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**COMPARATIVE ASSESSMENT OF HEAVY METAL CONTENTS OF  
*TELFAIRIA OCCIDENTALIS* (FRUITED PUMPKIN) LEAVES IN  
ANAMBRA MARKETS, NIGERIA**

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**ABSTRACT**

Plants normally take up nutrients, as well as pollutants from the soil, which they can biaccumulate. Fluted pumpkin (*Telfairia occidentalis*) is one of the highly cultivated and commercial green leafy vegetables with general acceptance in many states in Nigeria including Anambra state. The soil environment where green vegetables are planted and harvested in Nigeria, exposes them to contaminations by various heavy metals. Polluted air is one principal source of heavy metal contamination of soil, as metals are liberated into the atmosphere and laid on nearby road side soils due to automobile emissions. This study investigated the levels of some heavy metals in fluted pumpkin (*Telfairia occidentalis*) leaves, and their potential health risks to consumers within Anambra State, Nigeria, while further comparing the quantities between urban and rural areas and between three geopolitical zones in the state. Heavy metals were analyzed using standard atomic adsorption spectrophotometer. All the detected heavy metals had their concentrations above acceptable limits, and posed

significant health risks. The urban vegetable samples had higher amounts of the heavy metals than the rural vegetable samples. The results also showed that the mean values of lead, cadmium, mercury, chromium and arsenic in the selected urban and rural vegetable samples were not significantly different ( $p>0.05$ ). This study highlighted the need for enhanced regulatory frameworks, steady monitoring of heavy metal content of plants, intensive awareness campaigns, and the promotion of safer methods of cultivation or handling of leafy vegetables, without exposure to pollution by heavy metals in urban and rural settings.

**KEY WORDS:** Bioaccumulation, Health risks, Heavy metals, *Telfairia occidentalis*

## INTRODUCTION

### Background of study

The plant, Fluted pumpkin (*Telfairia occidentalis*) remains one of the most highly cultivated and commercial green leafy vegetables with general acceptance in many communities in Nigeria (Nwosu *et al.*, 2012). The soil environment where leafy green vegetables are planted and harvested in Nigeria, exposes them to contaminations by various heavy metals which are in substantial quantities in lands, harboring wastes from industries, agrochemicals wastewater and automobile used engines. This has continued to attract attention considering the fact that these heavy metals can be absorbed, and build up in the vegetable leaves over a period of time. Naturally, the heavy metals are found in soils; and geological and anthropogenic factors cause them to be highly concentrated such that they are hazardous to plants, animals and micro-organisms. Those typically present in polluted areas are lead (Pb), cadmium (Cd), chromium (Cr), Mercury (Hg), Arsenic (As), Zinc (Zn), Copper (Cu), and nickel (Ni) (GWRTAC, 1997). Most of these metals do not have any microbial or chemical degeneration (Kirpichtchikova *et al.*, 2006). Once heavy metals gain entry into the soil, they remain there for a long time (Andiano, 2003) though there may be changes in their form (speciation) and bioavailability. Studies have shown that unrestricted developments in non-rural areas, have accounted for high concentrations of heavy metals in the environment (Njoku-Tony *et al.*, 2020)).

Polluted air is one principal source of heavy metal contamination of soil, as metals are liberated into the atmosphere and laid on nearby road side soils due to automobile emissions (Panichaypichet *et al.*, 2007). Lead, Zinc, Cadmium and Copper are the chief metal pollutants at the road side areas because the metals are emitted from fuel burning, vehicle tyres wearing out, oil leakage, corrosion of batteries and metallic parts such as radiators (Dolan *et al.*, 2006).

Considering the unpleasant health effects of exposure to vegetables contaminated by heavy metals, it is extremely important to frequently examine public health risk connected with short and prolonged detrimental effects of metal accumulations in frequently consumed vegetables. Hence, this study was aimed at investigating the levels of some heavy metals in selected fluted pumpkin leaves, in both rural and urban areas of Anambra state of Nigeria, and comparing them to permissible limits, to ascertain their potential health risk to exposed consumers.

### **Aim of study**

The aim of this research is to investigate the concentrations of some heavy metal residues in fluted pumpkin (*Telfairia occidentalis*) gotten from selected urban markets (Eke Awka Market, Ose Market Onitsha, and Nkwo Nnewi Market) and selected rural markets (Ogbunike Market, Okofia Market, and Nwaagu Market Agulu) from Anambra North, Anambra South and Anambra Central respectively, and compare their concentrations to the permissible limit.

### **Statement of problem**

Heavy metals and metalloids can play crucial roles in plant development by taking part in metabolic reactions and by acting as micronutrients (e.g., Fe, Zn, Mn, Co, Cu, and Mo). When they are beyond their acceptable concentrations however, their functions are seen to be noxious to plant development. Both essential and nonessential micronutrients when surplus in the human body, cause negative effects on health. Additionally, there is a shortage of comprehensive health risk assessments to evaluate the possible dangers these heavy metal residues may pose to consumers. This research aims to address this knowledge gap by determining the levels of heavy metal remains in fluted pumpkin leaves sold in selected markets in Anambra State and assessing the health risks connected to it.

