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

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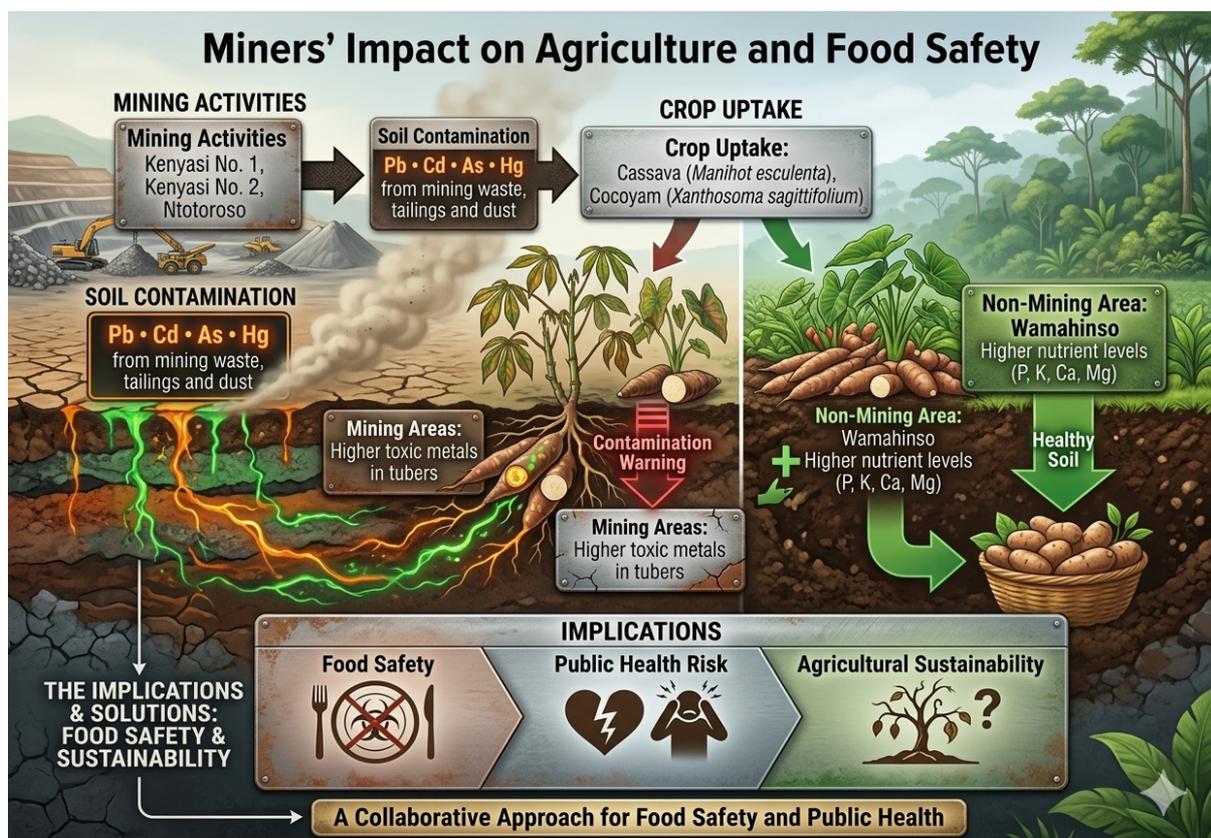[3]University of Energy and Natural Resources, Sunyani, Ghana
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Graphical Abstract

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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-affected 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 suggests 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; Ahafo.

1 Introduction

Food crop production and its quality are fundamentally interconnected to soil health and environmental conditions [49]. 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 proximity 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 [16, 13]. According to [47], 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 [36, 47]. In 2009 for example, there were allegations of cyanide spillage in Kenyasi and its satellite communities which affected the soil and water [18]. 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 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 affected 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 [22]. Nonetheless, their cultivation in mining-impacted communities raises serious trepidations due to their susceptibility to accumulate toxins [2]. Previous studies have reported toxic metal accumulation in crops grown near mining areas [13, 21], but majority of such research focused on vegetables and cereals, with limited attention to root and tuber crops [37], which may unveil dissimilar 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 toxic metals by the crops and the disruption of the basic nutrients in 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 [36].

