Trop J Nat Prod Res, February 2025; 9(2): 734 - 740 **ISSN 2616-0684 (Print)**
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article

The Impact of Mining on Antioxidant Activity and Nutritional Composition of *Zea mays* in Edo North, Edo State, Nigeria

Eseigbe M. Imade [1]* and Usunobun Usunomena [2]

[1] *Department of Biochemistry, Faculty of Basic Medical Sciences, Edo University Iyamho, Edo State, Nigeria.*
[2] *Department of Biochemistry, Faculty of Basic Medical Sciences, Edo University Iyamho, Edo State, Nigeria.*

ARTICLE INFO

Article history:
Received 09 January 2025
Revised 19 January 2025
Accepted 21 February 2025
Published online 01 March 2025

ABSTRACT

Mining operations can significantly alter soil conditions, leading to compaction and contamination. These changes can negatively affect plant growth and agricultural output. This research examined the effects of mining activities on the antioxidant properties and nutritional content of maize *(Zea mays)* cultivated in areas influenced by mining compared to areas unaffected by mining in Edo North, Nigeria. Maize was grown using soil samples collected from mining sites (Okpella, Ikpeshi) and a non-mining control site (Afuze). The methanolic extracts of the maize were analyzed for phytochemicals, proximate composition and antioxidant activity. Phytochemical screening revealed the presence of tannins, alkaloids, flavonoids, terpenoids, saponins, steroids, and phenols in both mining and non-mining sites. Maize from non-mining sites exhibited significantly higher concentrations of these phytochemicals. Non-mining site (Afuze site A) had the highest total phenolic content (28.31 ± 0.02 µg/mg), and the highest value of total flavonoid was obtained in the extracts from Afuze site A (10.35±0.13µg/mg). Ikpeshi and Okpella showed higher radical scavenging activity compared to non-mining site. The highest DPPH radical scavenging activity was recorded for extract from Ikpeshi site B (0.93±0.04µg/mg). Extracts from Ikpeshi site B were recorded to have the highest ABTS radical scavenging activities (0.93±0.05µg/mg). The highest hydroxyl scavenging activity was recorded for extract from Ikpeshi site A (0.94±0.05µg/mg). Reducing Antioxidant Power revealed that extracts from Ikpeshi site A had the highest scavenging activity (0.98±0.05µg/mg). Proximate analysis revealed that mining significantly reduced moisture content, ash, acid-insoluble ash, and water-soluble ash in maize. The results suggest that mining activities may negatively impact the overall nutritional value of maize.

Keywords: Mining, Phytochemicals, Soil degradation, *Zea mays*, Edo North, Antioxidants, Nutrient deficiency.

Introduction

Mining activities, like any endeavor, have both positive and negative consequences. On the positive side, they contribute significantly to the Gross Domestic Product (GDP) of mineral-rich nations and generate employment opportunities. However, negligence and human greed often lead to detrimental environmental impacts, including air, water, and land pollution, soil degradation, and the loss of vegetation and forest ecosystems.[1] In Edo North, Nigeria, mining operations have the potential to significantly impact the local environment, affecting soils, plants, and human health. Mineral extraction processes can lead to soil erosion, compaction, and contamination of both soil and water resources, consequently impacting plant growth and agricultural productivity. Furthermore, the release of dust and pollutants from mining activities can adversely affect human health, leading to respiratory problems and exposure to harmful heavy metals.[2]

*Corresponding author. Email: eseigbe.mercy@edouniversity.edu.ng
Tel: +2348062449246

Citation: Imade EM and Usunomena U. The Impact of Mining on Antioxidant Activity and Nutritional Composition of *Zea mays* in Edo North, Edo State, Nigeria. Trop J Nat Prod Res. 2025; 9(2): 734 – 740 https://doi.org/10.26538/tjnpr/v9i2.41

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

To foster the sustainable growth of the mining industry, a thorough assessment of its environmental and potential health impacts is crucial, especially in regions such as Okpella and Akoko Edo as seen in the geological and mineral resources map of Edo State, renowned for their significant dolomite and carbonate rock production. The selected plant, *Zea mays L*. (popularly called maize), a staple crop in Nigeria, is highly susceptible to soil contamination.[3]. Understanding the impact of heavy metal and metalloid pollution in mining sites on maize growth, yield, and quality is essential for ensuring food security and environmental sustainability.[4] This research is novel as it specifically examines the impact of mining activities on the phytochemical profile and antioxidant capacity of maize, a staple food crop in the region. Several studies have been conducted on the nutritional composition of maize, and it has been found to contain a wealth of beneficial nutrients, ranging from carbohydrates, proteins, macro-elements, minerals, and vitamins to phytochemicals, etc.[5] While studies have explored the environmental impacts of mining, few have focused on the direct effects on the nutritional quality of maize grown in mining-degraded soil. The aim of this study is to determine the nutritional composition and antioxidant activity of *Zea mays* grown in soils from mining sites in Edo North of Edo State, Nigeria, and also to provide insights into the potential health implications for local communities reliant on these crops.

