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Comparative Studies Of Mineral Composition In Maize, Melon, Okra And Cucumber Grown In Bayelsa State Farm.

Olubunmi Olusoga Ezomoh; And Sanusi Raliat Abike.
Department Of Biochemistry, Faculty Of Basic Medical Sciences, Niger Delta University.

Abstract
This study quantified heavy metal concentrations in four vegetable varieties using dry ashing digestion followed by atomic absorption spectrophotometric analysis. from the analyzed sample the okra has highest zinc value 1.1298 ppm and maize had the lowest zinc value 0.8965 ppm, for iron concentrations cucumber had the highest value 4.507 ppm with melon had the lowest value 2.597 ppm, the concentration of the other heavy metal analyzed from the samples were extremely very low and are the result of manganese indicate that sample okra had the highest value 0.305ppm with cucumber had the lowest value 0.0001. the concentration of lead ranged from 0.0001 to 0.0090 ppm among the samples. for cupper, samples cucumber had the lowest value 0.101 ppm and sample okra had 0.587 ppm as the highest value. the concentration levels of cadmium ranged from 0.210 to 0.492 ppm with sample melon had the lowest value and samples maize and cucumber had the highest level.
Keywords: *Concentration, Heavy metals, Vegetables, Atomic Absorption, Spectrophotometer, Okra, Cucumber.*

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I. Introduction

Increasing industrialization and economic development have substantially heightened global concerns about soil mineral contamination (Yang et al., 2018; Zhao et al., 2015). Anthropogenic sources including mining/smelting operations (Zhou et al., 2018; Shen et al., 2017), e-waste processing, and intensive agriculture contribute significantly to environmental mineral loading. Research by Zeng et al. (2020) revealed concerning exceedances, with 24.1% of vegetable field samples surpassing cadmium thresholds and 9.2% exceeding arsenic limits. Medicinal plants serve as crucial therapeutic resources for indigenous populations worldwide, offering treatment for various human and animal ailments (Cheeke, 2009; Radha et al., 2021). These botanicals contain essential macronutrients (carbohydrates, proteins, fats) that support fundamental physiological processes. Contemporary research increasingly focuses on plant-derived bioactive compounds, particularly their antioxidant, hypoglycemic, and hypolipidemic properties, for pharmaceutical and nutraceutical applications.

The bioaccumulation of both essential minerals and toxic elements in edible plant tissues can compromise their nutritional value and safety (Khan et al., 2015). This poses serious food safety challenges, as chronic exposure to metal-contaminated crops has been epidemiologically linked to various human pathologies (Jaishankar et al., 2014).

In geological sciences, minerals are defined as naturally occurring crystalline solids with distinct chemical compositions and atomic arrangements (Wenk et al., 2004; John & Rafferty, 2011). Wild edible plants constitute a significant dietary component, supplying essential macronutrients (carbohydrates, proteins, lipids) and serving as vital sources of micronutrients (vitamins and minerals) necessary for physiological balance. Notably, these undomesticated species often exhibit comparable or superior nutritional profiles relative to cultivated varieties (Ebert, 2014).

Recent research has increasingly focused on wild edible plants as sources of nutrition (Abdus Satter et al., 2016; Narzary et al., 2015; Seal et al., 2017) and traditional medicine for managing various pathologies including diabetes, cancer, and hepatic disorders (Mir, 2014). Oxidative stress has been identified as a key pathological mechanism underlying chronic conditions such as atherosclerosis, neurodegeneration, and immunosuppression (Young & Woodside, 2001). Scientific evidence confirms that plant-derived antioxidants can mitigate oxidative damage in biological systems (Cao et al., 1996). While synthetic antioxidants demonstrate efficacy, their prolonged use correlates with carcinogenic risks (Branen, 1975), driving research toward natural alternatives. Secondary metabolites including flavonoids, phenolic compounds, and alkaloids exhibit superior antioxidant potential (Cai et al., 2003; Zheng & Wang, 2001).

