops from environmental contamination is essential for ensuring food security and supporting the livelihoods of rural populations in Ghana and other resource-dependent regions.*

Keywords *Heavy metals; Cassava; Cocoyam; Food safety; environmental contamination*

Statement and Declarations

Competing Interest The authors declare that there is no conflict of interest regarding the publication of this manuscript.

Author contribution

Frederick Ansah Bonnah conceptualized and designed the study, developed the methodology, collected the data, conducted the analysis, and prepared the initial draft of the manuscript. Samuel Novor provided critical comments and suggestions during the drafting process. Prof. Mark Appiah supervised the work, reviewed the manuscript, and provided relevant feedback. Prof. Emmanuel Opuni Frimpong, and Prof Akoto Sarfo assisted Prof. Mark Appiah in the supervision by reviewing and providing relevant feedback. Richard Acheampong also commented critically after the first draft of the manuscript. All authors read and approved the final manuscript.

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Introduction

Food cropproduction and its quality are fundamentally interconnected to soil health and environmental conditions(Victoria & Nnebini, 2025). The production of crops in mineral-rich regions including Ahafo in Ghana is increasingly challenged by the spatial expansion of mining activities, particularly which often occurs in close propinquity to farmland. The outcome of these mining activities are the release of toxic metals including lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As)into the environment, contaminating soil and posing serious risks to food crops (Donkor et al., 2005; Darko et al., 2017). According to Tetteh et al (2019) these toxic metals can persist in soils, accumulate in edible plant tissues, and ultimately enter the food chain, posing considerable risks to human health and food security (Li et al., 2021; Tetteh et al., 2019).

In 2009 for example, there were allegations of cyanide spillage in Kenyasi and its satellite communities which affected the soil and water (Environmental Protection Agency [EPA] Ghana, 2010). After a thorough investigation by the regulatory agencies including EPA and Minerals Commission, together with the company's representatives, it became clear that there were traces of cyanide spillage in these communities and

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even led to death of fishes in some streams. This incident was confirmed by the inhabitants of Gyakakrom, a suburb of Kenyasi No 2. As a result, the government of Ghana made Newmont Ghana Gold Limited pay a penalty of $4.9 million in 2010 to help support these impacted satellite communities.

Root and tuber crops including cassava (*Manihot esculenta*) and cocoyam (*Xanthosoma sagittifolium*)are dietary staples for majority of the population in Ghana, valued for their energy content, affordability, and adaptability to diverse farming conditions (FAO, 2021). Nonetheless, their cultivation in mining-impacted communities raises serious trepidations due to their susceptibility to accumulate toxins (Agyei-Mensah et al., 2021). Previous studies have reported toxicmetal accumulation in crops grown near mining areas(Darko et al., 2017; Essumang et al., 2013), but majority of such research focused on vegetables and cereals, with limited attention to root and tuber crops(Mensah et al., 2023), which may unveildissimilar uptake dynamics. Additionally, while heavy metal contamination has received considerable attention, fewer studies have explored how mining affects the concentrations of essential nutrients such as potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), and sodium (Na), in edible crops. The absorption of these obnoxious metals by the crops and the disruption of the basic nutrientsin them presents a critical public health issue as these may not only affect crop quality and productivity but also have implications for human nutrition, particularly in communities that rely heavily on these crops for daily sustenance (Li et al., 2021)..

There is, therefore, a notable gap regarding the concurrent appraisal of both noxious elements and essential nutrients in root and tuber crops grown in mining-induced communities. Considering the impact of mining on food safety and the nutritional value is critical for developing targeted agronomic interventions, improving soil health, and safeguarding public health.

The study aims to address these gaps by analysing the concentrations of these chemicals and the nutrient in both cassava and cocoyam harvested from both mining-affected and anon-mining areas in Ahafo. The results will contribute to the broader discourse on sustainable agriculture in mining communities and inform environmental monitoring, food safety regulations, and land use policy in Ghana and sub-Saharan Africa.

Theoretical framework

This study utilises Agro-ecological Systems Theory, Ecological Risk Assessment (ERA), and the Food Systems Framework.Agro-ecological Systems Theory, as postulated by Stephen R. Gliessman (2014), provides a lens to understand how land-use changes such as mining disrupt ecological balances that support soil health and crop nutrient quality.ERA directed by theU.S. Environmental Protection Agency (EPA, 1998), facilitates the evaluation of potential risks posed by heavy metals in crops to human health, based on exposure pathways and benchmark thresholds. TheFood Systems Framework**,** proposed by Polly J. Ericksen(2008), contextualizes the findings within the broader dynamics of food availability, quality, and security, particularly within the

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vulnerable farming communities. Together, these frameworks support a holistic investigation of how mining in Ahafo, Ghana, alters both the chemical and nutritional integrity of tuber crops and the implications for local food systems and health.