Materials and Methods

Overview of the study area

Edo North, situated in the northern part of Edo State, Nigeria, encompasses a region spanning latitudes 6°50'N to 7°30'N and longitudes 5°40'E to 6°50'E. The underlying geology varies, with the

Precambrian Basement Complex dominating the north and Cretaceous and Tertiary sediments prevalent in the south. This region is known for its rich deposits of industrial and metallic minerals, currently undergoing various stages of exploitation.[2] As one of the three Senatorial Districts in Edo State, Edo North constitutes a significant portion of the state's territory. It comprises six Local Government Areas: Akoko-Edo, Etsako Central, Etsako East, Etsako West, Owan East, and Owan West. Geographically, it borders Kogi and Ondo States to the north, east, and west, respectively. To the south, it shares boundaries with Uhumwode, Esan West, Esan Central, and Esan North East Local Government Areas. Owan East, one of these Local Government Areas, has its headquarters in Afuze, located approximately 103 kilometers from Benin City. Owan East shares borders with Owan West to the east, Akoko Edo to the north, and Esan West to the south. Its geographical coordinates fall within the range of 7°15'N to 6°50'N latitude and 5°00'E to 6°15'E longitude.[6] Ikpeshi in Akoko-Edo local government area and it environ lies within latitudes 7008'N to 7010'N and longitudes 6010'E to 6015'E and is part of Igarra schist belt, southwestern Nigeria. It comprises of metasedimentary rocks which include clay, amphibolite, calc-silicate and marble,[6] this area, positioned within Etsako East Local Government Area of Edo State, Nigeria, lies along the Benin-Abuja federal highway. Geographically, it is situated at approximately 7.2721 degrees North latitude and 6.3465 degrees East longitude. Renowned for its limestone deposits, the region also supports a thriving industrial landscape, encompassing granite, clay, and marble processing industries, reflecting the abundance of diverse mineral resources.[7] The study area, located in the northern region of Edo State, exhibits a geological profile featuring sedimentary rocks overlying a stable crystalline bedrock. This sedimentary sequence encompasses a diverse range of rock types, including limestone, sandstone, basalt, and granite. Rock extraction within this region typically involves the utilization of explosives to fragment large boulders into smaller, more manageable pieces. Subsequent processing steps involve the employment of specialized quarrying equipment to produce a variety of rock and stone sizes. The resulting products find widespread application in domestic sectors, serving as essential components in road construction, building materials, and landscaping projects. Moreover, quarry waste generated during these operations can be effectively repurposed for various surface construction applications, including road surfacing, building foundations, and erosion control measures.

Chemical and Reagent

Chemicals such as 1,1-diphenyl 1-2-picryl-hydrazl (DPPH), 1-10 phenanthroline, trichloroacetic acid (TCA), ferric chloride reagent, Dragendorff's reagent, pyridine, sodium nitroprusside reagent, glacial acetic anhydride and other chemicals/reagents all are products of Evans Medical PLC, Lagos, Nigeria.

Sample Collection and Identification

Healthy maize seeds (with voucher number; 3035611) were obtained from the Department of Crop Science, Leventis Farm, Agenebode, Edo State, Nigeria, in July, 2024 and was identified by the head of the unit Mr. Kenneth. The soil collected from each location was loamy sandy soil. It was homogenized, crushed and dried in the dark at room temperature under a fume hood for 7days. 1kg of each soil was measured into a planting bag where eight seeds of the maize were grown for eight weeks.

Sample preparation

At eight weeks post-planting, all aerial parts of the maize plants were harvested. Following harvest, the plant material was meticulously washed with tap water to remove any adhering soil or debris. Subsequently, the washed plant material was subjected to a shade-drying process for a duration of approximately six weeks at ambient temperature. Upon thorough drying, the plant material was finely pulverized using a blender.

Sample Extraction

A 100g aliquot of each dried plant powder was individually subjected to maceration in 100 mL of a methanol-water solvent mixture (4:1 v/v) within conical flasks for a 24-hour period. Subsequent to this, the resulting mixtures were filtered through Whatman No. 42 filter paper. The filtrate was then subjected to solvent evaporation to yield concentrated plant extracts. These concentrated extracts were meticulously stored in sterilized, airtight containers, appropriately labeled, and maintained at a temperature of 4°C for subsequent utilization.

Phytochemical Screening

Various phytochemical tests (alkaloids, steroids, flavonoids, phlobatanin, cardio glycosides, phenols, tannins, anthraquinone, saponins and terpenoids) were conducted to identify presence of phytochemicals in the maize extract according to the procedure described by[7,8]

Determination of the Nutritional Composition

Standard analytical procedures were employed to determine key proximate components, including moisture content, dry matter, ash content, organic matter content, nitrogen content, crude fiber content, fat content, and crude protein content.[9] The available carbohydrate content was subsequently calculated by subtracting the sum of moisture, protein, fat, ash, and crude fiber percentages (expressed as a percentage of dry weight) from 100. The energy value of each sample was then estimated in kilocalories by applying the following conversion factors: crude protein (4 kcal/g), fat (9 kcal/g), and available carbohydrates (4 kcal/g), consistent with established methodologies for plant-based feed analysis.

Total Phenolic content

The total phenolic content of the methanolic extracts was quantified utilizing the Folin-Ciocalteu colorimetric method, as outlined in.[10] A stock solution of tannic acid was prepared by dissolving 0.05 g of anhydrous tannic acid in 50 mL of distilled water within a volumetric flask. A series of standard solutions with concentrations ranging from 0 to 1.0 µg/mL were subsequently prepared through serial dilution of the stock solution. For each analysis, 0.5 mL of either the methanolic plant extract or the tannic acid standard was added to 10 mL of distilled water. Following this, 2.5 mL of Folin-Ciocalteu reagent was introduced, and the mixture was thoroughly mixed and allowed to react for two minutes. Subsequently, 7.5 mL of sodium carbonate solution (20 g/100 mL) was added, and the mixture was vigorously mixed and brought to final volume with deionized water. After a two-hour incubation period, the absorbance of each solution was measured at 760 nm using a Lambda EZ150 spectrophotometer (Perkin Elmer, USA). The results of the analysis were expressed as micrograms of tannic acid equivalents per milligram of plant extract.

