

Effects of Electromagnetic Field Exposure from 33 KV Power Lines on the Physiochemical and Biochemical Properties of Cassava Tubers (*Manihot Esculenta Crantz*) in Benue State, Nigeria

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ABSTRACT

Electromagnetic fields (EMFs) from high-voltage power lines are potential environmental stressors for crops. Cassava, a staple food in sub-Saharan Africa, may exhibit altered physiological and biochemical profiles when cultivated under EMF exposure. This study investigated the relationship between EMF from a 33 kV power line and the proximate composition, pH, titratable acidity, cyanogenic glycosides, and oxidative stress biomarkers in cassava tubers. Cassava samples (variety TME 419) were collected at distances of 0, 5, 10, 15, 20, and 50 m from a 33 kV power line in Apir, Makurdi, Benue State, Nigeria. EMF intensity was measured using a TriField® EMF meter. Proximate composition (carbohydrate, protein, fat, fibre, moisture, ash), pH, titratable acidity, cyanogenic glycosides (HCN), malondialdehyde (MDA), total phenolic content (TPC) and DPPH antioxidant activity were analysed using standard protocols. Regression analysis was used to evaluate EMF-distance relationships. Linear regression revealed a significant inverse relationship between electric field strength and distance ($\beta = -13.9044$, $R^2 = 0.74$, $p = 0.027$). Magnetic field also decreased with distance ($\beta = -0.0566$, $R^2 = 0.64$, $p = 0.056$). Proximate composition showed no consistent trend across distances, with carbohydrate ranging from 63.18% to 74.95%. pH values ranged from 1.60 to 2.05, and cyanide concentration ranged from 0.013 to 0.35 mg HCN/kg, with no distance-dependent pattern. MDA levels showed irregular spikes (14.57–166.04), and TPC ranged from 13.92 to 158.63, also without consistent EMF correlation. Although EMF intensity decreased predictably with distance, no significant or consistent EMF-induced alterations were observed in cassava proximate composition, acidity, cyanogenic glycosides, or oxidative stress biomarkers. Cassava cultivated near 33 kV power lines in the study area retains its nutritional and biochemical integrity.

Keywords:

Electromagnetic field,
Cassava,
Proximate composition,
Oxidative stress,
Cyanogenic glycosides,
Benue State.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial woody shrub belonging to the Euphorbiaceae family and serves as the third largest source of carbohydrates globally after rice and maize (FAO, 2022). In Nigeria, the world's largest cassava producer, the crop occupies a central position in food security, with Benue State known as the "Food Basket of the Nation" being a major producing region (Nweke, 2020). Cassava roots are rich in starch (approximately 31% of fresh weight) but contain only 1–3% protein on a dry matter basis (Adugna Bayata, 2019). The increasing demand for electricity has led to the expansion of high-voltage power transmission lines across agricultural lands. Electromagnetic fields (EMFs)

generated by 33 kV power lines, operating at 50 Hz (extremely low frequency), represent a form of non-ionising radiation. While ICNIRP (2020) guidelines for public exposure limit electric fields to 5 kV/m and magnetic fields to 200 μ T, the biological effects of chronic low-level EMF exposure on plants remain incompletely understood.

Previous studies have reported mixed results. Some research suggests that EMFs can alter seed germination, chlorophyll content, and antioxidant enzyme activity in crops (Răuciu & Miclăuș, 2015; Halgamuge, 2017). However, other studies have found minimal effects, particularly regarding proximate composition and nutritional quality (Nwankwo & Ibeh, 2015; Akpolat et

al., 2018). Exposure to electromagnetic radiation may influence biological and physiological processes in living organisms (Oludare et al., 2025). In Nigeria, research on power line effects on agriculture remains limited despite the widespread presence of transmission lines over farmlands (Ogunlade & Adegoke, 2020).

Problem statement: Farmers in Benue State have expressed concerns about cassava productivity and quality on farms near power lines, and potential health risks from consuming such cassava. However, no scientific investigation has been conducted to validate these claims. There is a lack of field-based data on how 33 kV power lines affect cassava tuber biochemical properties in this region.

MATERIALS AND METHODS

Materials

The following materials were used for this work: a TriField® EMF Meter (Model TF2) or equivalent gaussmeter for electromagnetic field measurements, GPS device such as a Garmin eTrex 30x or GPS-enabled smartphone for geolocation data. Essential field tools consist of a 50m measuring tape, digital weighing scale with 0-10kg capacity, an analytical balance, UV-Vis spectrophotometer, centrifuge, temperature-controlled water bath (30-100°C), hot air oven, pH meter, magnetic stirrer, vortex mixer, a set of micro pipettes, beakers, flasks, and test tubes

EMF Measurement

EMF levels were measured using a calibrated TriField® EMF Meter (Model TF2), capable of detecting electric fields (V/m) and magnetic fields (μT) at 50/60 Hz. Measurements were taken at plant canopy height (1.5 m above ground), three times per day (morning, afternoon, evening) for three months (90 days). Averages were calculated for each distance.