Maize

Maize/corn represents a globally significant crop with diverse applications and substantial economic value (Toensmeier, 2020). Cultivated across all inhabited continents, maize comprises approximately 50 varieties distinguished by color, texture, and kernel morphology, with white, yellow, and red types being most prevalent (Hallauer & Carena, 2009). Following its domestication in Mesoamerica (~1500 BCE), maize spread to Africa in the 16th century CE, rapidly becoming the continent's dominant cereal crop, with regional preferences favoring white or yellow varieties

Maize belongs to the Maydeae tribe within the Poaceae family. This monoecious annual grass exhibits remarkable phenotypic plasticity, adapting to diverse environmental conditions including variable moisture, light intensity, elevation and temperature regimes. While requiring human intervention for seed dispersal, it demonstrates exceptional photosynthetic efficiency. Genetically compatible with teosinte (its wild progenitor) but only experimentally crossable with Tripsacum species, maize predominantly undergoes wind-mediated outcrossing (Hochholdinger, 2009).

Maize thrives in well-aerated, loose soils with balanced drainage and water retention capacity. Heavy clay soils or excessively sandy substrates with poor drainage are unsuitable. The crop demonstrates optimal growth within a pH range of 5.8-6.8, with yields potentially decreasing by 35% at pH 5.0. Zea mays exhibits moderate sensitivity to soil salinity levels.

Okra

Abelmoschus esculentus (commonly called okra, okro or lady's fingers) is a mallow family (Malvaceae) species valued for its edible green seed pods. While its precise geographic origin remains debated - with proposed sources including West Africa, Ethiopia, and South/Southeast Asia - this crop is now globally cultivated across tropical and warm temperate zones, featuring prominently in diverse culinary traditions.

The mucilage-rich pods of okra offer substantial nutritional value despite being low-calorie, serving as an excellent source of dietary fiber. Research has identified numerous bioactive components including ascorbic acid, β-carotene, B-complex vitamins (thiamine, riboflavin, niacin, folate), oxalic acid, and essential amino acids. This hairy annual herb features cordate, palmatifid leaves (3-5 lobes) and hibiscus-like flowers with yellow petals and crimson centers. Its characteristic angled capsules (10-25 cm long) contain multiple oval seeds, with only immature pods being consumed. While originating in Eastern Hemisphere tropics, okra is now extensively cultivated across global tropical and subtropical regions.

Cucumber

Cucumber is an annual cucurbitaceous vine cultivated for its cylindrical to spherical pepo fruits, botanically classified as berries but utilized culinarily as vegetables (Silvertown, 1985). Comprising 95% water, cucumbers are categorized into three primary groups: pickling, slicing and seedless varieties. While nutritionally dilute, they contain bioactive compounds like cucurbitacin C - a bitter-tasting defensive phytochemical against herbivores (Liu et al., 2019; Shang et al., 2014). Research indicates various extracts exhibit antioxidant (Chu et al., 2002) and amylolytic (Repka & Fischerova, 1999) properties, though most studies employed harsh extraction methods (organic solvents or high temperatures). Comparative analyses reveal both methanolic fruit and ethanolic leaf/stem extracts contain alkaloids, saponins, glycosides, and tannins (Mallik et al., 2013; Said et al., 2014), with the latter demonstrating mild antifungal activity against dermatophytes and yeasts, plus moderate cytotoxicity in brine shrimp assays (Mallik et al., 2013).

Melon

Cucumis melo, a trailing member of the Cucurbitaceae family, is cultivated globally in warm climates for its fragrant, edible fruits. Originating in Central Asia, this species has diversified into numerous cultivars, most notably sweet dessert varieties consumed fresh, while certain types are processed into preserves or pickles.