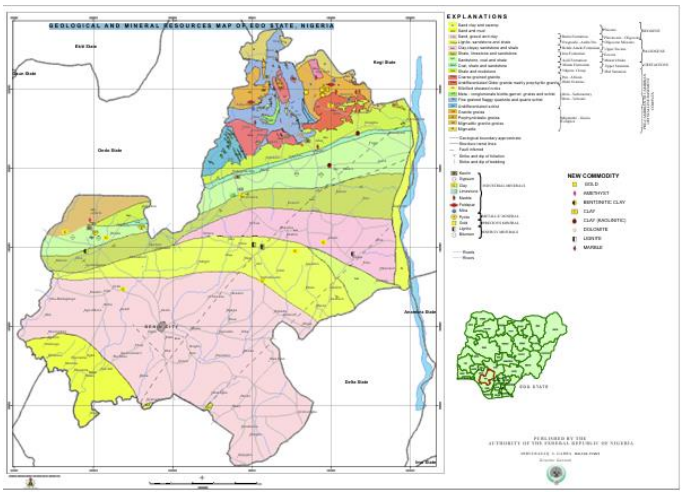

Figure 1: Geological and mineral resources map of Edo State, Nigeria.[2]

Total Flavonoid Content
The total flavonoid content was determined using a slightly modified method reported by.[11,12] 0.5ml of appropriately diluted plant extract was separately mixed with 50 µl of 10% aluminum chloride ($AlCl_3$), 50 µl of 1M potassium acetate, 1.4 ml distilled water, and left at room temperature for 30 minutes to incubate. The absorbance of the reaction mixture was measured at 415 nm using a Lambda EZ150 spectrophotometer (Perkin Elmer, USA). The calibration curve was prepared by preparing quercetin solutions at concentrations of 0, 0.2, 0.4, 0.6, 0.8, and 1.0 µg/ml, and the results were expressed as µg quercetin equivalents per mg of the plant material.

1,1-diphenyl 1-2-picryl-hydrazl (DPPH) Activity of Maize Extract
The DPPH radical scavenging activity was determined using a slightly modified method described by.[13] A stock solution of the sample was prepared at a concentration of 4 mg/ml in methanol. This stock solution was then serially diluted to obtain final concentrations of 200, 100, 50, 25, and 12.5 µg/ml in methanol. One milliliter of a 0.3 mM DPPH solution in methanol was added to 1 ml of each sample solution at the different concentrations. The reaction mixtures were allowed to react at room temperature for 30 minutes. After 30 minutes, the absorbance values of the reaction mixtures were measured at 517 nm using a Lambda EZ150 spectrophotometer (Perkin Elmer, USA). Tannic acid was used as the standard for comparison.

2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) ABTS radical scavenging Activity of Maize Extract
The antioxidant capacity of the samples was evaluated by measuring their ability to scavenge the 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical cation. This assay was adapted from a previously published method.[14] The ABTS radical cation was generated by reacting an 8 mM ABTS solution with 3 mM potassium persulfate and allowing the mixture to stand in the dark at room temperature for 12 hours. A Trolox standard curve was constructed using serial dilutions of a 1000 µg/ml Trolox stock solution to obtain concentrations of 12.5, 25, 50, 100, and 200 µg/ml. To determine the radical scavenging activity, 0.1 ml of each Trolox standard or sample solution was added to 2.9 ml of the ABTS radical cation working solution. The mixtures were incubated for 30 minutes, and the absorbance of each solution was measured at 734 nm using a Lambda EZ150 spectrophotometer (Perkin Elmer, USA). The absorbance values were plotted against the Trolox concentrations to generate a standard curve, which was then used to determine the antioxidant capacity of the samples.

Hydroxyl Radical Scavenging Activity of Maize Extract
The antioxidant capacity of the extract was assessed using a spectrophotometric method to measure its ability to inhibit Fe^{2+}/H_2O_2-induced lipid peroxidation. Serial dilutions of the extract in methanol were prepared at concentrations of 200, 100, 50, 25, and 12.5 µg/ml. Mannitol, a known antioxidant, was used as a positive control and diluted similarly. To each reaction mixture, 1.2 ml of phosphate buffer (pH 7.4), 7.5 µl of hydrogen peroxide (20 mM), 30 µl of $FeCl_3$, and 45 µl of 1,10-phenanthroline were added, followed by 0.5 ml of the extract or mannitol solution. After 30 minutes of incubation, the absorbance of the reaction mixture was measured at 532 nm using a Lambda EZ150 spectrophotometer (Perkin Elmer, USA).

Reducing Power Ability of the Maize Extract
The ferric-reducing antioxidant power (FRAP) of the extract was assessed using a modified method.[13] To each sample containing 0.5 ml of the extract at different concentrations, 1.25 ml of 0.2 M phosphate buffer (pH 6.6) and 1.25 ml of 0.1% potassium ferricyanide were added. The mixtures were incubated at 50°C in a water bath for 20 minutes. The reaction was terminated by adding 1.25 ml of 10% trichloroacetic acid (TCA). An aliquot (1.25 ml) of the supernatant was mixed with 1 ml of distilled water and 0.25 ml of 0.01% ferric chloride (FeCl3). After a 10-minute incubation at room temperature, the absorbance of the reaction mixture was measured at 700 nm using a Lambda EZ150 spectrophotometer (Perkin Elmer, USA) against a suitable blank. A higher absorbance value indicated greater reducing power. Ascorbic acid was used as a positive control.