Sample collection and preparation

A field-based comparative design was employed. Cassava tubers (variety TME 419, 12 months maturity) were collected at six distances from the 33 kV power line: 0 m (directly beneath), 5 m, 10 m, 15 m, 20 m, and 50 m (control). Soil analysis confirmed homogeneity across sampling points (Table 2 of dissertation), with all three soil samples classified as loamy sand, moderately acidic (pH 5.55–5.71), with similar organic matter, cation exchange capacity, and particle size distribution.

Cassava tubers were harvested, washed, peeled, sliced, and oven-dried at 60°C to constant weight. Dried samples were milled into fine powder using a stainless-steel grinder, sieved (1 mm mesh), and stored in airtight containers.

Proximate Composition Analysis

The proximate composition was determined using the standard method of Association of Official Analytical Chemists (AOAC 2016): moisture (oven-drying), ash (muffle furnace at 550 °C), crude protein (Kjeldahl method, $N \times 6.25$), crude fat (Soxhlet extraction), crude fibre (acid-alkali digestion), and carbohydrate (by difference).

pH and titratable acidity

pH measured using a digital pH meter in a cassava-water slurry. Titratable acidity titrated with NaOH using phenolphthalein indicator, expressed as percent citric acid equivalent.

Cyanogenic Glycosides

Cyanogenic glycosides were determined using the alkaline picrate method, with absorbance read at 510 nm using a UV-Vis spectrophotometer. Results expressed in mg HCN/kg fresh weight.

Oxidative Stress Biomarkers

Malondialdehyde (MDA) was determined using TBARS assay; total phenolic content (TPC) using Folin–Ciocalteu reagent; antioxidant activity using DPPH radical scavenging assay.

Statistical analysis

Linear regression analysis was conducted to evaluate the relationship between EMF intensity (electric and magnetic fields) and distance from the power line. A trend-based interpretation was employed. All analyses were performed using SPSS version 25, with significance set at $p < 0.05$.

RESULTS AND DISCUSSION

EMF attenuation with distance

Electric field strength decreased from 792.1 V/m at 0 m to 33.1 V/m at 50 m. Magnetic field strength decreased from 3.1 μT at 0 m to 0.0 μT at 50 m (Table 1).

Table 1: EMF measurements at varying distances from 33 kV power line

Distance (m)	Electric Field Strength E, (V/m)	Magnetic Field Strength B, (μT)
0	792.1	3.1
5	605.9	2.4
10	421.2	1.4
15	291.4	0.6
20	133.4	0.2
50	033.1	0.0

Linear regression analysis revealed a significant inverse relationship between electric field strength and distance ($\beta = -13.9044$, $R^2 = 0.74$, $p = 0.027$), indicating that approximately 74% of the variation in electric field is explained by distance. Magnetic field strength also

exhibited a negative relationship ($\beta = -0.0566$, $R^2 = 0.64$), though this was marginally non-significant ($p = 0.056$). The plot of Emf against distance is shown in figure 1 below;