Materials and methods

The study Area

This study was conducted in the Asutifi North District of the Ahafo Region of Ghana, located within the forest zone of the country (Figure 1). Specifically, samples were taken from farms that are located immediately after the buffer zones, closer to the waste dams, tailings ponds and mining pits and these communities are Kenyasi No 1, Kenyasi, No 2 and Ntotroso. Again, samples were taken from farms in Wamahinso which has no mining affiliation. The district is the hub for cocoyam produced in the country, particularly in communities around Ntotroso, Kenyasi No 1, and Kenyasi 2. With high annual mean precipitation ranging from 1500 to 2000 mm, this district has well drained soils and rich biodiversity characteristics that create a conducive environment for crop production.

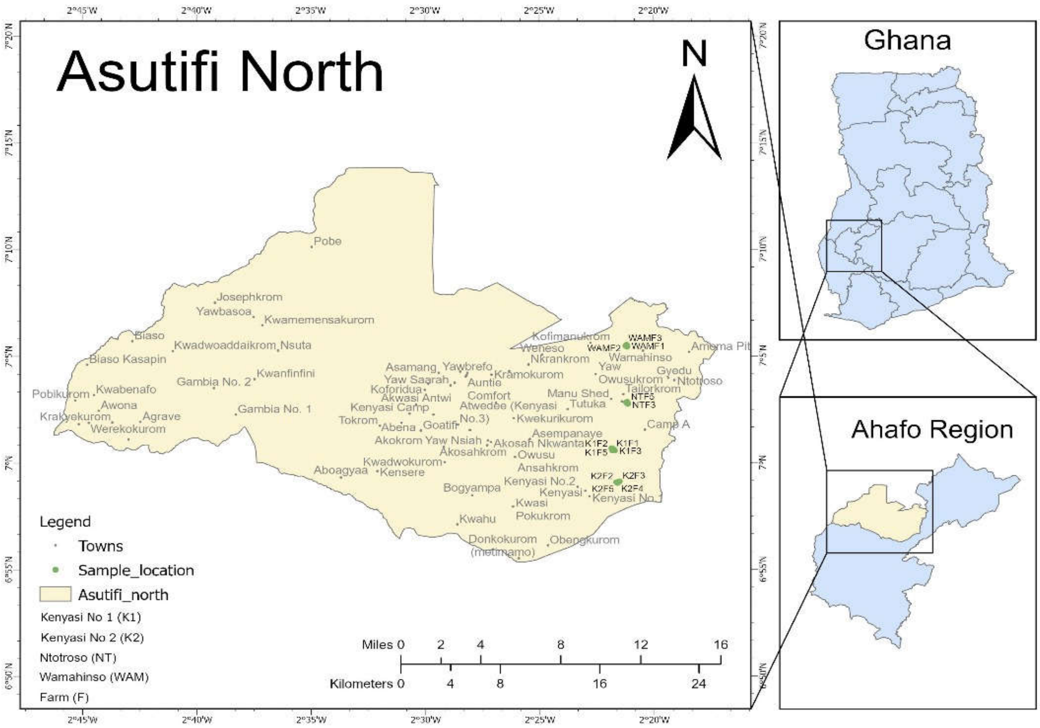

Figure 1: Map of the study communities in the Asutifi North District, Ahafo Region, Ghana, and showing sampling locations in K1, K2, NT and WAM. Symbols represent the

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average positions of sampled farms based on recorded GPS coordinates. The map also includes a north arrow and scale bar for orientation.

Sample collection and preparation

Tuber samples of cassava (*Manihot esculenta*) and cocoyam (*Xanthosoma sagittifolium*) were collected to assess potential contamination from mining-related environmental exposures in the Asutifi North District of Ghana. Sampling was conducted in four communities: Kenyasi No. 1, Kenyasi No. 2, and Ntotroso, which are situated within the vicinity of active gold mining operations and Wamahinso, which served as a non-mining (control) site.

A total of twelve (12) farms were selected across the four communities, with three farms sampled per community using purposive sampling based on proximity to mining activity and availability of mature crops. At each farm, five (5) healthy and mature plants of cassava and five (5) of cocoyam were randomly selected for tuber sampling, ensuring representative coverage of each field. This resulted in the collection of: 60 cassava tubers (5 plants × 12 farms), and 60 cocoyam tubers (5 plants × 12 farms), culminating in a total of 120 individual tuber samples for laboratory analysis.

Tuber samples were carefully excavated using clean, non-contaminating tools (e.g., plastic or stainless steel diggers) to avoid external metal contamination. Soil was gently brushed off without washing to preserve surface and internal integrity for heavy metal and nutrient analysis. Samples from each crop and farm were composited into one composite sample per crop per farm, placed in clean, labeled polyethylene bags, and stored in ventilated containers.