Statistical Analysis
Data were collected from three independent experiments (n = 3) and analyzed using IBM SPSS Statistics software (version 20, IBM Corporation, New York, USA). Statistical analysis was performed using one-way analysis of variance (ANOVA) followed by a t-test to identify significant differences between groups ($p < 0.05$)

Results and Discussion

Phytochemical Screening
The result of phytochemical screening of maize extract as shown in Table-1 revealed phytochemicals in mining and non-mining soils. From the table, tannins, saponins, flavonoids, and phenols showed maximum presence in the maize cultivated in the non-mining sites (Afuze) than in the mining sites. Alkaloids, terpenoids, and steroids were present in similar concentrations in all sites, cardiac glycosides and anthraquinone

Table 1: Qualitative Phytochemical screening of maize cultivated in a mining and non-mining soils

Parameters	AF Site A	AF Site B	OK Site A	OK Site B	IK Site A	IK Site B
Alka	+	+	+	+	+	+
Sapo	+	+	+	+	+	+
Phlo	-	-	-	-	-	-
Tan	+	+	+	+	+	+
Anthr	-	-	+	+	-	-
Ster	+	+	+	+	+	+
Ter	+	+	+	+	+	+
Flav	+	+	+	+	+	+
CG1	-	-	+	+	-	-
CG2	-	-	+	+	-	-
CG3	-	-	+	+	-	-
Phenols	+	+	+	+	+	+

IK = Ikpeshi, OK = Okpella, AF = Afuze Ster = Steriods, Terp= Terpernoids, Fla= Flavonroid Anthr = Anthraquinones, Phlo = phlobatannins, Sapo= Saponin, CG1= Cardiac glycosides with steroidal nucleus, CG2 = Cardiac glycosides with deoxy sugar, CG3 = Cardiac glycosides with cardenolides. + = Present, – = Absent

were exclusively detected in maize from the non-mining site and phlobatannins were seen to be absent in all maize extracts cultivated in the different soil types.

Mining activities, particularly those involving dolomite, clay, calcite, and marble, can significantly alter soil properties and consequently affect the growth and quality of crops like maize. The variation in the identified phytoconstituents could be attributed to their lipophilic and hydrophilic properties.[15,16] One of the reasons why tannins, saponins, flavonoids, and phenols will be lower in the maize extract from mining sites could be attributed to heavy metal stress[17]. Mining activities frequently release heavy metals such as lead, cadmium, and nickel into the surrounding soil. These heavy metals can induce oxidative stress in plants by promoting the generation of reactive oxygen species (ROS).[17] Plants have evolved antioxidant defense mechanisms to counteract oxidative stress, including the synthesis of secondary metabolites like phenols, flavonoids, and other antioxidants. However, prolonged exposure to heavy metal stress can overwhelm these defense systems, leading to a decline in antioxidant capacity.[18]Phenolic compounds possess various biological activities, including anti-inflammatory properties. They can inhibit enzymes involved in inflammatory pathways and modulate prostaglandin production, thereby protecting platelets from aggregation. Alkaloids can interact with various hormonal pathways and exhibit stimulant effects. Flavonoids are a diverse group of compounds known for their antioxidant and anti-inflammatory properties. They are potent water-soluble antioxidants that can scavenge free radicals, thereby protecting cells from oxidative damage and exhibiting anti-cancer activity across different stages of carcinogenesis. Saponins are characterized by their ability to form foams in aqueous solutions and exhibit hemolytic activity. They can also interact with cell membranes, leading to the precipitation and coagulation of red blood cells.[18]

Proximate composition

Proximate analysis of maize samples (Table 2) revealed significant variations across the sampling sites. Moisture content **r**anged from 8% to 24.16%, with significant differences observed between most sites, except between Ikpeshi sites A and B. Afuze site A exhibited the highest dry matter content (92%), while Okpella site B had the lowest (75%). Ikpeshi site B showed the highest ash content (21.48%), while Afuze site B had the lowest (6.10%). Significant differences were observed across most sites. Afuze site B had the highest organic matter content (93.90%), while Okpella site B had the lowest (76.61%). Afuze site B showed significantly higher crude fat content (1.65%) compared to other sites. Afuze site A exhibited the highest nitrogen content (2.22%), while Ikpeshi site A had the lowest (1.11%). Afuze site B showed the highest carbohydrate content (73%), while Okpella site B had the lowest (47.3%). Afuze site B had the highest crude protein content (8.51%), while Okpella site B had the lowest (3.42%). Afuze site A exhibited the highest food energy content (339.80 kcal), while Okpella site B had the lowest (214.58 kcal).

The higher percentage of dry matter, nitrogen, crude fiber, carbohydrate, fat, crude protein and food energy in Afuze sites and lower % of moisture, content, ash, acid insoluble ash and water-soluble ash compared to the mining sites (Okpella and Ikpeshi) could be attributed to the effect of mining activities. Mining activities significantly alter the proximate composition of plants through the introduction of heavy metals and other potentially harmful elements (PHEs) into the soil. Heavy metal contamination of agricultural soils can have detrimental effects on plant growth and development. Increased accumulation of heavy metals within plant tissues can disrupt various physiological processes, potentially leading to stunted growth and reduced overall plant health.[20] Heavy metals can also negatively impact plant reproduction, resulting in smaller seed size, decreased pollen viability, and lower seed yields. For instance, studies have shown that cadmium exposure can significantly impair these reproductive processes. Furthermore, heavy metal contamination can alter the nutritional composition of cereal crops, potentially leading to micronutrient deficiencies in populations that rely heavily on cereal-based diets for sustenance.[22,23,24]

The observed significant decrease in crude protein and carbohydrate content in maize from mining sites, as presented in Table 2, aligns with previous research findings. [25]reported a similar trend, observing a decline in growth performance, pigment content, carbohydrate content, and protein content in plants exposed to increasing levels of industrial pollution. Furthermore, numerous studies have documented a decrease in protein content in plants exposed to elevated levels of heavy metals[25]

Table 2: Proximate Composition of Maize Cultivated in Mining and Non-Mining Soils