There is, therefore, a notable gap regarding the concurrent appraisal of both harmful 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.

To address these gaps, the study sets out three broad objectives. First, it examines the concentrations of essential nutrients and potentially toxic elements (PTEs) in cassava and cocoyam grown in both mining-affected and non-mining areas of Ahafo. Second, it compares how mining activities may be altering the chemical composition and nutritional quality of these important staple crops. Finally, it considers the public health implications of these differences, especially where elevated metal levels could pose food safety concerns.

The novelty of this study stems from its dual-crop comparative design. By analysing

both cassava and cocoyam, two widely consumed staples in Ghana within the same soil–plant context; the study offers a more complete understanding of how mining-related soil conditions influence crop quality. This integrated approach goes beyond many earlier studies that tend to focus on a single crop or on soil properties alone. Moreover, the use of combined mining and non-mining sites within the same agro-ecological zone strengthens the reliability of the findings and provides new empirical evidence from the Ahafo mining enclave.

This study contributes to United Nations Sustainable Development Goals (SDG). It supports SDG 2 (Zero Hunger) by evaluating the nutritional quality of crops central to household food security; SDG 3 (Good Health and Well-being) by identifying potential dietary risks associated with PTE exposure; and SDG 12 (Responsible Consumption and Production) by providing evidence needed to guide safer food production in mining-influenced environments.

Finally, the results inform nature-based solutions for restoring soil health in affected farmlands. Practices such as improving organic matter, applying biochar, and adopting strategic crop choices can help reduce metal uptake and enhance the nutritional value of crops, offering sustainable and practical pathways for rehabilitating degraded agricultural landscapes in mining communities.

2 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 [27], 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 the U.S. Environmental Protection Agency [17], facilitates the evaluation of potential risks posed by heavy metals in crops to human health, based on exposure pathways and benchmark thresholds. The Food Systems Framework, proposed by [19], contextualizes the findings within the broader dynamics of food availability, quality, and security, particularly within the 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.

3 Materials and methods

3.1 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. The district receives a mean annual precipitation of approximately 1,250–2,000 mm, creating favourable moisture conditions that support intensive agricultural activities [9]. The area forms part of the moist semi-deciduous forest ecological zone, which is noted for its relatively well-

drained soils and rich biodiversity, providing a conducive environment for the cultivation of staple crops such as cassava and cocoyam [9, 42].

Figure 1: Map of the study communities in the Asutifi North District, Ahafo Region, Ghana, showing sampling locations in K1, K2, NT and WAM. Symbols represent the average positions of sampled farms based on recorded GPS coordinates.

3.2 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 [23, 48]. 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 [6].

3.3 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.

3.4 Quality assurance and quality control (QA/QC)

To ensure the reliability of the analytical results, several QA/QC measures were followed. All titrations were carried out in triplicate, and the average readings were used for the final calculations. Reagent blanks were analysed to account for any background EDTA consumption. Certified reference materials (CRMs) provided by the laboratory were processed together with the samples to verify the accuracy of the method. All glassware used in the analysis was thoroughly acid-washed, and titrant solutions were standardised before each session. Analytical precision was considered acceptable when the relative standard deviation (RSD) was below 5%. In addition, routine checks including instrument calibration logs and duplicate digests were used to confirm consistency throughout the analytical process.

3.5 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 ($\mathrm{mg\,kg^{-1}}$) was calculated as:

$$C_{\mathrm{HM}} = \frac{C \times V_{\mathrm{digest}}}{w} \tag{1}$$

where C is the concentration obtained from AAS ($\mu\mathrm{g\,mL^{-1}}$), V_{digest} is the digest volume (100 mL), and w is the sample weight (1.00 g). Thus, $C_{\mathrm{HM}} = C \times 100$.