Samples were then transported to the Soil Science Laboratory at the Kwame Nkrumah University of Science and Technology (KNUST) under ambient conditions for further preparation and analysis. This sampling and handling procedure aligns with internationally recognized protocols for trace metal studies in edible plant tissues in environmental assessments (FAO/IAEA, 2018; USEPA, 1996). Plant samples were washed thoroughly with distilled water to remove surface contaminants, oven-dried at 70 °C for 72 hours, and milled into fine powder using a mechanical grinder. The dried samples were then stored in clean, airtight containers prior to chemical analysis, in accordance with AOAC standard sample preparation procedures (AOAC, 2005).

Sample digestion

One gram (1.00 g) of each cassava and cocoyam sample was weighed into a Kjeldahl digestion tube. A mixture of nitric acid (HNO_3) and hydrochloric acid (HCl) in a 1:3 ratio was added, and digestion was carried out at 450 °C for 30–60 minutes until the solution turned whitish, indicating complete digestion. The digests were cooled and made up to a nominal volume of 100 mL with deionized water in a volumetric flask. The clear supernatant was decanted and used for subsequent analysis of heavy metals and nutrients.

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Determination of heavy metals (Hg, Pb, Cd, As)

Heavy metal concentrations were determined using Atomic Absorption Spectrophotometry (AAS) following standard protocols. The instrument was calibrated with certified standards using appropriate hollow cathode lamps and wavelengths (Hg: 253.7 nm; Pb: 217.0 nm; Cd: 228.9 nm; As: 193.7 nm). Air and acetylene pressures were maintained at 50–60 psi and 10–15 psi, respectively. Concentrations in samples were computed using calibration curves.

The heavy metal content ($mg \cdot kg^{-1}$) was calculated as:

$C\_HM = (C \times V\_digest) / w$ (1)

where C is the concentration obtained from AAS ($\mu g \cdot mL^{-1}$), V_digest is the digest volume (100 mL), and w is the sample weight (1.00 g). Thus,

$C\_HM = C \times 100$ (2)

Determination of phosphorus (P)

Phosphorus was determined colorimetrically using the vanadomolybdate method (Motsa et al., 2008; Moss, 1961). Ten milliliters of digest were reacted with 10 mL of vanadomolybdate reagent, diluted to 100 mL, and allowed to stand for 30 minutes for color development. Absorbance was measured at 420 nm with a Spectronic 20 spectrophotometer.

The digest concentration was obtained from the reaction concentration using the dilution factor:

$C\_digest = C\_rxn \times (100/10) = C\_rxn \times 10$ (3)

The percentage phosphorus was calculated as:

$\%P = C\_rxn / 10$ (4)

Determination of potassium (K) and sodium (Na)

Potassium and sodium were measured using a flame photometer, calibrated with standard curves prepared from analytical-grade KCl and NaCl solutions. The concentrations obtained from the standard curve were converted to percentages as:

$\%X = (C \times V\_digest) / (10 \times w)$ (5)

where X = K or Na, and C is the concentration ($\mu g \cdot mL^{-1}$). For V_digest = 100 mL and w = 1.00 g:

$\%X = C \times 10$ (6)

Determination of calcium (Ca) and magnesium (Mg)

Calcium and magnesium were determined by complexometric titration with 0.02 N EDTA. Reagents included NH_4Cl–NH_4OH buffer, triethanolamine (TEA), potassium

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cyanide (KCN), and the indicators Eriochrome Black T (EBT) and Calcon Red.

For Ca, 5 mL of digest was treated with KOH, TEA, KCN, and Calcon Red indicator, and titrated against EDTA to a blue endpoint. For Mg, the same procedure was applied using buffer, TEA, KCN, and EBT indicator.

The analyte content in the aliquot (mg) was given by:

$$mg\_Ca = T \times 0.4008, \quad mg\_Mg = T \times 0.243 \quad (7)$$

where T is the EDTA titre (mL). Adjusting for the digest volume ($V\_digest = 100$ mL) and aliquot size ($V\_aliquot = 5$ mL), the percentages were computed as:

$$\%Ca = (T \times 0.4008 \times (V\_digest/V\_aliquot)) / (10 \times w) \quad (8a)$$

$$\%Mg = (T \times 0.243 \times (V\_digest/V\_aliquot)) / (10 \times w) \quad (8b)$$

For a 1.00 g sample and 5 mL aliquot from a 100 mL digest, this simplifies to:

$$\%Ca = 0.8016 \times T \quad (9a)$$

$$\%Mg = 0.486 \times T \quad (9b)$$

Results

Chemical content in cocoyam and cassava produce

Effect of mining on Arsenic, cadmium, phosphorus, mercury, and potassium content in cocoyam and cassava produce from different locations