Parameter	AF Site A	AF Site B	OK Site A	OK Site B	IK Site A	IK Site B
MC (%)	8.00 ± 2.00*[a]	9.00 ± 1.00[a]	21.11 ± 0.09[b]	24.16 ± 0.05*[ab]	2.93 ± 0.15*	19.04 ± 0.01*
DM (%)	92.00 ± 0.43*[ab]	91.00 ± 0.20[ab]	78.89 ± 0.00*[b]	75.84 ± 0.22[ab]	77.07 ± 0.40[a]	80.96 ± 0.34*[a]
Ash (%)	8.20 ± 0.02[a]	6.10 ± 0.02*[a]	17.14 ± 0.05[ab]	23.39 ± 0.13*[ab]	18.25 ± 0.02*	21.48 ± 0.03*
OM (%)	91.80 ± 0.20[ab]	93.90 ± 0.40*[a]	82.86 ± 0.31*[ab]	6.61 ± 0.30*[b]	88.71 ± 0.32[a]	78.52 ± 0.21*
AIA (%)	3.89 ± 0.02[a]	3.11 ± 0.02*[a]	8.09 ± 0.07[ab]	9.32 ± 0.02*[ab]	11.29 ± 0.04*	9.18 ± 0.06*
ASA (%)	4.04 ± 0.03[a]	3.52 ± 0.02*[a]	6.22 ± 0.02[ab]	7.10 ± 0.02*[ab]	8.20 ± 0.02*	7.04 ± 0.05*
WSA (%)	4.09 ± 0.02[a]	3.46 ± 0.12*[a]	5.00 ± 0.11[ab]	5.08 ± 0.06[ab]	6.40 ± 0.05*[a]	5.63 ± 0.03*
NC. (%)	2.22 ± 0.00[a]	2.12 ± 0.05*[a]	1.06 ± 0.03[ab]	1.14 ± 0.07*[b]	1.11 ± 0.01[a]	1.27 ± 0.03*
CF (%)	0.86 ± 0.00[a]	1.20 ± 0.01*[a]	0.33 ± 0.01[ab]	0.43 ± 0.01*[ab]	0.21 ± 0.02	0.32 ± 0.02*
CHO (%)	72.95 ± 2.00[a]	73.54 ± 0.04[a]	57.01 ± 0.01[ab]	47.30 ± 0.30*[ab]	59.84 ± 0.04*[a]	52.16 ± 0.16*
Fat (%)	1.61 ± 0.02*[a]	1.65 ± 1.00[ab]	1.23 ± 0.01*[ab]	1.30 ± 0.30*[b]	1.34 ± 0.01[a]	1.38 ± 0.02*
CP (%)	8.38 ± 0.02[a]	8.51 ± 0.01*[a]	3.18 ± 0.05[ab]	3.42 ± 0.03*[ab]	4.10 ± 0.02*	5.63 ± 0.08*
FE (Kcal)	339.81 ± 0.01*[b]	343.05 ± 0.05*[a]	251.83 ± 0.03[ab]	214.58 ± 0.08*[ab]	267.82 ± 0.02[a]	243.40 ± 0.46*

IK = Ikpeshi, OK = Okpella, AFA = Afuze. AIA = Acid insoluble ash, ASA= Acid soluble ash, WSA= water soluble ash, MC=Moisture content, DM = Dry matter, OM = organic matter, NC = nitrogen content, CF= crude fiber, CHO = carbohydrate, CP = crude protein, FD = food energy

Data are presented as mean ± standard deviation (SD) with n = 3 replicates. indicates significant difference ($p < 0.05$) compared to SITE A. a indicates significant difference ($p < 0.05$) compared to IK. b indicates significant difference ($p < 0.05$) compared to OK. IK represents Ikpeshi, OK represents Okpella, and AF represents Afuze.

Antioxidant Contents

Biochemical assays have emerged as reliable and readily available methods for assessing the antioxidant capacity of plant materials. Antioxidants play a crucial role in human health by protecting against oxidative stress caused by reactive oxygen species[26]. This study investigated the antioxidant properties of maize extracts, including total phenols, flavonoids, and various antioxidant activity assays (DPPH radical scavenging, ABTS radical scavenging, ferric reducing power, and hydroxyl radical scavenging). The results, summarized in Table 3, demonstrated that maize extracts from non-mining sites generally exhibited higher antioxidant activity compared to those from mining sites, with activity increasing with increasing extract concentration. Analysis revealed variations in phenolic and flavonoid content across the different maize samples. Maize extracts from mining sites AF site A and B exhibited the highest total phenolic content (28.31 ± 0.02 µg/mg and 10.82 ± 0.06 µg/mg) at 0.2 µg/ml, with AF site A showing the highest overall phenolic content (28.31 ± 0.0 µg/mg) at 1.0 µg/ml. The lowest phenolic content was observed in extracts from mining sites IK site B and OK site B (4.29 ± 0.16 µg/mg and 5.18 ± 0.05 µg/mg) at 0.2 µg/ml. Extracts from non-mining sites AF site A and B displayed the highest total flavonoid content (28.31 ± 0.02µg/mg and 26.03 ± 0.02 µg/mg). Extracts from mining sites IK site A and OK site A also showed relatively high flavonoid levels (24.02 ± 0.500.02µg/mg and 23.20 ± 0.030.02µg/mg) at a concentration of 1.0 µg/ml. For in vitro antioxidant activity, the highest DPPH radical scavenging activity was recorded for IK Site B (0.93 ± 0.04 µg/mg), lowest for AF Site A (0.60 ± 0.10 µg/mg). ABTS radical scavenging activities highest value was recorded for IK Site B and A (0.93 ± 0.05 µg/mg), lowest value for AF Site A (0.52 ± 0.02 µg/mg). The highest hydroxyl scavenging activity was recorded IK Site A (12.5: 0.94 ± 0.05 µg/mg; 25: 0.92 ± 0.03 µg/mg) and the lowest value recorded for AF Site A (0.61 ± 0.02 µg/mg).