### **Justification for the study**

Fluted Pumpkin leaves belong to the Cucurbitaceae family together with cucumbers, gourds, squashes, and melons. Fluted Pumpkin leaves are held in high esteem in many countries in Africa, and often cooked in local delicacies. Heavy metal contamination of food products is one of most relevant components of food quality assurance (Khana and Khanna, 2011). Vegetables also take up heavy metals in quantities that could lead to so much clinical challenges to the consumers (Bahemuka and Mubofu, 1999). Given these concerns, it is of utmost significance to assess the health risks linked to heavy metal remains in fluted pumpkin

leaves sold in the local markets. It is also essential to evaluate compliance with regulatory standards, and make data available to inform policy interventions. By focusing on these markets, the study will address a critical breach in local food safety research and contribute to protecting consumer health and enhancing agricultural practices in Anambra State.

### **Hypothesis**

Fluted pumpkin leaves sourced from the selected urban markets (Eke Awka Market, Ose Market Onitsha, and Nkwo Nnewi Market), will contain significantly higher levels of heavy metals (such as lead, cadmium, and arsenic) compared to those gotten from the selected rural markets (Ogbunike Market, Okofia Market, and Nwaagu Market).

### **Scope of study**

The scope of this study centres on fluted pumpkin leaves sold in the selected urban markets (Eke Awka Market, Ose Market, and Nkwo Nnewi Market) and the rural markets selected (Ogbunike Market, Okofia Market, and Nwaagu Market), given their significance as major trading hubs for fresh agricultural produce in southeastern Nigeria. The study included sampling and laboratory analysis to ascertain and quantify the heavy metal residues in fluted pumpkin leaves. Additionally, the study contributes to public consciousness regarding the precarious effects of heavy metal remains in vegetables and emphasizes the necessity for safer agricultural practices by fluted pumpkin farmers.

### **Origin and geographical distribution of *Telfairia occidentalis***

Fluted pumpkin, scientifically named *Telfairia occidentalis*, is considered to have come from the southeastern part of Nigeria, and is extensively grown in the forest regions of West and Central Africa, especially in countries like Nigeria, Benin, and Cameroon. It is a well-known vegetable all over Nigeria. It is scarce in Uganda, and missing in the rest of East Africa. It has been proposed that it originated in south-east Nigeria and was spread by the Igbo people, who have planted this crop quite longer than could be remembered. It is also called "ugu" (Igbo), "ugwu" (Yoruba), and "ekobon" (Cameroonians).



**Figure 1: Picture of *Telfairia occidentalis*.**

The fluted pumpkin is a dioecious perennial plant, that is ordinarily grown with sticks for support. It climbs with the coiled, often branched tendrils to a height of more than 20 m, and can survive in drought. The leaves are arranged spirally, pedately compound having 3–5 leaflets; stipules are absent; petiole is (2–4) to (11–15) cm long; leaflets have petiolules that are 0.5–3.5 cm long, central one is broadest, about (15–19) cm × (10–12) cm, lateral ones are not symmetrical, usually dentate in the upper two-thirds, sometimes rough underneath, and 3-veined from near the base. Male inflorescence, an axillary raceme up to (3–5.5) cm long, on a peduncle about 25 cm long, at base of peduncle, one long-pedicellate flower flowering long before the others; female flowers solitary in leaf axils. *T. occidentalis* flowers grow in sets of five, with creamy-white and dark red petals, pedicel about 4 cm long, receptacle is campanulate, sepals are triangular, could be about 5 mm long, petals are free, oblong, fringed; male flowers with 3 stamens, two 4-locular and one 2-locular, with large reddish connective; female flowers are identical to male flowers but with inferior, cylindrical, 3-celled ovary and three large, and heart-shaped stigmas. The fruit is an ellipsoid berry (40–95) cm × (20–50) cm, weighing about 6 kg, with 10 conspicuous ribs, pale green and covered with white bloom wax, yellow fruit pulp with many seeds, and drooping. Seeds are condensed and ovoid, up to 4.5 cm long, could be black or brown-red. Seedling undergoes hypogeal germination, developing first a taproot and then profuse, spreading axillary roots; epicotyl is 5–12 cm long; cotyledons are planoconvex, and fleshy. There are branching roots in the top surface of the soil and the stem is angular, glabrous, and becomes fibrous when old.

### **Cultivation and Growth Requirements**

Fluted pumpkin can be cultivated under a broad array of soil conditions. It can be managed as a short-term perennial when grown on well-drained soils, slightly shaded and mulched to retain soil moisture. On soggy soils and in sunlit sites, it can only be grown as an annual. Fluted pumpkin grows quick in the warm humid tropics, producing edible leaves in the wet season and at the start of the dry season, for 6–10 months. Although it fairly survives in drought, rainfall or watering appears to be the most important factor in its productivity. The best leaf and fruit produced, and highest plant survival rate occur when the plants are supplied water 2–3 times a week in the dry season.