Cucumis melo plants are frost-sensitive annuals characterized by pubescent, trailing stems and grasping tendrils. Their morphology includes large palmate leaves and monoecious yellow flowers (2.5cm diameter). The fruits are pepo-type berries exhibiting substantial varietal diversity in size (1-4 kg), morphology, exocarp texture, and mesocarp characteristics. Ripeness indicators differ by cultivar: cantaloupes exhibit abscission ("slipping") and aromatic volatiles, while honeydew varieties require color change assessment (yellowing). Winter melons (honeydew/casaba) demonstrate post-harvest maturation without significant sugar accumulation. Pathogen susceptibility includes multiple fungal diseases (powdery/downy mildews, Fusarium wilt, anthracnose), with resistance varying among cultivars.

Heavy Metal

Heavy metals are defined as metallic elements exhibiting both elevated atomic density and significant toxicity at minimal exposure levels. (Lenntech, 2004). The classification "heavy metals" encompasses metallic and metalloid elements possessing an atomic density exceeding 4 g/cm³ or demonstrating at least fivefold greater density than water. (Nriagu, 1989; Huton and Symon, 1986; Nriagu and Pacyna 1988; Garbarino *et al*., 1995, Hawkes, 1997 Battarbee *et al*., 1988). The classification as a heavy metal depends more on chemical behavior than physical density. This group comprises Pb, Cd, Zn, Hg, As, Ag, Cr, Cu, Fe, and platinum-group metals. The environment comprises the complete set of external conditions and factors that collectively influence an organism's life processes, including its growth, development, and survival (Farlex, 2005). The environment encompasses both biotic components (flora and fauna) and abiotic factors across aquatic, terrestrial, and atmospheric systems. It includes not only physical elements like air, water, and nutrients but also the critical yet less visible social and ecological communities that shape living conditions (Gore, 1997). A pollutant refers to any environmental contaminant that exceeds established threshold limits, producing detrimental effects on ecosystem health and human wellbeing. Environmental pollution occurs when such harmful substances - whether chemical, physical, or biological agents are present in air, water or soil at concentrations capable of causing ecological damage or organismal toxicity.

Toxicity

Many heavy metals demonstrate carcinogenic potential (Tchounwou, 2012), with even essential elements like Cu and Zn - despite their roles in enzymatic processes and genetic regulation - capable of inducing malignancies and other pathologies at elevated concentrations (Fergusson, 1990; Hambidge & Krebs, 2007). Their toxicity primarily operates through ROS-mediated oxidative damage pathways (Bánfalvi, 2011). Paradoxically, these hazardous metals remain integral to industrial applications, appearing in batteries, automotive emissions, and even children's products through pigmented materials (Finch et al., 2015).

Cadmium

Cadmium (Cd) occurs minimally in natural environments, primarily entering ecosystems through industrial and agricultural contamination (Wilson et al., 2006). Despite its extreme toxicity, Cd finds application in battery manufacturing, metal plating (Morrow, 1990; Sathyanarayana et al., 1979), and as a pigment component in various art supplies (Kawasaki et al., 2004). The principal toxic mechanism involves oxidative stress, with animal studies demonstrating Cd's capacity to impair hepatic and renal antioxidant defenses (Shaikh et al., 1999; Casalino et al., 2002). Chronic exposure triggers metallothionein (MT) gene upregulation, forming Cd-MT complexes that accumulate in renal tubules. This process induces tubular cell deformation and glomerular dysfunction, ultimately disrupting calcium homeostasis and promoting nephrolithiasis and renal carcinogenesis (Nordberg et al., 1975; Dudley, 1985).

Zinc

As an essential transition metal, zinc predominantly exists in its Zn^{2+} state in biological systems. This micronutrient participates as a cofactor in numerous enzymatic processes critical for DNA synthesis, cellular membrane integrity, retinol metabolism, and sensory functions (Terrin et al., 2015). Serum zinc concentrations typically range from 109-130 μg/dL, with dietary requirements varying across demographic groups.

The mechanisms of zinc toxicity are exposure-dependent, varying considerably between acute and chronic intake scenarios. Both the administration route and delivered dose critically determine the pathological manifestations.