The data indicate statistically significant differences ($p < 0.05$) in arsenic (As) concentrations across the various crop types and sampling locations. Cocoyam cultivated in Wamahinso, a non-mining area, recorded the lowest mean arsenic content at 0.49 mg/kg. Cassava from the same location also exhibited relatively low arsenic concentration, with a mean value of 0.83 mg/kg. These results suggest that crops grown in Wamahinso are comparatively less affected by arsenic contamination. In contrast, elevated arsenic concentrations were observed in crops sourced from mining-impacted areas. Cocoyam from Kanyasi No. 1 recorded the highest arsenic level, with a mean concentration of 3.21 mg/kg, followed by cassava from Ntotroso, which had a mean arsenic content of 3.02 mg/kg. Cocoyam and cassava sampled from Kanyasi No. 2 recorded mean values of 2.55 mg/kg and 1.91 mg/kg, respectively, while cassava from Kanyasi No. 1 and cocoyam from Ntotroso had intermediate values of 1.70 mg/kg and 1.72 mg/kg, respectively (Table I).

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The data reveal significant differences ($p < 0.05$) in cadmium concentrations among the various crop and location combinations. Cocoyam cultivated in Wamahinso recorded a mean cadmium concentration of 0.66 mg/kg. Among all samples analyzed, cassava from Wamahinso exhibited the lowest cadmium content at 0.08 mg/kg. In contrast, cocoyam cultivated in Kanyasi No. 1 and Ntotroso recorded the highest cadmium concentrations, with values of 0.74 mg/kg and 0.73 mg/kg, respectively. These values were significantly higher than those observed in the control and all other treatments. Intermediate cadmium levels were observed in the remaining samples. Cassava cultivated in Ntotroso and Kanyasi No. 2 recorded cadmium concentrations of 0.34 mg/kg and 0.46 mg/kg, respectively. Cassava from Kanyasi No. 1 showed a slightly higher concentration at 0.48 mg/kg, while cocoyam from Kanyasi No. 2 had a mean cadmium level of 0.51 mg/kg (Table I).

The results reveal statistically significant differences ($p < 0.05$) in phosphorus content among the various root crop samples collected from different locations. Among all the samples analyzed, cocoyam obtained from Wamahinso recorded the highest phosphorus concentration, with a mean value of 0.38 mg/kg. Cocoyam from Kanyasi No. 2 recorded a phosphorus content of 0.36 mg/kg. Similarly, cocoyam from Kanyasi No. 1 recorded a relatively high phosphorus concentration of 0.30 mg/kg. In contrast, cassava samples demonstrated markedly lower phosphorus concentrations. Cassava from Kanyasi No. 2 had the lowest phosphorus content among all treatments, with a mean value of 0.19 mg/kg. Cassava from Wamahinso also exhibited low phosphorus accumulation of 0.22 mg/kg. Other cassava samples, including those from Kanyasi No. 1 and Ntotroso, had phosphorus concentrations of 0.28 mg/kg and 0.27 mg/kg, respectively. Cocoyam from Ntotroso recorded a phosphorus level of 0.27 mg/kg, which is comparable to the values obtained in cassava from the same location (Table I).

The results indicated statistically significant differences ($p < 0.05$) in mercury concentrations across the various root crop samples obtained from different locations. Cocoyam from Wamahinso, recorded a mean mercury content of 0.22 mg/kg and was used as the baseline for comparison. Among all treatments, cassava from Wamahinso exhibited the lowest mercury concentration at 0.04 mg/kg. In contrast, cassava obtained from Ntotroso recorded the highest mercury concentration at 0.37 mg/kg. Cocoyam samples from Kanyasi No. 1 and Kanyasi No. 2 recorded intermediate mercury concentrations of 0.29 mg/kg and 0.27 mg/kg, respectively. These values were significantly higher than the control. Notably, cassava from both Kanyasi No. 1 and Kanyasi No. 2 recorded lower mercury concentrations (0.25 mg/kg each) compared to their cocoyam counterparts from the same locations, though still higher than the control. Also, cassava and cocoyam sampled from Ntotroso demonstrated contrasting mercury levels, with cassava from this site exhibiting the highest mercury accumulation (0.37 mg/kg), while cocoyam recorded a lower value of 0.26 mg/kg (Table I).

