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Proximate and Mineral Composition of *Talinum triangulare* (Waterleaf) from Quarry and Non-Quarry Sites in Port Harcourt: Implications for Nutrition and Food Safety

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ABSTRACT

Background: Quarrying activities have been shown to influence the geochemical properties of surrounding soils, potentially affecting edible plants' nutrient and heavy metal composition. *Talinum triangulare* (waterleaf), a commonly consumed leafy vegetable in Nigeria, may indicate environmental contamination due to its widespread cultivation and consumption.

Objectives: This research focused on assessing the proximate and mineral composition of waterleaf samples from a quarry site in Eleme and a non-quarry site in Igwuruta, Port Harcourt, Nigeria, to assess the influence of quarrying on nutritional quality and heavy metal content.

Methods: Waterleaf samples were collected from both sites, sun-dried, and analyzed for proximate composition (carbohydrates, protein, moisture, ash, fat, fiber) using AOAC methods. Mineral and heavy metal contents (potassium, calcium, magnesium, sodium, phosphorus, copper, manganese, zinc, iron, lead, cadmium, nickel) were determined via atomic absorption spectroscopy and flame photometry. Data were analyzed using one-way ANOVA ($p < 0.05$).

Results: Quarry site samples showed slightly higher carbohydrate (56.34%) and ash (8.47%) contents but lower protein (11.85%), moisture (5.67%), and fat (6.53%) compared to control samples (54.10%, 13.30%, 6.39%, 7.34%, 7.62%, respectively). Fiber content remained consistent (~11%). Essential minerals like potassium, calcium, and iron were present appreciably, with quarry site samples showing elevated levels of copper (1.58 mg/100g) and manganese (5.35 mg/100g). Notably, lead (0.21 mg/100g), cadmium (0.52 mg/100g), and nickel (0.38 mg/100g) were detected exclusively in quarry samples (dry weight). Approximate fresh weight conversions (assuming 90% moisture) yield cadmium (0.052 mg/100g) and nickel (0.038 mg/100g) exceeding WHO/FAO limits (0.02 mg/100g for Cd, 0.1 mg/100g for Ni), while lead (0.021 mg/100g) is within limits (<0.1 mg/kg).

Conclusions: Although waterleaf remains an important nutrient source, heavy metals from the quarry site sample indicate health risks. Regular monitoring of crops grown in such industrially impacted areas is recommended.

Keywords: Heavy Metals; Mineral Composition; Proximate Analysis; *Talinum triangulare*; Nutritional Quality; Food Safety; Environmental Contamination; Quarry Site; Atomic Absorption Spectroscopy; Flame Photometry; Health Risks; Bioaccumulation.

1. Introduction

In the quest for rapid industrialisation and economic growth, several nations, including Nigeria, are exploiting natural resources to fuel their economy, and modern equipment in construction work is being used to carry out quarrying. Quarrying, the process of extracting non-metallic and non-fuel minerals from rock, is an activity that involves extensive equipment and profoundly affects the landscape on which it takes place; this is as a result of the increase in construction materials to support the rising population and housing construction. Quarrying has economic importance, as a matter of fact, minerals extraction, including quarrying of durable goods, contributed a total of 5.37 trillion naira to Nigeria's Gross Domestic Product in 2021, making it the second-largest supersector [1]. However, it has substantial environmental and health impacts, especially on the surrounding ecosystems and human populations [2,3].

Extracting stones like granite, limestone, and sand from quarries, as done in Eleme, Port Harcourt, involves using explosives to break the rock into submission. These can, in turn, have severe environmental implications, such as air and noise pollution and the leaching out of heavy metals into the water and soil around them [4]. Heavy metals generally released from quarrying can accumulate in plants and ultimately flow into the human food chain through agricultural products grown in and around these areas. One of the plants commonly grown near quarry sites in southern Nigeria is *Talinum triangulare* (waterleaf), a widely consumed leafy vegetable that is highly susceptible to heavy metal extraction from the soil [5,6].

Leafy vegetables are crucial in the diets of many households across Nigeria. Beyond enhancing meal variety, they serve as essential nutrient sources—particularly in rural communities—providing fibres, vitamins, minerals, protein, and other nutrients often lacking in daily food intake. Additionally, they enhance meals with colour, variety, flavour, taste, and visual appeal, helping to break the monotony of regular diets [7,8]. It is worth noting that consuming numerous edible plants as food sources could benefit populations facing nutritional challenges, especially in developing nations where climate change and poverty are severely impacting the rural population. In several developing nations, mineral availability falls short of the needs of livestock and expanding populations, as animals cannot produce minerals independently and must rely on mineral-enriched water or plants [9,10].