3.6 Determination of phosphorus (P)

Phosphorus was determined colorimetrically using the vanadomolybdate method [40, 41]. 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 (C_{digest}) was calculated from the reaction concentration (C_{rxn}) by applying the dilution factor. The reaction mixture analysed by the instrument had a volume of 10 mL, while the final digest volume was 100 mL, giving a dilution factor of 10. Thus, $C_{\mathrm{digest}} = C_{\mathrm{rxn}} \times 10$. The percentage phosphorus was calculated as:

$$\%\mathrm{P} = C_{\mathrm{rxn}}/10. \tag{2}$$

3.7 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:

$$\%X = \frac{C \times V_{\mathrm{digest}}}{10 \times w} \tag{3}$$

where $X = \mathrm{K}$ or Na, and C is the concentration ($\mu\mathrm{g\,mL^{-1}}$). For $V_{\mathrm{digest}} = 100$ mL and $w = 1.00$ g: $\%X = C \times 10$.

3.8 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 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.

In these equations, T represents the EDTA titre volume (mL) obtained during titration. The constants 0.4008 and 0.243 correspond to the milligrams of Ca and Mg, respectively, that react with 1.00 mL of 0.01 M EDTA. V_{digest} is the total volume of the sample digest (100 mL), while V_{aliquot} is the volume of digest taken for titration (5 mL). The factor ($V_{\text{digest}}/V_{\text{aliquot}}$) therefore accounts for the dilution of the aliquot relative to the full digest. The term w denotes the oven-dry weight of the sample (g), and the divisor 10 converts milligram values to percentage composition.

Using these definitions, the analyte content in the aliquot (mg) was given by: $\text{mg}_{\text{Ca}} = T \times 0.4008$, $\text{mg}_{\text{Mg}} = T \times 0.243$. Adjusting for the digest volume ($V_{\text{digest}} = 100$ mL) and aliquot size ($V_{\text{aliquot}} = 5$ mL), the percentages were computed as:

$$\%\text{Ca} = \frac{T \times 0.4008 \times (V_{\text{digest}}/V_{\text{aliquot}})}{10 \times w}, \tag{4}$$

$$\%\text{Mg} = \frac{T \times 0.243 \times (V_{\text{digest}}/V_{\text{aliquot}})}{10 \times w}. \tag{5}$$

For a 1.00 g sample and 5 mL aliquot from a 100 mL digest, this simplifies to: $\%\text{Ca} = 0.8016 \times T$, $\%\text{Mg} = 0.486 \times T$.

4 Results

4.1 Chemical content in cocoyam and cassava produce

4.1.1 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 Kenyasi 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 Kenyasi No. 2 recorded mean values of 2.55 mg/kg and 1.91 mg/kg, respectively, while cassava from Kenyasi No. 1 and cocoyam from Ntotroso had intermediate values of 1.70 mg/kg and 1.72 mg/kg, respectively (Table 1).

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 Kenyasi 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 Kenyasi No. 2 recorded cadmium concentrations of 0.34 mg/kg and 0.46 mg/kg, respectively. Cassava from Kenyasi No. 1 showed a slightly higher concentration at 0.48 mg/kg, while cocoyam from Kenyasi No. 2 had a mean cadmium level of 0.51 mg/kg (Table 1).

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 Kenyasi No. 2 recorded a phosphorus content of 0.36 mg/kg. Similarly, cocoyam from Kenyasi No. 1 recorded a relatively high phosphorus concentration of 0.30 mg/kg. In contrast, cassava samples demonstrated markedly lower phosphorus concentrations. Cassava from Kenyasi 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 Kenyasi 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 1).

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 Kenyasi No. 1 and Kenyasi 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 Kenyasi No. 1 and Kenyasi 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 1).

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 Kenyasi No. 1 and Kenyasi 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 Kenyasi

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No. 1 and Kenyasi 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 1).

4.2 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 Kenyasi No. 1, which also registered 0.42 mg/kg. Among all treatments, cassava from Kenyasi 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 Kenyasi No. 2 and Ntotroso, as well as cassava from Kenyasi No. 2, exhibited calcium contents ranging between 0.36 and 0.37 mg/kg (Table 2).