### **Propagation**

Fluted pumpkin is propagated by seeds, which can be sown in the field directly or commenced in nurseries. Germination occurs within 7–10 days under suitable conditions. The traditional method of propagation is by seed, sown directly at a rate of 30,000–70,000 seeds per hectare, and spaced at (0.3–1) m × (0.3–1) m. Densely spaced plants are most suitable for leaf production, while the wider spacing favors fruit production when staked. Depending on rainfall, type of soil and cropping pattern, fluted pumpkin can be planted on a flat land or on ridges or mounds. In southern Nigeria, application of Phosphorus was found to be especially essential, as Nitrogen and Potassium only enlarge yields when mixed with application of Phosphorus. Organic manures like compost or poultry droppings, can also be applied.

### **Health and economic benefits of fluted pumpkin vegetable**

Fluted pumpkin leaves are a source of dietary fiber that helps preserve health of the digestive system. It plays a critical role in improving digestion, thereby lessening health conditions such as irritable bowel movement, constipation, and those caused by indigestion problems like ulcers and gastroparesis. The protein and vitamin contents of this vegetable help preserve healthy tissues, cells, membranes, and skin and treat wounds in the case of vitamin C. They are rich in alkaloids, resins, hydrocyanic acid, tannins, and flavonoids, powerful antioxidants that provide some immune system and anti-inflammatory benefits. High antioxidant content in foods is proficient in preventing cancer and other related health conditions like ulcers, because they can inhibit the damages that oxidative stress have ability to cause in the body. Fluted pumpkin leaves are a reliable source of essential vitamins (A, C), calcium, iron, and other micronutrients. Vegetable has high protein content. Fluted pumpkin leaves contain the

protein needed for hormone balancing; tissue repairs and controls the acidity of body cells and organs. Consuming fluted pumpkin leaves is important, because their protein content will also help improve the body cells and replace worn-out ones. It has an anti-diabetic effect, indicating it can treat diabetes mellitus by reducing glucose in the blood. It is possible due to the availability of polysaccharides and ethyl acetate, which have effectively lowered blood sugar levels. They also effectively promote glucose tolerance and serum insulin. The extract of the leaves has proved suitable in this case, and it has been used as an anti-diabetic agent to regulate the blood sugar level. Fluted pumpkin leaves are always suggested for patients who suffer from hypovolemia due to certain illnesses; the presence of iron and other essential minerals contributes to boosting blood in the body system and prevents anemia. To help enhance blood production, leaves are recommended to be pounded, then strain the mashed vegetable to collect the liquid or juice. Fluted pumpkin vegetables contain a good quantity of calcium required to maintain healthy bones and teeth and keep the skeletal systems functioning normally. It also contains magnesium, which is required in making the bone firm and strong. It may be surprising to say that calcium is almost without effect to bones without magnesium, as it helps the adequate uptake of calcium by the bones. Fluted pumpkin leaves also contain potassium, which also helps preserve bone mineral density. It helps to inhibit osteoporosis, which affects the bones, especially in the elderly. Fluted pumpkin leaves have been discovered to be efficient in treating convulsions in children. It becomes medicinal when shredded and mixed with coconut water and a small amount of salt. Scientifically, there might be no evidence, but it was used hundreds of years ago, to treat high fever and convulsion as well as other health conditions. Vegetables such as fluted pumpkin leaves contain a large amount of dietary fiber, which can help you lose weight as it makes you fuller and lowers your appetite. It contains little or no calories, eliminating the chances of accumulating more calories in the body. Fluted pumpkin leaves have been used traditionally to treat infertility challenges in both men and women. The vital nutrients and compounds have proven effective in its use to improve sperm count in men and the total functioning of their testicles. It enhances fertility in women and improves post-pregnancy health as it helps the nursing mother adequately feed their babies, by increasing breast milk production. Fluted pumpkin leaves, just like most green leafy vegetables, have certain compounds that help to enhance memory. It also contains essential nutrients such as vitamins and magnesium, for the improvement and normal activity of the brain and nervous system. It can help to ameliorate cognitive reasoning, memory loss (dementia), and other health conditions connected with memory health, such as Alzheimer's disease.

### **Economic Benefits**

Fluted pumpkin leaves are a well-known and highly consumed vegetable, creating a constant demand and opportunity for farmers to earn income through their cultivation and trade. As a normally eaten vegetable, fluted pumpkin leaves share in food security in the region, ensuring a readily available and alimental food source for local communities. Fluted pumpkin leaves and seeds have conventional uses, including being used as a blood tonic and in various cuisines. The leaves are sold in local markets, adding to the local economy and making employment opportunities available for traders and vendors.