The data demonstrate a statistically significant variation ($p < 0.05$) in potassium content among the different root crop samples evaluated. Notably, cocoyam sourced from Wamahinso exhibited the highest mean potassium concentration, recording a value of 0.92 mg/kg. In contrast, cassava samples obtained from Kanyasi No. 1 and

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Kanyasi No. 2 displayed the lowest potassium concentrations, with mean values of 0.75 mg/kg and 0.76 mg/kg, respectively. These were significantly lower than the Wamahinso cocoyam and most other treatments included in the study. Cocoyam samples from Kanyasi No. 1 and Kanyasi No. 2 recorded intermediate potassium levels of 0.87 mg/kg and 0.81 mg/kg, respectively. Although these values were significantly lower than that of the Wamahinso cocoyam, they were however, higher than the cassava samples from the same locations. A similar trend was observed among samples collected from Ntotroso. Cocoyam from this location had a potassium content of 0.81 mg/kg, which was again higher than the corresponding cassava sample, which recorded a value of 0.76 mg/kg. Cassava from Wamahinso demonstrated a relatively higher potassium concentration of 0.83 mg/kg compared to other cassava samples from different locations, although still lower than the cocoyam from the same site (Table I).

Table I: Arsenic, cadmium, phosphorus, mercury, and potassium content in cocoyam and cassava produce from different locations

Treatments	Arsenic (mg/kg)	Cadmium (mg/kg)	Phosphorus (mg/kg)	Mercury (mg/kg)	Potassium (cmol/kg)
K1COC	3.21 ± 2.34^{a}	0.74 ± 0.03^{a}	0.30 ± 0.00^{c}	0.29 ± 0.00^{b}	0.87 ± 0.01^{b}
K1CAS	1.70 ± 0.06^{ab}	0.48 ± 0.01^{cd}	0.28 ± 0.01^{d}	0.25 ± 0.00^{e}	0.75 ± 0.00^{e}
K2COC	2.55 ± 0.10^{ab}	0.51 ± 0.02^{c}	0.36 ± 0.00^{b}	0.27 ± 0.00^{c}	0.81 ± 0.01^{d}
K2CAS	1.91 ± 0.00^{ab}	0.46 ± 0.03^{d}	0.19 ± 0.00^{g}	0.25 ± 0.00^{e}	0.76 ± 0.01^{e}
NT/GCOC	1.72 ± 0.03^{ab}	0.73 ± 0.02^{a}	0.27 ± 0.00^{e}	0.26 ± 0.01^{d}	0.81 ± 0.00^{cd}
NT/GCAS	3.02 ± 0.07^{a}	0.34 ± 0.03^{e}	0.27 ± 0.00^{e}	0.37 ± 0.00^{a}	0.76 ± 0.01^{e}
WAMCOC	0.49 ± 0.05^{b}	0.66 ± 0.04^{b}	0.38 ± 0.00^{a}	0.22 ± 0.00^{f}	0.92 ± 0.01^{a}
WAMCAS	0.83 ± 0.06^{ab}	0.08 ± 0.00^{f}	0.22 ± 0.00^{f}	0.04 ± 0.00^{g}	0.83 ± 0.01^{c}
CV	4.3 %	5.1 %	1.7 %	1.4 %	1.2 %
LSD	2.39	0.04	0.01	0.01	0.02

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Means with the same alphabet within a column are not significantly distinct at a 5% probability level. K1COC = Cocoyam from Kanyasi No. 1, K1CAS = Cassava from Kanyasi No. 1, K2COC = Cocoyam from Kanyasi No. 2, K2CAS = Cassava from Kanyasi No. 2, NT/GCOC = Cocoyam from Ntotroso, NT/GCAS = Cassava from Ntotroso, WAMCOC = Cocoyam from Wamahinso, WAMCAS = Cassava from Wamahinso

Effect of mining on calcium, magnesium, sodium, and lead content in cocoyam and cassava produce from different locations

The results indicate statistically significant differences ($p < 0.05$) in calcium content among the various crop types and locations assessed. Cocoyam cultivated at Wamahinso, recorded a moderate calcium content of 0.42 mg/kg. This value was comparable to that observed in cocoyam cultivated at Kanyasi No. 1, which also registered 0.42 mg/kg. Among all treatments, cassava from Kanyasi No. 1 demonstrated the highest calcium content at 0.44 mg/kg. This value was significantly greater than both the control and all other treatments. Conversely, cassava cultivated at Ntotroso exhibited the lowest calcium concentration at 0.29 mg/kg, a level significantly lower than that of the control and all other treatments. Cassava from Wamahinso also recorded a relatively low calcium content of 0.33 mg/kg. Other treatments, including cocoyam from Kanyasi No. 2 and Ntotroso, as well as cassava from Kanyasi No. 2, exhibited calcium contents ranging between 0.36 and 0.37 mg/kg (Table II).
The results reveal statistically significant differences ($p < 0.05$) in magnesium content among the various treatments. Cocoyam from Wamahinso recorded a mean magnesium concentration of 0.13 mg/kg. Notably, cassava cultivated in Kanyasi No. 1, cocoyam from Kanyasi No. 2, and cocoyam from Ntotroso exhibited the highest magnesium concentrations, each averaging 0.14 mg/kg. These treatments were statistically similar to one another but significantly higher than the control. In contrast, cassava from Ntotroso and cassava from Wamahinso showed the lowest magnesium levels, with mean values of 0.11 mg/kg and 0.12 mg/kg, respectively. These values were significantly lower than those observed in the control and other treatment groups (Table II).
The data reveal statistically significant variations in sodium content among the different crop types and locations studied. Cocoyam cultivated in Wamahinso recorded a mean sodium concentration of 0.05 mg/kg. Cocoyam cultivated in Ntotroso exhibited the highest sodium concentration among all treatments in contrast, cassava grown in both Ntotroso and Wamahinso showed the lowest sodium concentrations, with each recording a mean of 0.04 mg/kg. Meanwhile, cocoyam from Kanyasi No. 1 and Kanyasi No. 2, as well as cassava from Kanyasi No. 1, exhibited sodium levels equivalent to that of the control (Table II).
The data indicate statistically significant differences ($p < 0.05$) in lead (Pb) concentrations among the various crop samples collected from different locations. The lowest lead concentration was observed in cocoyam cultivated in Wamahinso, a non-