Acute zinc toxicity manifests differently depending on exposure route. Oral ingestion of zinc salts (sulfate/chloride) produces direct GI corrosion, resulting in hematemesis and potential renal damage from hematuria to acute tubular necrosis (Barceloux, 1999). Parenteral overdose can induce multisystem failure (ARDS, hepatic necrosis, coagulopathies). Inhalation of zinc fumes triggers metal fume fever - a nanoparticle-induced inflammatory response causing respiratory irritation and systemic flu-like symptoms through incompletely understood mechanisms.

Iron

In adult males, total body iron averages 4.5 g, distributed primarily in hemoglobin (65%), myoglobin/cytochromes (10%), and storage proteins (20-30%). Iron catalyzes ROS production via Fenton chemistry, converting superoxide/hydrogen peroxide into hydroxyl radicals (Crichton et al., 2002). These reactive species preferentially attack 8-OHG, creating oxidative DNA lesions linked to mutagenesis. Lipid peroxidation generates additional radicals (ROO·, RO·) with prolonged half-lives that induce cumulative cellular damage during iron overload conditions.

Manganese

Manganese (Mn) is a recognized neurotoxicant that preferentially targets the basal ganglia. Chronic overexposure can induce motor impairments resembling Parkinson's disease (tremors, bradykinesia) along with cognitive deficits, particularly in executive function domains.

Lead

Lead represents the most abundant heavy metal contaminant in our environment, with both metallic and compound forms being utilized since antiquity (Nriagu, 1992). Historical applications ranged from Roman industrial uses (water pipes, tableware) to medicinal preparations and even as a wine additive ("sugar of lead") until the 1800s (Machiej, 2014). While lead itself lacks redox activity, it promotes oxidative stress through indirect mechanisms: enhancing ROS production via oxyhemoglobin interactions (Ribarov & Bochev, 1982) and disrupting cellular antioxidant defenses (Gurer and Ercal, 2000). These effects collectively overwhelm endogenous protective systems, leading to oxidative damage (Kathuria et al., 2018).

Copper

Copper serves as an essential cofactor for numerous proteins, with virtually all bodily copper existing in protein-bound form. Free Cu^{2+} ions exhibit significant toxicity, necessitating strict genetic regulation of copper incorporation into apoproteins and homeostasis maintenance. The biliary system eliminates any copper exceeding physiological needs.

Potassium

As the predominant intracellular cation, potassium (K^+) is vital for maintaining physiological equilibrium (Giebisch, 1998). Approximately 98% of total body potassium resides intracellularly, with skeletal muscle containing 80% of these stores. The typical 40-100 mEq daily intake undergoes rapid cellular uptake via insulin-mediated mechanisms post-absorption, preventing dangerous plasma concentration spikes. Renal excretion (90%) and colonic secretion (10%) maintain balance by matching dietary intake under normal conditions.

Sodium

Soil salinization poses a growing challenge to global agriculture, with over 40% of irrigated lands affected by elevated salt concentrations. Research demonstrates that under saline conditions, Na^+ enters root cells through cation-permeable transporters (Amtmann et al., 1997), disrupting cellular ion homeostasis. This Na^+ influx competes with essential nutrients like Ca^{2+} and K^+ for uptake pathways (Tyerman et al., 1997), ultimately leading to cytotoxic sodium accumulation (Kingsbury & Epstein, 1986)

II. Materials And Methods

Sample collection

The produce samples analyzed in this study were collected from the College of Health Sciences at Niger Delta University, Amassoma, Bayelsa State, Nigeria.

Sample preparation

The fruit and vegetable underwent dry ashing digestion: 2g aliquots were weighed into crucibles and dehydrated at 105°C. Samples were then transferred to a muffle furnace for gradual temperature ramping to 550°C, maintaining this temperature for 8 hours to ensure complete mineralization. After cooling in a desiccator, the resulting ash was solubilized with 1ml concentrated HCl and diluted to 25ml with deionized water. The solution was filtered through ashless filter paper and refrigerated pending AAS analysis.