Talium Triangulare

Waterleaf (*Talinum triangulare*), a herbaceous, fast-growing perennial plant from the Portulaceae family, is indigenous to tropical regions [11,12]. This leafy vegetable got its common name “Waterleaf” because of its high moisture content of fresh waterleaf (about 90.8 g/100g), making it an integral component of various traditional dishes in many parts of Nigeria where it is cultivated extensively [13]. Waterleaf typically grows to a height of 30 to 100 cm. Its branches feature two lateral basal buds, and the plant has succulent stems and swollen roots. The leaves are usually clustered at the top of the stem, spirally arranged to be nearly opposite [14]. Waterleaf demonstrates notable tolerance for drought conditions by adopting a crassulacean acid metabolism (CAM) pathway, thus allowing it to use moisture efficiently, absorb carbon dioxide at night, and enhance its growth [15].

The phytochemical analysis of *Talinum triangulare* was conducted on both dried and fresh samples following the methodology outlined by Harbourne [16], as documented by Ezekwe et al. [17], Sofowora [18], and Tiamiyu's PhD Thesis [19], to ascertain its active constituents. The results of the phytochemistry revealed that the leaves contain bioactive compounds, including anthraquinones, tannins, phlobatannins, cardiac glycosides, alkaloids, terpenes, steroids, saponins, phenols, and flavonoids. Some bioactive compounds were found in significant amounts, while others were present in moderate amounts or detected in trace quantities.

Table 1. The phytochemical composition of the fresh leaves of *Talinum triangulare*

S/N	Bioactive Compounds	Relative Abundance
1	Carbohydrates	+++
2	Flavonoids	+++
3	Reducing Sugars	+
4	Alkaloids	++
5	Terpenoids	+++
6	Glycosides	++
7	Resins	+++
8	Saponins	+
9	Tannins	+
10	Fats and Oils	+
11	Steroids	++
12	Proteins	+++

Adapted from: Ezekwe et al. [17]

Table 2. The phytochemical composition of the dried leaves of *Talinum triangulare*

S/N	Bioactive Compounds	Relative Abundance
1	Phenols (PPP)	+++
2	Flavonoids	+
3	Anthraquinones	+
4	Cardenolides	-
5	Tannins (PP)	++
6	Phlobatannins	+++
7	Terpenes	+
8	Alkaloids	+++
9	Cardiac Glycosides	++
10	Terpenes	+
11	Chalcones	-
12	Steroids	+

Observation Remarks:

- +++ = Substantial quantity present
- ++ = Moderate quantity present
- + = Trace quantity present
- – = Absent

Adapted from: Tiamiyu [19]

Moreover, previous studies have reported the antidiabetic, hepatoprotective, antioxidative, and other bioactivities of *T. triangulare* [20]. Furthermore, evidence supports the existence of bioactive phytochemicals in the *T. triangulare* leaves, which have many biological activities, including Quercetin. This bioactive compound has shown antiviral, antiallergenic, antidiabetic, antibacterial, anti-inflammatory, and analgesic properties [21].

Ingesting vegetables grown in contaminated sites, particularly quarry sites, presents a serious threat to public health. Vegetables like *Talinum triangulare* cultivated in areas affected by quarrying can absorb heavy metals from the soil. Upon ingestion, these vegetables introduce a toxic substance into the human body that might accumulate and lead to chronic health problems [22]. Studies by Ogbonnaya & Phil-Eze [5] demonstrated that heavy metals commonly found in quarry dust harm plants and humans. High concentrations of these metals in plants can inhibit growth and reduce resistance to pests and diseases [23]. In humans, consuming the contaminated vegetables can result in acute or chronic toxicity to some organs and systems [24].

Although some consumers may consider the dark green, undamaged, and large leaves as signs of high-quality leafy green vegetables, appearance on the outside does not guarantee that the veggies are free of contaminants. According to Mapanda et al. [25], heavy metals are significant pollutants in leafy vegetables. Given the continuous accumulation and potential toxic effects of heavy metals from vegetable consumption, it is imperative to analyse and evaluate these food items from time to time for their trace element levels, following the international permitted limits [26].