Table 3: Antioxidant of maize cultivated in a mining and non-mining soils

Total Phenolic content (µgTAE/mg)

Conc. Sample	IK Site A	IK Site B	OK Site A	OK Site B	AF Site A	AF Site B
0.2	4.06 ± 0.03*[a]	5.16 ± 0.03*	5.24 ± 0.05[a]	4.83 ± 0.05*[a]	10.35 ± 0.13[ab]	6.11 ± 0.02*[ab]
0.4	4.36 ± 0.07*[a]	5.42 ± 0.01*	6.66 ± 2.00[a]	5.41 ± 0.02[a]	11.11 ± 0.01[ab]	8.15 ± 0.06[a]
0.6	7.28 ± 0.03*	8.43 ± 0.01*	9.16 ± 0.05[a]	8.31 ± 0.02*[a]	13.02 ± 0.02[ab]	11.40 ± 0.03*[ab]
0.8	7.46 ± 0.05[a]	10.26 ± 0.06*[a]	10.14 ± 0.04[a]	9.22 ± 0.00*[a]	15.59 ± 0.08[ab]	13.11 ± 0.02*[ab]
1.0	11.49 ± 0.05*[a]	10.26 ± 0.06*	14.32 ± 0.11[a]	9.22 ± 0.00*[a]	17.07 ± 0.02[ab]	15.38 ± 0.07*

Total Flavonoid content (µg quercetin/mg)

Conc. Sample	IK Site A	IK Site B	OK Site A	OK Site B	AF Site A	AF Site B
0.2	4.06 ± 0.03*[a]	5.16 ± 0.03*	5.24 ± 0.05[a]	4.83 ± 0.05*[a]	10.35 ± 0.13[ab]	6.11 ± 0.02*[ab]
0.4	4.36 ± 0.07*[a]	5.42 ± 0.01*	6.66 ± 2.00[a]	5.41 ± 0.02[a]	11.11 ± 0.01[ab]	8.15 ± 0.06[a]
0.6	7.28 ± 0.03*	8.43 ± 0.01*	9.16 ± 0.05[a]	8.31 ± 0.02*[a]	13.02 ± 0.02[ab]	11.40 ± 0.03*[ab]
0.8	7.46 ± 0.05[a]	10.26 ± 0.06*[a]	10.14 ± 0.04[a]	9.22 ± 0.00*[a]	15.59 ± 0.08[ab]	13.11 ± 0.02*[ab]
1.0	11.49 ± 0.05*[a]	10.26 ± 0.06*	14.32 ± 0.11[a]	9.22 ± 0.00*[a]	17.07 ± 0.02[ab]	15.38 ± 0.07*

DPPH (µgTAE/mg)

Conc. Sample	IK Site A	IK Site B	OK Site A	OK Site B	AF Site A	AF Site B
12.5	0.90 ± 0.04[a]	0.93 ± 0.04*	0.88 ± 0.18*[a]	0.90 ± 0.20*	0.78 ± 0.02*[a]	0.84 ± 0.13[ab]
25	0.86 ± 0.02[a]	0.91 ± 0.10*	0.85 ± 0.01[a]	0.87 ± 0.04*[a]	0.67 ± 0.13[ab]	0.82 ± 0.02*
50	0.84 ± 0.04*	0.87 ± 0.03*	0.82 ± 0.03*[a]	0.85 ± 0.02*[a]	0.72 ± 0.18[ab]	0.79 ± 0.03*[ab]
100	0.82 ± 0.12[a]	0.84 ± 0.18*	0.81 ± 0.01[a]	0.81 ± 0.01[a]	0.63 ± 0.02[ab]	0.75 ± 0.14*[ab]
200	0.81 ± 0.05[a]	0.80 ± 0.03*[a]	0.73 ± 0.02*	0.80 ± 0.04*[a]	0.60 ± 0.10[ab]	0.65 ± 0.02[ab]

ABTS (µgTE/mg)

Conc. Sample	IK Site A	IK Site B	OK Site A	OK Site B	AF Site A	AF Site B
12.5	0.90 ± 0.03[a]	0.93 ± 0.05*	0.78 ± 0.02[a]	0.86 ± 0.03*[a]	0.64 ± 0.02[ab]	0.73 ± 0.17*[ab]
25	0.84 ± 0.03[a]	0.91 ± 0.00*	0.76 ± 0.00[a]	0.84 ± 0.03*[a]	0.63 ± 0.10[ab]	0.72 ± 0.02*[ab]
50	0.82 ± 0.12*[a]	0.88 ± 0.00*[a]	0.73 ± 0.03[a]	0.82 ± 0.02*[a]	0.60 ± 0.10[ab]	0.67 ± 0.01[ab]
100	0.75 ± 0.10[a]	0.83 ± 0.03*	0.70 ± 0.02[a]	0.80 ± 0.03*[a]	0.56 ± 0.01[ab]	0.63 ± 0.02*[ab]
200	0.71 ± 0.02[a]	0.81 ± 0.03*	0.67 ± 0.02[a]	0.76 ± 0.00*[a]	0.52 ± 0.02[ab]	0.58 ± 0.01*[ab]

Hydroxyl (OH) (µgTE/mg)