### **Overview of heavy metals and their classification**

Heavy metals are a general collective term for metals and metalloids that have relatively high density and are deleterious even at very trace levels. These metals are discharged into the environment through geological and anthropogenic sources such as industrial wastes, vehicles emissions, and mining. Compared to organic contaminants, heavy metals are non-biodegradable and have the ability to build up in living beings (Manavi *et al.*, 2019). The heavy metals can be broadly classified into two categories- essential and nonessential heavy metals. Essential heavy metals are those needed by living organisms for performing the indispensable processes like growth, metabolism, and development of diverse organs. They include Cu, Fe, Mn, Co, Zn and Ni needed by plants as they become the cofactors that are structurally and functionally crucial for enzymes and other proteins. Essential elements also called micronutrients, are often required in infinitesimal quantities in the level of 10-15 ppm. Nonessential heavy metals like Pb, Cd, Hg, Cr and Al are not needed by plants, even in quite small levels, for any of the metabolic processes (Sarmistha *et al.*, 2021). Some studies also differentiate heavy metals into hazard classes (Ojovan *et al.*, 2005), such as high-hazard (As, Cd, Hg, Pb), medium-hazard (B, Co, Ni, Cu, Sb, Cr), and low-hazard (Ba, V, W, Mn, Sr). Some studies also grouped them into macronutrient elements, micronutrient elements, highly toxic elements, precious elements and radionuclides.

### **Sources of exposure of heavy metals to vegetables**

Vegetables can be exposed to heavy metals through polluted soil, water, and air, originating from industrial activities, agricultural practices (fertilizers, pesticides), and natural causes like rock weathering, volcanic eruptions and soil erosion. Metals may seep into the ground, ground water, and finally enter crop plants. Heavy metals can have negative effects on human health when vegetables containing these metals are eaten. Although minute levels of nickel

(Ni), copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn) are required in plants, substantial quantities of these metals can be quite harmful. Metals including aluminium (Al), lead (Pb), arsenic (As), mercury (Hg), and cadmium (Cd), are not necessary for regular bodily functions and can cause toxicity without delay (Boyd *et al.*, 2013).

### **Mechanism of toxicity of heavy metals**

These mechanisms of toxicity are the basis for the health risks connected with the ingestion of contaminated vegetables. By drinking or eating foods, fruits and vegetables, heavy metals like arsenic, cadmium, manganese, as well as lead could be introduced into the body via the gastrointestinal system or digestive system. The greater portion of heavy metals are carried from blood to tissues of the body. Red blood cells transfer lead to the liver as well as kidneys, where it is further re-assigned as phosphate salt to the teeth, bone and hair. Cadmium first attaches to red blood cells and albumin and later, to metallothionein in the kidney as well as liver. It is carried through the blood to the lungs. Vapor of manganese is distributed over the pleural membranes to the central nervous system. Water soluble inorganic manganese ions are also distributed in the plasma, and the kidney for renal excretion, whereas fat soluble manganese salts are diffused in the gut for anal excretion. Accumulated arsenic in the heart, lungs, liver, kidneys, muscles, neural tissues, skin, nails, and hair, is subsequently being dispersed by blood circulation. Free radicals are known to be generated by some heavy metals, which can result in oxidative stressing as well as cellular damaging. The pattern by which free radicals are formed is peculiar to heavy metal. Heavy metals are acetified by the acidic medium of the stomach when they are ingested as food or drink. They are oxidized to different oxidative states ( $Zn^{2+}$ ,  $Cd^{2+}$ ,  $Pb^{2+}$ ,  $As^{2+}$ ,  $As^{3+}$ ,  $Ag^+$ ,  $Hg^{2+}$ , etc.) in this acidic media, which can immediately bind to biological molecules especially proteins, such as enzymes to develop into persistent and strong complexes. The most predominant functional groups that heavy metals bind to, are the thio groups (SH group of cysteine and  $SCH_3$  group of methionine). Cadmium had shown to combine with cysteine remains in the catalytic surface of human thiol transfers in vitro, consisting of thioredoxin reductase, glutathione reductase, and thioredoxin. Heavy metal-bounded proteins might be useful as a substratum by some enzymes. The heavy metal-bounded protein has an enzyme-substrate combination in a particular order, which inhibits the enzyme from absorbing any more substrates till it is liberated. Considering the fact that the enzyme is being inhibited, the product of substratum is not formed, and the heavy metal becomes persistent in the tissues, leading to dysfunctions, abnormalities, and damage.

### **Health implications of heavy metal residues**

Heavy metals in soil, air, as well as water are a stringent problem since they will have a detrimental consequence on food sustainability and human health. Intake of heavy metal-contaminating vegetables can result in a lot of health issues in consumers. Vegetable eating is the fundamental route for heavy metals to infect humans. Cadmium had been found to have negative effects on vital enzymes. The adverse consequences might include a discomforting bone condition called osteomalacia, to destruction of the red blood cell and renal disorders. High levels of lead in the blood can stimulate hypertension, nephritis, and cardiovascular illness, and also affect children's brain development. Copper alongside Zinc, can lead to acute gastrointestinal issues and liver damage. Arsenic exposure is associated with angiosarcoma, and skin cancer. Zinc, on the other hand, can negatively affect immunological functions and, increase plasma levels of the high density lipoproteins albeit conflicting opinions.