Atomic Abosrptioin Spectrophotometer (AAS)

This method is based on the Beer-Lambert principle establishing a direct correlation between absorbance and analyte concentration. AAS quantifies elemental composition by comparing sample absorption against calibrated standards. The instrument configuration includes: an element-specific hollow cathode lamp emitting characteristic wavelengths, a flame atomization system (acetylene/air), optical wavelength isolation components, and a photomultiplier detection system. Measurement involves first establishing a baseline flame reading, then determining sample concentration through differential light absorption at the resonant wavelength.

III. Results

Table 4.1 Concentration of the metals in some selected vegetable (Okra), Maize, Melon and Cucumber

Metals	Zn	Fe	Mn	Pb	Cd	Cu	K	Na
OKRA	1.130 ±0.046	3.451 ±0.031	0.305 ±0.16	0.0072 ±0.0023	0.455 ±0.046	0.587 ±0.023	48.538 ±0.035	23.105 ±0.54
MAIZE	0.897 ±0.027	4.079 ±0.027	0.078 ±0.013	0.0075 ±0.0015	0.492 ±0.022	0.302 ±0.033	53.021 ±0.012	16.818 ±0.64
MELON	1.273 ±0.048	2.597 ±0.048	0.215 ±0.025	0.0090 ±0.0031	0.210 ±0.012	0.2498 ±0.035	33.340 ±0.22	25.935 ±0.026
CUCUMBER	1.034 ±0.018	4.507 ±0.033	0.0001 ±0	0.0001 ±0	0.492 ±0.076	0.101 ±0.017	35.070 ±0.045	9.336 ±0.034

The results were Mean ± SD, OKRA=Okra, MAIZE= Maize, MELON=Melon, CUCUMBER=Cucumber

The table 4.1 show the concentrations in part per millions of various metals analyzed in the samples where OKRA has highest Zinc value (1.1298 ppm) and MAIZE had the lowest Zinc value (0.8965 ppm). For iron concentrations CUCUMBER had the highest value (4.507 ppm) with AS3 had the lowest value (2.597ppm). The result of Manganese indicate that sample OKRA had the highest value (0.305ppm) with CUCUMBER had the lowest value (0.0001). The concentration of Lead ranged from (0.0001 to 0.0090) ppm among the samples. The concentration levels of cadmium ranged from (0.210 to 0.492) ppm with sample MELON had the lowest value and samples MAIZE and CUCUMBER had the highest level. For Cupper, samples CUCUMBER had the lowest value (0.101 ppm) and sample OKRA had (0.587 ppm) as the highest value. Meanwhile, the level of Potassium ranged from (33.340 to 53.021) ppm in samples MELON and MAIZE as the lowest and the highest concentration values respectively. Also, samples CUCUMBER and MELON with concentration levels of (9.336 ppm) and (25.935 ppm) as the lowest and the highest concentration for Sodium in the samples analyzed.

Key

Code No	**Sample Names**
SA1	**Okra**
SA2	**Maize**
SA3	**Melon**
SA4	**Cucumber**

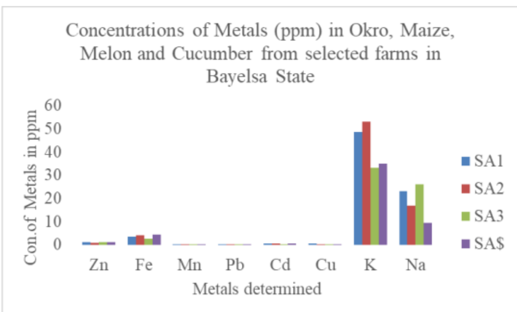
Table 4.3 Pearson correlation coefficient of metals determined (Okra, Maize, Melon and cucumber)

	Zn	Fe	Mn	Pb	Cd	Cu	K	Na
Zn	1							
Fe	-0.83818	1						
Mn	0.621142	-0.7609	1					
Pb	0.334179	-0.78824	0.710285	1				
Cd	-0.85262	0.906936	-0.43494	-0.55851	1			
Cu	0.136655	-0.34413	0.851552	0.565526	0.080904	1		
K	-0.65811	0.270949	0.174165	0.337772	0.591647	0.619551	1	
Na	0.680621	-0.94445	0.892098	0.903031	-0.72253	0.613072	0.046775	1

Table 4.5 Pearson's Correlation interpretation.