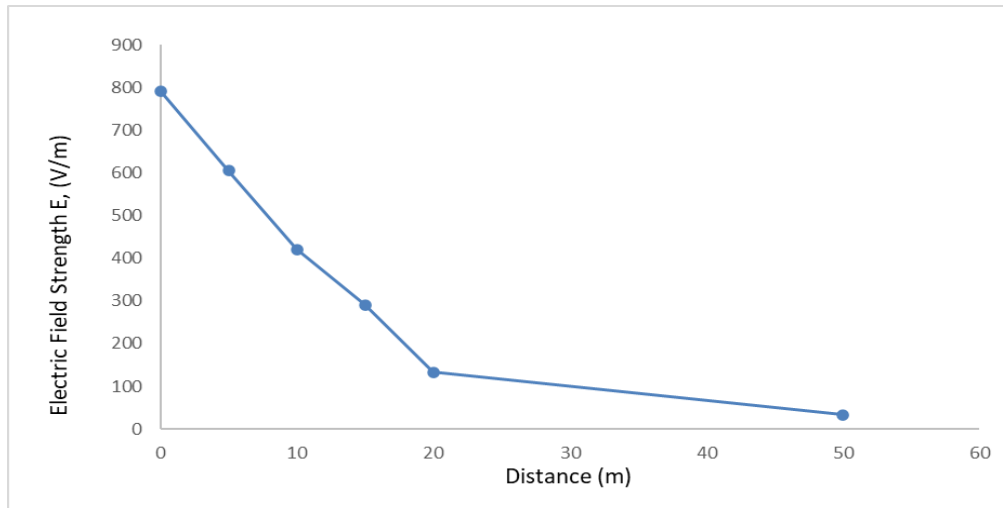


Figure 1a: Relationship Between EMF and Distance

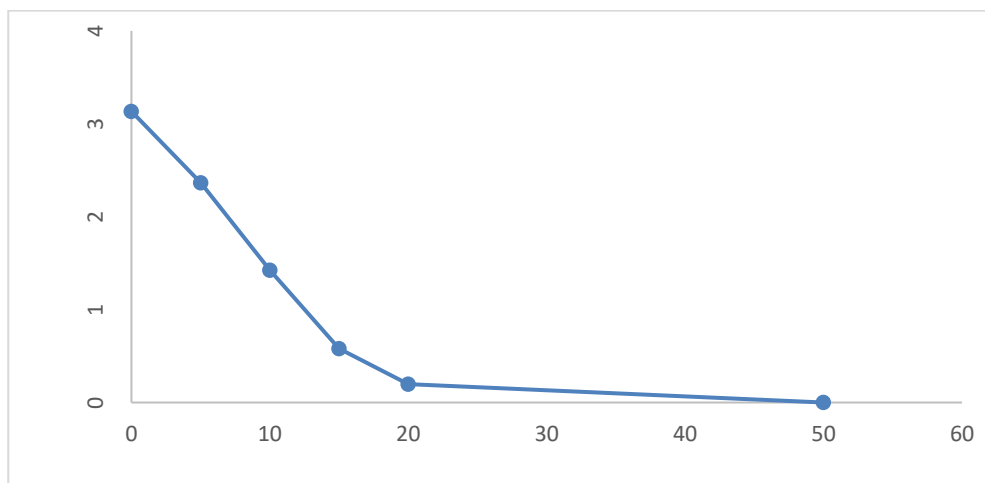


Figure 1b: Relationship Between EMF and Distance

Proximate composition

Proximate composition results showed fluctuations across sampling distances without any consistent

increasing or decreasing trend relative to distance from the power line (Table 2).

Table 2: Proximate composition of cassava tubers at different distances (%)

Distance	0 m	5 m	10 m	15 m	20 m	50 m
Unit	%	%	%	%	%	%
Carbohydrate	74.95	70.92	63.18	73.05	66.35	70.05
Protein	3.93	3.95	4.15	3.94	3.68	4.30
Fat	5.56	6.69	7.70	7.78	8.80	6.98
Fiber	6.55	6.89	6.78	6.12	6.91	6.46
Moisture	8.62	11.01	17.01	8.61	13.61	11.63
Ash	0.44	0.55	1.21	0.51	0.68	0.59

Carbohydrate content ranged from 63.18 % to 74.95 %. Protein remained relatively stable (3.68–4.30 %). Fat content peaked at 20 m (8.80 %). Moisture content displayed the widest range (8.61–17.01 %), with no discernible pattern related to EMF proximity. Ash content showed minimal variation (0.44–1.21 %). No parameter followed a consistent trend relative to distance.

pH and total titratable acidity (TTA)

pH values ranged from 1.60 to 2.05, with the lowest at 15 m. Titratable acidity ranged from 2.11% to 6.10%, with the highest also at 15 m (Table 3). No uniform pattern relative to distance was observed.

Table 3: pH and total titratable acidity of cassava tubers

Distance	0 m	5 m	10 m	15 m	20 m	50 m
pH	2.01	1.95	1.85	1.60	2.05	1.75
Total titratable acidity	2.30	2.51	3.00	6.10	2.11	3.76

Cyanogenic Glycoside Content

Cyanide concentration ranged from 0.013 to 0.35 mg HCN/kg (Table 4). The highest concentration occurred at 5 m (0.35 mg/kg), while the lowest was observed directly

beneath the power line at 0 m (0.013 mg/kg). No linear pattern relative to distance was observed, and all values remained within safe limits for cassava consumption.