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 Kenyasi No. 1, cocoyam from Kenyasi 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 2).

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 Kenyasi No. 1 and Kenyasi No. 2, as well as cassava from Kenyasi No. 1, exhibited sodium levels equivalent to that of the control (Table 2).

The data indicate statistically significant differences ($p < 0.05$) in lead (Pb) concentra-

tions among the various crop samples collected from different locations. The lowest lead concentration was observed in cocoyam cultivated in Wamahinso, a non-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 Kenyasi No. 1 and cocoyam from Kenyasi No. 2 showed intermediate lead concentrations, with mean values of 0.34 mg/kg and 0.37 mg/kg, respectively. Cocoyam from Kenyasi 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 Kenyasi 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 2).

5 Discussion

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

5.1.1 Arsenic content

Among the samples, cocoyam from Kenyasi 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 Kenyasi No. 1 and Ntotroso may stem from natural arsenopyrite in the bedrock and disturbances caused by artisanal mining activities [37]. Mining disrupts soil, mobilizes heavy metals, and raises the likelihood of plant uptake [3]. 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 [44]. Cassava, which can tolerate drier soils, may be exposed to less arsenite and absorb less [55, 54]. These findings align with those of [44] and [15], 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 [50, 31]. Codex Alimentarius Commission [24] established a maximum permissible limit of 0.1 mg/kg for arsenic in root and tuber crops due to these health risks. The arsenic concentrations observed in cocoyam from Kenyasi No. 1 thus raise legitimate food safety concerns in mining-induced zones.

5.1.2 Cadmium content

Cocoyam from Kenyasi No. 1 had the highest cadmium concentration, while the lowest was recorded in cassava from Wamahinso. The elevated cadmium in Kenyasi No. 1 can be linked to mining-related contamination and how efficiently different crops absorb heavy metals [21, 39]. Mining in the area may have increased soil cadmium levels due to the presence of metal ores and residues [46]. Cocoyam, known for its high capacity to exchange cations, tends to absorb more heavy metals, including cadmium [39]. [4] also observed that plants grown in mining-affected areas accumulate more cadmium due to its increased bioavailability. Additionally, [5] 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 [51, 10]. Children and pregnant women are especially at risk due to cadmium's bioaccumulative nature. To alleviate these risks, the Codex Alimentarius Commission [24] established a maximum permissible level (ML) of 0.1 mg/kg for cadmium in root and tuber crops. The levels observed in cocoyam from Kenyasi No. 1 suggest a potential food safety hazard since it goes beyond the permissible level of (ML) 0.1 mg/kg.

5.1.3 Phosphorus content

Phosphorus levels were highest in cocoyam from Wamahinso, while the lowest were found in both cassava and cocoyam from Kenyasi 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 [35, 43]. Consequently, crops in mining areas often show reduced phosphorus content. These findings are consistent with [34], who found that soil contamination in mining zones reduces phosphorus levels in food crops. [20] 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.

5.1.4 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 [29]. Once in the soil, mercury binds with particles and can be taken up by plant roots, accumulating in edible tissues over time. [7] reported similar findings in crops and soils from mining areas in Ghana. Likewise, [29] 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 disabilities in children and fetuses [53, 12]. To respond to this, the Codex Alimentarius Commission [24] recommends a maximum limit of 0.1 mg/kg total mercury for root and tuber vegetables. Nonetheless, cassava from Ntotroso exceeds this benchmark and thus makes it a critical issue in the mining-affected communities.

5.1.5 Potassium content

Cocoyam from Wamahinso had the highest potassium content, while the lowest level was found in cassava from Kenyasi No. 1. The reduced potassium in the mining area may be attributed to soil disturbance and leaching of nutrients caused by mining activities [32]. Potassium is a mobile nutrient and can be easily washed away when soil is disturbed or vegetation is cleared [8]. [14] observed that mining reduces soil fertility and causes significant declines in essential nutrients like potassium. Similarly, [32] found that food

crops from mining communities have consistently lower nutrient levels, due to erosion, pollution, and nutrient imbalance associated with mining activities.