Eating of heavy metal-polluted food can decrease some bodily nutrients that are necessary, leading to weakened immune system, impaired physico-social behavior, stunted intrauterine growth, and problems associated with malnourishment. Metal poisoning has also been connected with mutagenic, neurotoxic, teratogenic, or carcinogenic repercussions, which might be acute, chronic, or sub-chronic. The heavy metal exposure in the period of pregnancy, connected to fetal development has been widely ascertained. Heavy metals have ability to harm the female reproductive system thereby causing damage to the ovaries, and alter hormone production and release. (Kumar, 2004) found that heavy metals can cause impairments in the morphology and function of the ovaries, as well as embryonic development. In vivo and in vitro findings have indicated the accumulation of heavy metals in the ovaries. Lead in the body of the pregnant females, has been linked to incidence of lower birth weights, stillbirths, spontaneous abortions, preterm births, and hypertension (Grant *et al.*, 2013), while Arsenic in the body of the pregnant females has been discovered to cause fetal loss, stillbirths, spontaneous abortions, impaired growth and development. Cadmium exposure is also associated with incidence of low birth weight. Arsenic has potential to cause spontaneous abortions and neurotoxicity. Copper toxicity causes decreased birth weights, spontaneous abortions, and gestational diabetes. The incidence of stillbirths, miscarriages, and impaired fetal development, have also been indicated as a result of mercury poisoning. (Benefice *et al.*, 2010) revealed that women who had miscarriages had high methylmercury levels, indicating a connection between methyl mercury exposure, and spontaneous abortion.

**Table 1. Heavy metals, applications and health effects.**

Heavy metal	Applications	Health effects
Chromium	Paints, pigment, fungicide, pesticide	Cancer, nephritis and ulceration
Lead	plastic, batteries, auto exhaust, gasoline	Risk of cardiovascular disease and neurotoxic diseases
Cadmium	Pigments, fertilizer, plastics	Disrupts endocrine system, carcinogenic, alters calcium regulation in biological systems, mutagenic, lung damage, fragile bones
Zinc	Fertilisers	Dizziness, fatigue, vomiting, renal damage, decreased immune function
Nickel	Electroplating	Lung cancer, immuno-toxic, allergic diseases, neurotoxic, genotoxic, infertility
Copper	Electronics, wood preservative, Architecture	Brain damage, chronic anaemia, kidney damage, Intestine irritation, liver cirrhosis, spontaneous abortions and gestational diabetes
Arsenic	Pesticides, Wood products & herbicides	Immunological, reproductive and developmental impairments, carcinogenic
Mercury	Catalysts, Electric Switches, rectifiers, CFLs	Neurological and immune disorders, fatal to kidney and lungs

**Maximum permissible limit of heavy metals**

Heavy metals have deleterious repercussions on the natural environment and living things as well, being carcinogenic and toxic. Since some of them have the potential to build up in the body, the harm they do to living organisms may be greater than the damage caused by other contaminants that cannot bioaccumulate. The maximum permissible limits for heavy metals differ based on the particular metal, the medium (water, soil, food, etc.), and the regulatory body (e.g., WHO, EPA). MPLs are frequently kept up to date depending on new toxicological data and environmental considerations. The World Health Organization (WHO) and Food and Agriculture Organization (FAO) have provided guideline values for the acceptable limits of heavy metals in food, and leafy vegetables, primarily through the Codex Alimentarius and other technical reports.

**Table 2. Maximum Permissible Limits of heavy metals.**

Heavy Metal Types	Maximum Permissible Limits	Reference
Cadmium (Cd)	0.2 mg/kg	Codex Alimentarius Commission (CAC)
Lead (Pb)	0.3 mg/kg	Codex Alimentarius Commission (CAC)

Mercury (Hg)	Not specified for vegetables; primarily set for fish	
Arsenic (As)	0.1 mg/kg (inorganic form)	WHO/FAO Joint Expert Committee on Food Additives (JECFA)
Chromium (Cr)	Not specified; toxicity depends on valence state	

## MATERIALS AND METHOD

### Study area

The study location was some major markets in Anambra State, which is situated in the southeastern region of Nigeria, located on latitudes 5°32' and 6°45'N and longitudes 6°43' and 7°22'E respectively, and has an estimated land area of 4,865sq km. Anambra State is a hub of trade center and well known for lots of agricultural produce including fruits, vegetables, yams, fishes among others, which gave rise to several markets within the state. The urban markets selected are Eke Awka Market, Ose Market, and Nkwo Nnewi Market while the rural markets selected are Ogbunike Market, Okofia Market, and Nwaagu Market.

### Materials

Chemicals/Reagents used: aqua regia (acid mixture of 65ml conc HNO<sub>3</sub>, 8ml perchloric acid and 2ml conc H<sub>2</sub>SO<sub>4</sub>).