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mining area, with a mean value of 0.03 mg/kg. Both cocoyam and cassava samples from Wamahinso consistently recorded the lowest lead levels among all treatments. In contrast, higher levels of lead were detected in samples obtained from communities associated with mining activities. Cassava from Kanyasi No. 1 and cocoyam from Kanyasi No. 2 showed intermediate lead concentrations, with mean values of 0.34 mg/kg and 0.37 mg/kg, respectively. Cocoyam from Kanyasi No. 1, cassava from Ntotroso, and cocoyam from Ntotroso exhibited moderately elevated lead concentrations, each around 0.46–0.47 mg/kg. Notably, cassava from Kanyasi No. 2 recorded the highest lead concentration, with a mean value of 0.67 mg/kg. This level significantly exceeded those observed in all other samples (Table II)

Table II: Calcium, magnesium, sodium, and lead content in cocoyam and cassava produce from different locations

Treatments	Calcium (cmol/kg)	Magnesium (cmol/kg)	Sodium (cmol/kg)	Lead (mg/kg)
K1COC	0.42 ± 0.01^{c}	0.13 ± 0.00^{bc}	0.05 ± 0.00^{cd}	0.46 ± 0.06^{b}
K1CAS	0.44 ± 0.00^{a}	0.14 ± 0.01^{a}	0.05 ± 0.00^{bc}	0.34 ± 0.05^{c}
K2COC	0.36 ± 0.00^{e}	0.14 ± 0.00^{a}	0.05 ± 0.00^{bcd}	0.37 ± 0.02^{c}
K2CAS	0.37 ± 0.00^{d}	0.14 ± 0.01^{ab}	0.05 ± 0.00^{d}	0.67 ± 0.05^{a}
NT/GCOC	0.36 ± 0.00^{e}	0.14 ± 0.00^{a}	0.05 ± 0.00^{a}	0.47 ± 0.04^{b}
NT/GCAS	0.29 ± 0.00^{g}	0.11 ± 0.00^{d}	0.04 ± 0.00^{e}	0.46 ± 0.06^{b}
WAMCOC	0.42 ± 0.00^{b}	0.13 ± 0.01^{c}	0.05 ± 0.00^{ab}	0.03 ± 0.00^{d}
WAMCAS	0.33 ± 0.00^{f}	0.12 ± 0.00^{d}	0.04 ± 0.00^{e}	0.03 ± 0.00^{d}
CV	1.0 %	2.7 %	3.7 %	12.3 %
LSD	0.01	0.01	0.00	0.08

Means with the same alphabet within a column are not significantly distinct at a 5% probability level. K1COC = Cocoyam form Kanyasi No. 1, K1CAS = Cassava form Kanyasi No. 1, K2COC = Cocoyam form Kanyasi No. 2, K2CAS = Cassava form Kanyasi No. 2, NT/GCOC = Cocoyam form Ntotroso, NT/GCAS = Cassava form Ntotroso, WAMCOC = Cocoyam form Wamahinso, WAMCAS = Cassava form Wamahinso

Discussion

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Effect of mining on the chemical composition of cocoyam and cassava tubers