5.1.6 Calcium content

Cassava from Kenyasi 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 Kenyasi 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 [28, 30]. [45] noted that heavy metals can block the absorption of essential nutrients like calcium. [20] 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.

5.1.7 Magnesium content

Magnesium content was highest in cocoyam from Kenyasi No. 2 and cassava from Kenyasi No. 1 both mining zones. The lowest magnesium was recorded in cassava from Ntotroso. The high magnesium levels in Kenyasi 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 [28]. Ntotroso soils may be more degraded or more heavily contaminated, reducing magnesium uptake. [28] support the idea that nutrient levels, including magnesium, differ across mining locations due to varying environmental conditions and soil characteristics.

5.1.8 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 [38]. 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. [20] observed similar trends, showing that mining contributes to changes in soil chemistry, including higher sodium levels, which affect plant nutrient content.

5.1.9 Lead content

Cassava from Kenyasi No. 2 had the highest lead concentration, while the lowest levels were found in cassava and cocoyam from Wamahinso. The high lead levels in Kenyasi No. 2 are likely due to contamination from mining residues and tailings, which contain lead [33]. In mining zones, lead gets into the soil through leaching and dust from mining activities [1]. Once in the soil, lead can be taken up by plant roots and build up in edible parts like cassava tubers [25]. [29] and [26] 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 [52, 11]. Codex Alimentarius Commission [24] in recognizing these established a maximum permissible level of 0.1 mg/kg for lead in root and tuber staple foods. The concentration of lead found in cassava from Kenyasi No. 2 exceeds this threshold and makes it unsafe for consumption in the mining communities.

6 Conclusion

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.

Overall, the study emphasises the need for continuous monitoring of soil and crop quality to safeguard the health of residents and ensure the long-term sustainability of agricultural production in mining-impacted landscapes.

7 Socio-economic and policy implications

The contamination of staple crops such as cassava and cocoyam has direct socio-economic implications for households that depend on these foods as primary sources of nutrition and income. Reduced crop quality can undermine local food security, increase household vulnerability, and eat away farmer livelihoods in already resource-constrained rural communities.

From a policy perspective, the findings emphasise the necessity for stronger regulatory oversight of agricultural activities near mining operations. Integrating agricultural impact assessments into mining licensing, monitoring, and reclamation frameworks would help ensure that food production systems are not compromised by extractive activities. Government agencies and district authorities should also facilitate regular testing of edible crops in mining-affected communities and communicate the results clearly to residents to support informed decision-making.

Community-focused environmental education programmes should be enhanced. Strengthening farmer awareness about the risks associated with cultivating and consuming crops grown in contaminated soils can enhance local resilience and promote safer agricultural practices. Protecting the integrity of rural food systems is essential for preserving public health, sustaining local economies, and advancing long-term sustainable development in mining-dependent districts.

Statement and Declarations

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Tables and Figures

Table 1: Arsenic, cadmium, phosphorus, mercury, and potassium content in cocoyam and cassava produce from different locations. Means with the same letter within a column are not significantly different at 5% probability. K1COC = Cocoyam from Kenyasi No. 1, K1CAS = Cassava from Kenyasi No. 1, K2COC = Cocoyam from Kenyasi No. 2, K2CAS = Cassava from Kenyasi No. 2, NT/GCOC = Cocoyam from Ntotroso, NT/GCAS = Cassava from Ntotroso, WAMCOC = Cocoyam from Wamahinso, WAMCAS = Cassava from Wamahinso.

Treatments	As (mg/kg)	Cd (mg/kg)	P (mg/kg)	Hg (mg/kg)	K (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

Table 2: Calcium, magnesium, sodium, and lead content in cocoyam and cassava produce from different locations. Means with the same letter within a column are not significantly different at 5% probability. Abbreviations as in Table 1.

Treatments	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	Pb (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