Equipment used: sterile polythene bags, digestion flask, electric hot plate, dessicator, Whatman filter papers, sample vial, Atomic Absorption Spectrophotometer.

### Sample collection

At each market, the vegetable samples were randomly selected. The selected samples were put into different sterile polythene bags and labelled appropriately to avoid mistakes. A fluted pumpkin vegetable sample was pressed for 10 days before taking it to the department of Pharmacognosy and Traditional Medicine where a pharmacognosist, Mrs. Onwunyili Amaka identified the plant as *Telfairia occidentalis* (family of Curcubitaceae) PCG/ 474/ C/ 026, before they were transported to the laboratory for extraction and analysis.

### Digestion of vegetable sample for heavy metal analysis

The samples were cut into small pieces, and air-dried in the laboratory. The dried samples were pulverized separately and sieved. 2g of the vegetable samples each, were measured into a digestion flask containing 20ml of aqua regia (acid mixture of 65ml conc HNO<sub>3</sub>, 8ml perchloric acid and 2ml conc H<sub>2</sub>SO<sub>4</sub>). The mixture sample in the flask was heated on electric hot plate at temperature of 65°C until a clear digest was obtained. The digest was unplugged,

and allowed to cool in a dessicator. The digest was diluted with distilled water to the 100ml mark, filtered with Whatman filter paper and the filtrate was stored in a sample vial for heavy metal assay. The process was done for each vegetable sample.

### Atomic Absorption Spectrophotometer (AAS)

Atomic absorption spectrometer's working principle is built basically on the sample being aspirated into the flame and atomized when the AAS's light beam from the monochromator, is directed through the flame onto the detector that measures the amount of light absorbed by the atomized element in the flame when ignited. Metal elements on their own, have distinct characteristic wavelength on the source hollow cathode lamp composed of the element/metals to be analyzed. The amount of energy of the characteristic wavelength absorbed in the flame is directly proportional to the concentration of the element in the tested sample. The sample is aspirated into the oxidizing air-acetylene flame. When the aqueous sample is aspirated, the sensitivity for 1% absorption is observed.

### Statistical analysis

Data gotten from the experiment was analyzed using ANOVA with Statistical Product for social sciences (SPSS) software. Outcomes was recorded as mean  $\pm$  standard error of mean (SEM). Mean values with  $p < 0.05$  was considered statistically significant. Statistical analysis of data was done using SPSS version 22.

## RESULTS AND DISCUSSION

### Results

**Table 3: Mean concentrations of heavy metals in *Telfairia occidentalis* in urban markets.**

Market	Lead (Pb) mg/l	Cadmium (Cd) mg/l	Mercury (Hg) mg/l	Chromium (Cr) mg/l	Arsenic (As) mg/l
Nkwo Nnewi	0.263	0.010	0.125	0.437	0.164
Ose Onitsha	0.437	0.038	0.169	0.250	0.119
Eke Awka	0.428	0.055	0.039	0.088	0.089
<b>Mean-Mean <math>\pm</math> S.E.M</b>	<b>0.376 <math>\pm</math> 0.06</b>	<b>0.034 <math>\pm</math> 0.01</b>	<b>0.111 <math>\pm</math> 0.04</b>	<b>0.258 <math>\pm</math> 0.10</b>	<b>0.124 <math>\pm</math> 0.02</b>

**Table 4: Mean concentrations of heavy metals in *Telfairia occidentalis* in rural markets.**

Market	Lead (Pb) mg/l	Cadmium (Cd) mg/l	Mercury (Hg) mg/l	Chromium (Cr) mg/l	Arsenic (As) mg/l
Ogbunike	0.034	0.015	0.070	0.067	0.139
Okofia Nnewi	0.444	0.002	0.117	0.194	0.035
Nwagu Agulu	0.385	0.038	0.086	0.315	0.057

Mean-Mean $\pm$ S.E.M	0.288 $\pm$ 0.13	0.018 $\pm$ 0.01	0.091 $\pm$ 0.01	0.192 $\pm$ 0.07	0.077 $\pm$ 0.03
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**Table 5: Comparison of heavy metal concentrations in urban and rural markets.**

S/n	Heavy metal	Mean-mean urban conc. (mg/l) $\pm$ S.E.M	Mean-mean rural conc. (mg/l) $\pm$ S.E.M	P-value
1	Lead	0.376 $\pm$ 0.06	0.288 $\pm$ 0.13	0.607675
2	Cadmium	0.034 $\pm$ 0.01	0.018 $\pm$ 0.01	0.314572
3	Mercury	0.111 $\pm$ 0.04	0.091 $\pm$ 0.01	0.973555
4	Chromium	0.258 $\pm$ 0.10	0.192 $\pm$ 0.07	0.486769
5	Arsenic	0.124 $\pm$ 0.02	0.077 $\pm$ 0.03	0.089292

## DISCUSSION

There were varying concentrations (mg/l) of the heavy metals (Pb, Cd, Hg, Cr and As) in the fluted pumpkin vegetable samples, sourced from the selected urban markets (Eke Awka Market, Ose Market, and Nkwo Nnewi Market) and the rural markets selected (Ogbunike Market, Okofia Market, and Nwaagu Market) from Anambra North, Anambra South and Anambra Central respectively.