Table 4: Cyanogenic glycoside content (mg HCN/kg)

Distance	0 m	5 m	10 m	15 m	20 m	50 m
Unit	HCN/kg	HCN/kg	HCN/kg	HCN/kg	HCN/kg	HCN/kg
Cyanide	0.013	0.35	0.112	0.075	0.028	0.195

Oxidative Stress Biomarkers

MDA values ranged from 14.57 to 166.04, showing irregular spikes at 5 m (166.04) and 50 m (127.63). TPC ranged from 13.92 to 158.63, with a large value at 50 m

suggesting a possible data anomaly. DPPH values ranged from 94.8 to 332.4 $\mu\text{g/mL}$, indicating wide variability in antioxidant activity (Table 5).

Table 5: Oxidative stress biomarkers in cassava tubers

Distance	0 m	5 m	10 m	15 m	20 m	50 m
Malondialdehyde	59.87	166.04	33.74	14.57	20.97	127.63
Total phenolic content	57.20	158.63	32.23	13.92	20.03	121.95
DPPH ($\mu\text{g/mL}$)	187.0	94.8	241.2	332.4	298.7	106.3

The absence of a consistent distance-dependent pattern strongly suggests that the observed fluctuations in oxidative stress markers are not EMF-induced but likely due to normal plant physiological variability or other environmental factors.

Discussion

This study demonstrated that EMF intensity from a 33 kV power line decreases significantly with distance for electric fields ($R^2 = 0.74$, $p = 0.027$) and shows a negative trend for magnetic fields, consistent with inverse-square law principles for electromagnetic field propagation from line sources. These findings align with ICNIRP (2020) characterisations of EMF behaviour around power lines. However, despite this predictable EMF attenuation, no consistent distance-dependent changes were observed in cassava proximate composition, pH, titratable acidity, cyanogenic glycosides, or oxidative stress biomarkers. Carbohydrate content (63.18–74.95%) and protein content (3.68–4.30%) fell within expected ranges for cassava, which typically contains 1–3 % protein on a dry

matter basis (Adugna Bayata, 2019). The absence of a consistent EMF effect on proximate composition is consistent with previous studies. Nwankwo and Ibeh (2015) reported that electromagnetic radiation did not significantly influence proximate composition of cassava, and Akpolat et al. (2018) found no substantial EMF effects on crop nutrient composition.

Cyanogenic glycoside levels (0.013–0.35 mg HCN/kg) remained well within safe limits for cassava consumption. The highest value (0.35 mg/kg) is far below the WHO (2004) guideline of 10 mg HCN/kg for safe sweet cassava varieties. This contrasts with earlier suggestions that EMF stress might upregulate cyanogenic glycoside synthesis (Elias et al., 2020; Nambisan, 2023). The irregular pattern observed; with the lowest value directly under the power line; suggests that factors other than EMF, such as soil moisture or individual plant variation, were more influential.

Oxidative stress biomarkers (MDA, TPC, DPPH) showed substantial variability without distance-dependent trends. The spike in MDA at 5 m (166.04)

followed by a low at 15 m (14.57) and another spike at 50 m (127.63) does not support a dose-response relationship. This pattern is consistent with literature reporting that EMF-induced oxidative stress is often inconsistent and non-dose-dependent (Aksenov et al., 2011; Farnsworth et al., 2019).

Soil homogeneity across sampling points (Table 2 of dissertation) was confirmed by analysis showing entire study location had loamy sand texture, pH 5.55–5.71, and similar exchangeable properties. This strengthens the conclusion that observed biochemical variations were not due to soil differences.

The physiological basis for the lack of EMF effect may relate to cassava's robust stress tolerance mechanisms. Cassava is known for its adaptability to marginal growing conditions, including drought tolerance and ability to thrive in poor soils (El-Sharkawy, 2021). The EMF levels measured (maximum 792.1 V/m and 3.1 μ T) are substantially below ICNIRP (2020) public exposure limits (5 kV/m and 200 μ T), suggesting they may be below the threshold required to induce measurable biochemical stress responses in this hardy crop.

Agricultural implications

The findings indicate that cassava cultivated near 33 kV power lines in Benue State is not nutritionally compromised by EMF exposure. Farmers' concerns about reduced cassava quality from power line proximity are not supported by the biochemical evidence from this study.

CONCLUSION

This study evaluated the effects of EMF exposure from a 33 kV power line on cassava tubers in Benue State, Nigeria. While electric field strength decreased significantly with distance, no consistent or significant EMF-induced alterations were observed in proximate composition, pH, titratable acidity, cyanogenic glycosides, or oxidative stress biomarkers. The irregular variations observed across distances are more likely attributable to normal plant physiological variability or environmental factors such as soil nutrient distribution and microclimate.

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