Arsenic content

Among the samples, cocoyam from Kanyasi No. 1 showed the highest arsenic content, while the lowest concentration was found in cocoyam from Wamahinso, a location not impacted by mining. The elevated levels in mining areas like Kanyasi No. 1 and Ntotroso may stem from natural arsenopyrite in the bedrock and disturbances caused by artisanal mining activities (Mensah *et al.,* 2023). Mining disrupts soil, mobilizes heavy metals, and raises the likelihood of plant uptake (Alengebawy et al, 2021). Cocoyam, compared to cassava grown in similar areas, had generally higher arsenic levels likely due to its preference for moist environments. In such soils, anaerobic conditions promote the presence of arsenite (As^{3+}), a more toxic and absorbable form of arsenic (Punshonet al., 2017). Cassava, which can tolerate drier soils, may be exposed to less arsenite and absorb less (Zhao *et al.,* 2009; Xu *et al.,* 2015). These findings align with those of Punshon *et al.* (2017) and Ding *et al.* (2013), who also reported that both plant type and soil conditions influence arsenic accumulation in root crops.Continuous consumption of crops contaminated with arsenic poses significant health risks, including skin injuries, cardiovascular disease, neurotoxicity, and an elevated risk of cancers, especially of the lungs, skin, and bladder (WHO, 2020; IARC, 2018). Codex Alimentarius Commission (FAO/WHO, 2014) established amaximum permissible limit of 0.1 mg/kg for arsenic in root and tuber crops these to these health risks. The arsenic concentrations observed in cocoyam from Kanyasi No. 1 thus raise legitimate food safety concerns in mining-induced zones.

Cadmium content

Cocoyam from Kanyasi No. 1 had the highest cadmium concentration, while the lowest was recorded in cassava from Wamahinso. The elevated cadmium in Kanyasi No.1 can be linked to mining-related contamination and how efficiently different crops absorb heavy metals (Essumang et al., 2013; Mongi & Chove, 2020) Mining in the area may have increased soil cadmium levels due to the presence of metal ores and residues (Razaket al*.,* 2022). Cocoyam, known for its high capacity to exchange cations, tends to absorb more heavy metals, including cadmium (Mongi & Chove, 2020). Alfaifi (2018) also observed that plants grown in mining-affected areas accumulate more cadmium due to its increased bioavailability. Additionally, Alloway (2013) highlighted that both soil chemistry and the plant's physiology play significant roles in cadmium uptake, with cocoyam generally accumulating more than cassava in similar conditions.Cadmium accumulation in edible crops poses serious public health concerns. Prolonged exposure to dietary cadmium is associated with kidney damage, skeletal demineralization, and increased risks of hypertension and certain cancers (WHO, 2020; ATSDR, 2012). Children and pregnant women, are especially at risk due to cadmium's bioaccumulative nature. To alleviate these risks, the Codex Alimentarius Commission (FAO/WHO, 2014) established **a** maximum permissible level (ML)of0.1 mg/kg for cadmium in root and tuber crops. The levels observed in cocoyam from Kanyasi No. 1

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suggest a potential food safety hazard since it goes beyond the permissible level of (ML) 0.1 mg/kg.

Phosphorus content

Phosphorus levels were highest in cocoyam from Wamahinso, while the lowest were found in both cassava and cocoyam from Kanyasi No. 2, a mining community. Mining activities often degrade soil by removing the top layer and introducing heavy metals, which affects the availability of nutrients like phosphorus. Heavy metals such as iron, aluminum, and lead in mining soils can bind with phosphorus to form insoluble compounds, reducing its availability to crops (Kumar et al., 2020; Padmavathiamma et al., 2021).Consequently, crops in mining areas often show reduced phosphorus content. These findings are consistent with Kasowska et al. (2017), who found that soil contamination in mining zones reduces phosphorus levels in food crops. Essandoh et al, (2021) also observed that crops from Ghanaian gold mining areas tend to have lower concentrations of essential nutrients due to soil quality decline and heavy metal presence.

Mercury content

The analysis showed that cassava from Ntotroso, a mining site, had the highest mercury level, while cassava from Wamahinso, a non-mining location, recorded the lowest. This difference is largely due to mercury pollution from mining operations, where mercury used in gold extraction is often released into the environment (Hayford et al., 2015). Once in the soil, mercury binds with particles and can be taken up by plant roots, accumulating in edible tissues over time. Ansah *et al.* (2022) reported similar findings in crops and soils from mining areas in Ghana. Likewise, Hayfordet al*.* (2015) found cassava and other tubers grown near mining sites to contain high mercury levels, posing health risks to consumers. These studies consistently link elevated mercury in food crops to contamination from mining processes.It must be stated that chronic exposure to mercury is associated with neurotoxicity, renal impairment, and developmental disability in children and fetus (WHO, 2020; ATSDR, 2022). To respond to this, the Codex Alimentarius Commission(FAO/WHO, 2014) recommends amaximum limit of 0.1 mg/kg total mercury for root and tuber vegetables. Nonetheless, cassava from Ntotroso exceeds this benchmark and thus make it a critical issue in the mining-affected communities.