In Table 3, the mean values of the heavy metals in the vegetable samples, gotten from the urban markets were recorded as mean  $\pm$  standard error of mean, and their mean-mean  $\pm$  standard error of mean were calculated. Mean values of Pb ranged from 0.263 to 0.437, with Ose having the highest Pb content and Nkwo Nnewi having the least. The mean concentration (0.376  $\pm$  0.06) suggests that the Pb contents are notably elevated, especially in Ose and Eke Awka vegetable samples. This may indicate higher levels of environmental contamination in those markets, potentially due to traffic emissions, industrial activities, or soil and water pollution. Chukwumati *et al.* (2023) compared fluted pumpkin vegetables growing along busy urban roads to the rural controls near Uniport-Choba, and observed that urban specimen had greater Pb levels. Okwelle & Marcus (2023) equally reported fluted pumpkin from urban dumpsites in Port Harcourt, had Pb in leaves higher than rural controls. Mean values of Cd ranged from 0.010 to 0.055, with Eke Awka having the highest Cd content and Nkwo Nnewi having the lowest. The mean (0.034  $\pm$  0.01) indicates moderate cadmium contents, though Eke Awka's mean value is well above the mean. Since Cd is a harmful metal with cumulative outcomes, its relatively high amount in Eke Awka vegetable sample might raise concerns for prolonged exposure. According to another research by Bayissa & Gebeyehu (2021), Cd concentrations in tomato and cabbage were also high. Mean values of Hg ranged from 0.039 to 0.169, with Ose having the highest Hg level and Eke Awka having the least. The mean level (0.111  $\pm$  0.04) implies that mercury is more prevalent

in Ose and Nkwo Nnewi vegetable samples, which may be due to industrial activities or improper waste disposal. The disparity suggests localized environmental differences affecting metal bioaccumulation in the vegetables. Zhang *et al.*, (2017) studied vegetable and grain samples (lettuce, amaranth, water spinach, tomato, eggplant, pepper, cucumber, cowpea, rice, maize) gathered from farmlands near two coal-fired power plants, and discovered they exhibited high mercury concentrations, especially in the leaves.

Mean values of Cr ranged from 0.088 to 0.437, with Nkwo Nnewi having the highest Cr level and Eke Awka having the lowest. The mean (0.258) shows Nkwo Nnewi vegetable sample as an outlier, with significantly elevated chromium levels. Chromium content may be associated with metal-based workshops or industrial activities. According to (Wang *et al.*, 2023)), chromium (Cr) concentration in vegetable samples was also high. Mean values of As ranged from 0.089 to 0.164, with Nkwo Nnewi having the highest As content and Eke Awka having the lowest. The mean ( $0.124 \pm 0.02$ ) shows a moderate level of arsenic in the vegetable samples, but the wide standard error in Eke Awka suggests considerable variability. Arsenic may be absorbed from pesticide residues or contaminated irrigation water. In plants, arsenic is taken up through the root and is translocated to the shoot and grains (Neidhardt *et al.* 2015). In Table 4, the mean values of the heavy metals in the vegetable samples, gotten from the rural markets were recorded as mean $\pm$ standard error of mean, and their mean-mean $\pm$ standard error of mean were calculated. Mean values of Pb ranged from 0.034 to 0.444, with Okofia having the highest Pb content and Ogbunike having the lowest. The mean value ( $0.288 \pm 0.13$ ) is increased due to the high Pb in Okofia and Nwaagu vegetable samples. Ojiego *et al.*, (2022) found lead at Okofia and Nwaagu vegetable samples may be due to localized contamination, potentially from roadside farming, lead polluted soil or water. Mean values of Cd ranged from 0.002 to 0.038 with Nwaagu having the highest Cd level and Okofia having the least. The mean concentration ( $0.018 \pm 0.01$ ) is relatively low, but Nwaagu's value is over 19 times that of Okofia. Cd content may come from phosphate fertilizers or natural soil composition. Shumaker *et al.*, (2005) revealed that winter wheat (*Triticum aestivum*) can be used as indicator for Cd pollution in soil, as its root and shoot accumulated high concentrations of Cd.