Conc. Sample	IK SITE A	IK SITE B	OK SITE A	OK SITE B	AF SITE A	AF SITE B
12.5	0.94 ± 0.05[a]	0.86 ± 0.14*[a]	0.84 ± 0.10[a]	0.82 ± 0.00[b]	0.76 ± 0.03[a]	0.75 ± 0.02[a]
25	0.92 ± 0.03*[a]	0.85 ± 0.04*	0.82 ± 0.02[a]	0.81 ± 0.00*[a]	0.73 ± 0.00[ab]	0.72 ± 0.16[ab]
50	0.91 ± 0.03[a]	0.84 ± 0.00*[a]	0.81 ± 0.11*	0.80 ± 0.03[b]	0.66 ± 0.02[ab]	0.70 ± 0.20[a]
100	0.85 ± 0.01[a]	0.82 ± 0.02*[a]	0.80 ± 0.17[a]	0.76 ± 0.02[b]	0.63 ± 0.00[ab]	0.66 ± 0.03[a]

200	0.86 ± 0.00[a]	0.81 ± 0.01*	0.72 ± 0.03[a]	0.73 ± 0.14*[a]	0.61 ± 0.02[ab]	0.63 ± 0.02*[ab]

	FRAP (µgTE/mg)					
Conc. Sample (µgTE/mg)	**IK SITE A**	**IK SITE B**	**OK SITE A**	**OK SITE B**	**AF SITE A**	**AF SITE B**
12.5	0.98 ± 0.05[a]	0.95 ± 0.03*	0.89 ± 0.02[a]	0.97 ± 0.04*[a]	0.62 ± 0.02[ab]	0.88 ± 0.03*[ab]
25	0.96 ± 0.04[a]	0.93 ± 0.03*	0.88 ± 0.02[a]	0.94 ± 0.02*[a]	0.61 ± 0.13[ab]	0.86 ± 0.16*[ab]
50	0.91 ± 0.05[a]	0.91 ± 0.04*	0.84 ± 0.03[a]	0.91 ± 0.04*[a]	0.60 ± 0.02[ab]	0.83 ± 0.03*[ab]
100	0.91 ± 0.03[a]	0.84 ± 0.17*	0.82 ± 0.03[a]	0.84 ± 0.04*[a]	0.56 ± 0.02[ab]	0.80 ± 0.03*[ab]
200	0.85 ± 0.02*[a]	0.81 ± 0.14*	0.70 ± 0.10[a]	0.81 ± 0.01*	0.52 ± 0.01[ab]	0.72 ± 0.02*[ab]

Data are presented as mean ± standard deviation (SD) with n = 3 replicates. indicates significant difference ($p < 0.05$) compared to SITE A. a indicates significant difference ($p < 0.05$) compared to IK. b indicates significant difference ($p < 0.05$) compared to OK. IK represents Ikpeshi, OK represents Okpella, and AF represents Afuze.

Highest the Ferric Reducing Antioxidant Power was recorded for IK Site A (0.98 ± 0.05 µg/mg) and OK Site B (0.97 ± 0.04 µg/mg) with the least recorded for AF Site A (0.52 ± 0.01 µg/mg)This reduction could be attributed the effect of mining activities. It has been reported that Mining soils are often enriched with heavy metals, which can induce oxidative stress in plants. As a defense mechanism, plants may synthesize higher levels of antioxidants to counteract the harmful effects of these metals.[27] The nutrient profile of mining soils, including essential micronutrients like iron, zinc, and copper, can influence the biosynthesis of secondary metabolites, including antioxidants. A deficiency or imbalance of these nutrients in non-mining soils may limit the plant's ability to produce antioxidants.[28] This study demonstrates that mining activities significantly impact the phytochemical profile, proximate composition, and antioxidant properties of maize. Mining contamination can alter plant growth, nutrient uptake, and the production of secondary metabolites. Further research is necessary to identify the specific heavy metals responsible for the observed changes in maize, a comprehensive assessment of the potential health implications of consuming maize grown in mining areas is crucial, considering both the increased antioxidant levels and the potential accumulation of heavy metals and investigating potential remediation techniques to mitigate the impact of mining on soil quality and maize production in Edo North is essential for sustainable agricultural practices.

Conclusion

Maize grown in areas unaffected by mining activities exhibited higher concentrations of key phytochemicals, including tannins, saponins, flavonoids, and phenols, which are known for their antioxidant properties. In contrast, maize cultivated near mining sites showed significantly lower levels of these beneficial compounds, suggesting that mining activities may negatively impact the nutritional quality and medicinal value of maize. Proximate analysis revealed that mining also significantly affected the overall nutrient composition of maize. Maize grown in non-mining areas exhibited higher levels of essential nutrients such as protein, fat, and carbohydrates compared to maize grown near mining sites. The observed reduction in antioxidant content in maize from mining sites highlights potential health concerns associated with consuming crops grown in contaminated environments. The findings of this study emphasize the critical need for the implementation of sustainable mining practices and further research to mitigate the adverse effects of mining on agricultural productivity and food quality.

Conflict of Interest

The authors declare no conflict of interest**.**

Authors' Declaration

The authors hereby declare that the work presented in this article are original and that any liability for claims relating to the content of this article will be borne by them.
by them

Acknowledgments

This research was made possible by the generous support of the Tertiary Education Trust Fund (TETFUND) through the 2024 Institution-Based Research (IBR) Grant. We extend our sincere gratitude to the Laboratory staff of the Department of Biochemistry, Edo State University Iyamho, Nigeria, for their invaluable assistance. We also thank Mr. Kenneth for his contribution in providing the plant materials used in this study