Potassium content

Cocoyam from Wamahinso had the highest potassium content, while the lowest level was found in cassava from Kanyasi No. 1. The reduced potassium in the mining area may be attributed to soil disturbance and leaching of nutrients caused by mining activities (Idris et al*.,* 2023). Potassium is a mobile nutrient and can be easily washed away when soil is disturbed or vegetation is cleared (Arienzo *et al.,* 2009). Dey et al, (2024)observed that mining reduces soil fertility and causes significant declines in

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essential nutrients like potassium. Similarly, Idris et al (2023) found that food crops from mining communities have consistently lower nutrient levels, due to erosion, pollution, and nutrient imbalance associated with mining activities.

Calcium content

Cassava from Kanyasi No. 1 had the highest calcium level, whereas cassava from Ntotroso had the lowest, even though both areas are affected by mining. This variation could be due to differences in the severity of soil degradation or the chemical composition of the soils. Soils in Kanyasi No. 1 may be less contaminated with heavy metals like cadmium or lead, which can interfere with calcium uptake, allowing for better calcium accumulation in cassava (Gransee & Führs, 2013; Hemmler et al., 2024). Qiu et al., (2024) noted that heavy metals can block the absorption of essential nutrients like calcium. Essandoh et al., (2021)also emphasized that calcium levels in crops can vary within mining zones depending on soil contamination levels, texture, and whether any soil improvement practices have been applied.

Magnesium content

Magnesium content was highest in cocoyam from Kanyasi No. 2 and cassava from Kanyasi No. 1 both mining zones. The lowest magnesium was recorded in cassava from Ntotroso. The high magnesium levels in Kanyasi may result from the area's geological makeup, which contains magnesium-rich minerals. Magnesium availability in soil is also influenced by pH, organic matter, and cation exchange capacity (Gransee & Führs, 2013). Ntotroso soils may be more degraded or more heavily contaminated, reducing magnesium uptake. Gransee & Führs (2013 support the idea that nutrient levels, including magnesium, differ across mining locations due to varying environmental conditions and soil characteristics.

Sodium content

Cocoyam from Ntotroso showed the highest sodium content, while cassava from Wamahinso had the lowest. Mining operations can increase sodium levels in soil by exposing deeper layers and spreading waste materials containing salts. When these salts dissolve in rainwater, they can increase the sodium content of the surrounding soil (Meuser, 2013). Crops like cocoyam grown in these areas may absorb more sodium. On the other hand, soils in non-mining areas such as Wamahinso are less exposed to such salts, resulting in lower sodium content in crops. Essandoh *et al.* (2021) observed similar trends, showing that mining contributes to changes in soil chemistry, including higher sodium levels, which affect plant nutrient content.

Lead content

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Cassava from Kanyasi No. 2 had the highest lead concentration, while the lowest levels, were found in cassava and cocoyam from Wamahinso. The high lead levels in Kanyasi No. 2 are likely due to contamination from mining residues and tailings, which contain lead (Karaca *et al.,* 2018). In mining zones, lead gets into the soil through leaching and dust from mining activities (Abouian et al., 2020). Once in the soil, lead can be taken up by plant roots and build up in edible parts like cassava tubers (Finster et al*.,* 2004). Hayfordet al*.* (2015) and Garrido *et al*. (2017) found similar results in crops grown near mines, confirming the link between lead contaminations and mining operations. These studies stress the dangers of consuming food crops grown in contaminated areas.Food contaminated with lead is associated with cognitive impairment, particularly in children, as well as kidney dysfunction, anemia, and cardiovascular effects in adults (WHO, 2020; ATSDR, 2020). Codex Alimentarius Commission (FAO/WHO, 2014) in recognizing these established amaximum permissible level of 0.1 mg/kg for lead in root and tuber staple foods. The concentration of lead found in cassava from Kanyasi No. 2 exceeds this threshold and makes it unsafe for consumption in the mining communities

Conclusion and policy implications

This study reveals that cassava and cocoyam tubers cultivated in mining-affected communities in the Asutifi North District of Ghana exhibit elevated concentrations of toxic metals, particularly lead (Pb), cadmium (Cd), and arsenic (As), compared to those from non-mining area. These findings point to significant environmental contamination and bioaccumulation in food crops grown near mining zones, with direct implications for food safety, ecological integrity, and public health.

The results emphasize the need for integrated approaches that link land-use practices with food system safety assessments in mining regions. The contamination patterns observed also underscore the urgency of regulating agricultural activities in proximity to active or abandoned mines. It will be prudent for the government to include agricultural impact assessments into mining licensing, monitoring and reclamation framework to ensure sustainable mining practices.There should be awareness community programmes to strengthen environmental health education for farmers and local population about the risk of consuming contaminated produce.Government should consider routine testing of edible crop testing in the mining affected communities to enable them inform and advice community members on what to do. Protecting staple crops like cassava and cocoyam from environmental contamination is crucial to safeguarding food security and promoting sustainable development in resource-dependent rural communities

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