Mean values of Hg ranged from 0.070 to 0.117, with Okofia having the highest Hg content and Ogbunike having the lowest. The mean ( $0.091 \pm 0.01$ ) shows that all three vegetable samples had similar levels, with Okofia vegetable sample being slightly elevated. It suggests likelihood of exposure to mercury through atmospheric deposition, pesticides, or waste contamination. Bayissa & Gebeyehu (2021) added that cabbage and tomato showed

considerable amounts of Hg. Mean values of Cr ranged from 0.067 to 0.315, with Nwaagu having the highest and Ogbunike having the least. The mean ( $0.192 \pm 0.07$ ) reflects moderate Cr levels, but Nwaagu's mean value is significantly above the mean, indicating localized chromium pollution, possibly from industrial processes or contaminated irrigation water. Among the several vegetables studied, (Memon *et al.*, 2020; Zayed *et al.*, 1998) stated that certain species in the Brassicaceae family also had the highest Cr levels. Mean values of As ranged from 0.035 to 0.139, with Ogbunike having the highest As level and Okofia having the least. The mean ( $0.077 \pm 0.03$ ) is moderate, though Ogbunike is nearly twice the average, suggesting arsenic exposure could be through soil water contamination, or use of arsenic-containing agrochemicals. In their study, Bayissa & Gebeyehu (2021) indicated that cabbage and tomato were contaminated, with cabbage showing higher arsenic accumulation.

In Table 5, the p-values of the trace metals were calculated and recorded together with the mean-mean  $\pm$  standard error of mean. The trace metals showed no significant difference ( $p > 0.05$ ) between locations. For lead, urban mean (0.376 mg/L) is higher than rural mean (0.288 mg/L). The p-value = 0.608 reflects no statistically significant difference. This suggests that both rural and urban vegetables have comparable Pb levels, although urban produce may be more exposed to traffic or industrial pollution. For cadmium, urban mean (0.034 mg/L) is almost double that of the rural mean (0.018 mg/L). The p-value = 0.315 shows no statistically significant difference. Urban markets may still have slightly higher exposure, possibly due to fertilizer residues or wastewater irrigation. For mercury, urban mean (0.111 mg/L) is relatively same as rural mean (0.091 mg/L). The p-value = 0.974 means no statistically significant difference. This could suggest similar atmospheric deposition patterns or use of similar water sources for irrigation. For chromium, urban mean (0.258 mg/L) exceeds rural mean (0.192 mg/L), though both are moderately high. The p-value = 0.487 shows no statistically significant difference. Chromium may originate from tools, fertilizers, or industrial pollutants, and affects both locations. Urban mean indicates higher As levels (0.124 mg/L) compared to rural mean (0.077 mg/L). The p-value = 0.089 is the closest to significance and suggests a potential trend toward elevated arsenic in urban environments. This could be associated with urban pesticide use, polluted water sources, or industrial emissions. The trace metals exceeded the WHO maximum permissible limits. Similar observations of heavy metal contaminated fluted pumpkin or leafy vegetables exceeding the maximum permissible limits have been reported previously (Ara *et al.*, 2018; Eteng *et al.* 2021; Njoku-Tony *et al.* 2020; Orubite *et al.*, 2015).

In Anambra North; Ose vegetable sample (urban) had the highest mercury content and relatively high cadmium content. Ogbunike vegetable sample (rural) had the least chromium level. In Anambra South; Nkwo Nnewi vegetable sample (urban) showed highest chromium level while Okofia vegetable sample (rural) had the least cadmium and arsenic levels, suggesting minimal anthropogenic contamination and it is the cleanest. In Anambra Central; Eke Awka vegetable sample (urban) had the highest cadmium content and Nwaagu vegetable sample (rural) showed high chromium and mercury content, indicating potential health risks. This could be linked to variations in locations of the study areas, and the extent of pollution of the irrigation water used, air and soil where the vegetables were cultivated. Lead, cadmium, mercury, chromium and arsenic levels were higher in urban markets than in the rural markets so, this result agreed with the hypothesis that fluted pumpkin leaves sourced from the selected urban markets (Eke Awka Market, Ose Market, and Nkwo Nnewi Market), will contain significantly higher levels of heavy metals (such as lead, cadmium, and arsenic) compared to those gotten from the selected rural markets (Ogbunike Market, Okofia Market, and Nwaagu Market). Studies assessing leafy vegetables (including fluted pumpkin) in Kwara urban markets and rural farms found significantly higher levels of Pb, Cd, Hg, Cr and others in urban market samples. Kacholi *et al.*, (2018) investigated many African vegetable species and observed that matembele (*Ipomoea batatas*) plants had the highest heavy metal concentrations, followed by mchicha (*Amaranthus hybridus*), eggplant (*Solanum melongena*), and bamia (*Abelmoschus esculentus*).

## CONCLUSION

The findings emphasize the variability of heavy metal contamination within and across the three geopolitical zones, with urban areas being more polluted, though certain rural locations also show signs of concern, and calls for regular monitoring, strict environmental regulations, and safe agricultural practices in urban and rural settings.

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## Disclosure of conflict of interest

Ogbonnaya Mba declared no conflict of interest

Okeke Ebere Maryvera declared no conflict of interest

Harrison Odera Abone declared no conflict of interest

Daniel Ikechukwu Oraekei declared no conflict of interest

Onyeka Chinwuba Obidiegwu declared no conflict of interest

### **Statement of ethical approval**

This was not applicable in this research because, neither animals nor humans were used.

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