References

1 Osama MSEK and Elhassan Bashier E. A review study in mining industry. Int. J. Eng App Sci. Tech. 2022;7(6):455-2143.
2 Ndinwa G., and Ohwona C. Environmental and Health Impact of Solid Mineral Exploration and Exploitation in South-Northern Nigeria: A Case Study of Igarra in Edo State: Rev Environ. Earth Sci..2018;1; 24-36.
3 Ozcan S. Corn, Indispensable Crop of the Modern World: Contribution of Genetically Modified (Transgenic) Corn on Agricultural Production. Türk Bili Der Derg. 2019;2(2): 01-34
4 Mboya R, Tongoona P, Derera J, Mudhara M and Langyintuo A. The dietary importance of maize in Katumba ward, Rungwe district, Tanzania and its contribution to household food security Afr J. Agric Res. 2019; 6(11):2617-2626.
5 Sheng, S, Li T, Liu R. Corn phytochemicals and their health benefits. Food Sci. Hum. Wellness. 2018.;7(3):185-195
6 Agomuo MS, Egesi N. Petrology and Structural Geology of Ikpeshi and its Environ of Igarra Schist Belt Southwestern Nigeria. Inte. J. Sci Invent Today. 2016;5(4):03-319
7 Edema OG, Inobeme A, Adekoya MA, Olori E, Obigwa PA. Physicochemical Parameters and Heavy Metals Characterization of Soil from Okpella Mining Area in Edo State, Nigeria. Nig J. Mat Sci.Eng. 2019; 9:6-11
8 Ijoma JO, Ebosie NP, Anumaka MC, Enedoh MC. Evidence-based preferential in vitro Antisickling mechanism of three native Nigerian plants used in the management of sickle cell disease. Malays. J. Biochem. Mol Biol. 2022; 3: 9 – 17
9 Harborne JB. Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis. Chapman & Hall. 1998
10 Ijoma KI, Ajiwe VIE, Odinma SC. The organic extracts from the leaves of *Ficus thonningii Blume*, *Jatropha tanjorensis* J.L. Ellis and Saroja and *Justicia carnea* Lindley as potential

nutraceutical antioxidants and functional foods. Trends
11 Shahidi F and Ambigaipalan P. Phenolic compounds in foods and their effects on health. Adv. Food Nutr. Res. 2018; 85:149-151.
12 Ghasemzadeh A and Jahangir M. Antioxidant activities and phenolic compounds of selected medicinal plants. J. Med Plants Res. 2016;10(15): 173-182.
13 Cui Y, Wang Y, Li Y. Wang Y, Liu Y. Phytochemical composition and antioxidant activity of different parts of *Moringa oleifera*. J. Food Sci. Tech. 2018;55(11):4523-4532.
14 Okafor CE, Ijoma IK, Igboamalu CA, Ezebalu CE, Eze CF, Osita-Chikeze, JC, Uzor CE, Ekwuekwe AL. Secondary metabolites, spectra characterization, and antioxidant correlation analysis of the polar and nonpolar extracts of *Bryophyllum pinnatum (Lam)* Oken. Bio Tech. 2024; 05(2):121–136
15 Kumar S, Singh DP, Singh VP. Phytochemical constituents and pharmacological properties of *Withania somnifera* (Ashwagandha): An overview. Inter J. Pharm Sci. Res. 2020;11(1):1-11
16 Khan MR, Khan MA, Khan I. Phytochemical composition and pharmacological activities of *Moringa oleifera.* A comprehensive review. J. Ethno. 2021; 272:113880.
17 Aslam MS, Ahmad MS, Mamat AS. Phytochemical evaluation of polyherbal formulation of *Clinacanthus nutans* and *Elephantopus scaber* to identify flavonoids. Pharm J. 2016;8(6):534-541
18 Vinod K, Jogendra S, Pankaj K. Heavy metals accumulation in crop plants: Sources, response mechanisms, stress tolerance and their effects. Contaminants in Agriculture and Environment: Health Risks and Remediation. 2019. Chapter 4. 4
19 Vivian II, Donatus CB, Samson EO. Effects of quarrying Phytochem. Res. 2023; 7(1): 76-85
activities on soil quality and nutritional composition of selected vegetables in Southeastern Nigeria. Bio 2021;41(2): 24-38
20 Siyuan S, Tong L, Rui HL. Corn phytochemicals and their health benefits. Food Sci. Hum. Wellness 2018; 7:185–195
21 Shahidi F and Yeo YC. Phenolics and polyphenols: Major classes, antioxidant activities, and sources of dietary intake. Adv. Food Nutr Res. 2018; 85:1-48.
22 Mohammad RB and Hai-Yang Z. *Arbuscular Mycorrhizal* Fungi Are an Influential Factor in Improving the Phytoremediation of Arsenic, Cadmium, Lead, and Chromium. J. Fungi. 2022; 08:176
23 Wang L, Li L, Zhang T. Natural products from plants as sources of drug leads and drug candidates. J. Ethno. 2018; 216:38-69.
24 Serna-Saldivar SO. Cereal Grains: Properties, Processing, and Nutritional Attributes; CRC Press: Boca Raton, FL, USA. 2016
25 Raheem D, Dayoub M, Birech R, Nakiyemba A. The contribution of cereal grains to food security and sustainability in Africa: Potential application of UAV in Ghana, Nigeria, Uganda, and Namibia. Urban Sci. 2021; 3:5-8
26 Abdul G. Toxic Effects of Heavy Metals on Plant Growth and Metal Accumulation in Maize (*Zea mays L.*). Iran J. Toxicol. 2010; 3:325-33
27 Moukette BM, Constant AP, Jacques RN, Cabral PNB, Bravi M, Jeanne YN. In vitro antioxidant properties, free radicals scavenging activities of extracts and polyphenols composition of a non-timber forest product used as spice: *Monodora myristica*. Bio Res. 2016;45 (15): 1-17.
28 Mohammed K, Khalid EK., Ahmed A. Using Mine Tailings as a Soil Improver to Reduce Micronutrient Deficiencies in Wheat Crops, Western Morocco. J. Ecol. Eng. 2024;25(9): 44–59