S/No	Degree of Correlation	Types of Correlation
1	±0.00 to ±0.20	Negligible
2	±0.20 to ±0.40	Low
3	±0.40 to± 0.70	Moderate
4	±0.70 to± 0.90	High
5	±0.90 ±1.00	Very High
6	±1.00	Perfect

The above table was used to interpreted the interrelationship between the elements.



IV. Discussion

The standard recommendations for each of the element determined by FAO/WHO are: Cd (0.2 mg/kg), Pb (0.3 mg/kg), Fe (425.5 mg/kg), Cu (73.3 mg/kg), Zn (99.4 mg/kg), Mn (2.3mg/kg) (WHO. 1989). Likewise, NAFDAC also recommended Cd (0.1 mg/kg), Pb (0.2mg/kg), Fe (14 mg/kg), Cu (73.3 mg/kg), Zn (11 mg/kg), K (2,500mg/kg), Na (2g), Mn (50-100mg/kg)

The table 4.1 show the concentrations in part per millions of various metals analyzed in the samples OKRA has highest Zinc value (1.1298 ppm) and MAIZE had the lowest Zinc value (0.8965 ppm). From the analyzed samples in this study the concentration of zinc in all the samples are below World Health Organization (WHO) permissible limits, in a report by Assayomo, *et al*., 2022, who carried out heavy metals analysis on soil from Amassoma, he find out that the detection of zinc in the soil is very insignificant, this is in an agreement with this report the zinc content of the vegetables are extremely very low.

For iron concentrations CUCUMBER (cucumber) had the highest value (4.507 ppm) with MELON had the lowest value (2.597 ppm). The concentration of cucumber gotten from this study is below WHO permissible limit and also NAFDAC permissible limit

The concentration of the other heavy metal analyzed from the samples were extremely very low and are the result of Manganese indicate that sample OKRA had the highest value (0.305ppm) with CUCUMBER had the lowest value (0.0001). The concentration of Lead ranged from (0.0001 to 0.0090) ppm among the samples. For Cupper, samples CUCUMBER had the lowest value (0.101 ppm) and sample OKRA had (0.587 ppm) as the highest value.

The concentration levels of cadmium ranged from (0.210 to 0.492) ppm with sample MELON had the lowest value and samples MAIZE and CUCUMBER had the highest level, in all the samples analyzed the concentration of cadmium was above WHO permissible limits.

The level of potassium and sodium were extremely high in all the analyzed samples.

Table 2 was used to interpreted the interrelationship between the elements, from the table, the consumers of these samples will be obtaining multiple macro and micro elements in their food/ diet, which will improve the well-being and general health conditions. While, Negatively Negligible, low, and moderate heavy metals show that there is little or no point source or a common source of these toxic metals in the analyzed samples but in case of Pb and Na (r=0.903031) with high correlation it shows there is a point or common source of the toxic metal from the sample analyzed from the natural background level at a certain period.

The low level of heavy metal in these samples may be as a result of the less usage of inorganic fertilizers and herbicides in the sampling areas.

The concentration of heavy metal gotten from this report is above those that were reported by Opaluwa *et al*., 2012, who worked on the concentration of different crop plants in nassara state, Nigeria.

V. Conclusion

From the result obtained from the various plant crops, it can be deduced that the level of almost all the analyzed metals were below World Health Organization permissible limits except cadmium, which indicated that the crop samples will have little or no effect to human health when consumed.

VI. Recommendation

The use of inorganic fertilizers can be a gate for these metals to get access into the root system of these plants and bioaccumulate into the plants, hence the less usage of this inorganic substance will reduce the exposure of these metals to the soil, the organic manures have less of these heavy metals and the using them in farm lands will improve the growth and well-being of the plants generally.

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