In this research, we intend to study the nutritional profile, including proximate and mineral composition, of the *Talinum triangulare* samples collected from the quarry site in Eleme, Port Harcourt, and compare it with that of the control samples from a non-quarry site in Igwuruta, Port-Harcourt. The focus will be on assessing essential minerals and heavy metals like copper and zinc levels. This study emphasises the probable hazard of the consumption of crops cultivated in and around quarrying sites by comparing the mineral composition of waterleaf planted in contaminated and non-contaminated soils.

This study's outcomes will contribute important knowledge regarding the environmental and health impacts of quarrying activities on agricultural practices in Port Harcourt. Furthermore, it will highlight the need for the routine monitoring and evaluation of food crops cultivated in industrial-prone sites to protect consumers and ameliorate food safety risks associated with heavy metal contamination.

1.1. Study Objectives

The key aims of this research include:

1. To analyse the proximate composition (carbohydrates, fat, protein, ash, fibre, and moisture) of *Talinum triangulare* (waterleaf) samples collected from a quarry site in Eleme and a non-quarry site in Igwuruta, Port Harcourt, Nigeria.

2. To evaluate the mineral composition, including essential minerals (phosphorus, sodium, magnesium, calcium, and potassium) and trace elements (magnesium, iron, zinc, copper), as well as heavy metals (nickel, cadmium, lead), in waterleaf samples from both sites.

3. To compare the nutritional profiles of waterleaf samples from the quarry and non-quarry sites to assess the impact of quarrying activities on nutrient content and potential heavy metal contamination.

4. To evaluate the potential environmental and health implications of consuming waterleaf grown near quarry sites, focusing on the risks of heavy metal accumulation.

2. Materials and Methods

2.1. Sample sources, collection, and preparation

The waterleaf samples utilised in this research were obtained from two locations in Rivers State, Nigeria: Eleme and Igwututa. At the time of collection, the former had downstream quarry activities and is located between latitude 4°48'23" North and longitude 7°07'04" East. The latter, our control, had no quarry activities and is located between latitude 4°56'29.1" North and longitude 7°02'28.8" East. All samples were collected aseptically in plastic bags using simple farm tools and promptly delivered to a laboratory.

The waterleaf samples underwent destalking and then thoroughly rinsed under running water to remove any sand and debris. Afterwards, the samples were dried in an oven at 105°C for 4-6 hours to a constant weight, determined by two consecutive weighings showing a difference of less than 0.1%, following AOAC guidelines to ensure uniform moisture removal. Once dried, the samples were blended into a powder using a blender and then sieved to achieve a fine powder consistency. Note: Mineral and heavy metal concentrations are reported on a dry weight basis. An approximate conversion to fresh weight is intended, assuming a moisture content of approximately 90% in fresh waterleaf, to facilitate comparison with WHO/FAO limits.

2.2. Determination of Proximate and Mineral Composition

The samples' proximate composition, including ash, protein, fat, moisture, carbohydrates, and fiber, was analysed following the Association of Official Analytical Chemists (AOAC) method. The nitrogen content was measured using the micro-Kjeldahl method, and the percentage of nitrogen was converted to crude protein by multiplying by 6.25. Additionally, minerals were evaluated using atomic absorption spectroscopy. The following procedures are outlined below:

2.2.1. Determination of Crude Fat/Lipid

In the Soxhlet extraction process, the crude fat content of a food sample is determined through solvent extraction, followed by measuring the weight of the recovered fat. This approach provides a reliable assessment of the fat percentage in the sample. The principle of this extraction is based on fats being soluble in certain organic solvents like hexane or petroleum ether, while other food constituents—like carbohydrates and proteins—remain insoluble and therefore will not be extracted. Crude fat analysis encompasses all lipid forms present in the sample, including phospholipids, glycolipids, and free fatty acids, but does not differentiate between types of fats, such as saturated, unsaturated, or trans fats.

Procedure: Construct a thimble using filter paper, place it on a balance, and zero the balance to account for the thimble's weight. Remove the thimble from the balance, weigh 5 g of the blended sample, and transfer it into the thimble, recording the weight. Insert cotton into the thimble to cover the sample, then fold the thimble to secure the sample inside. Insert the sample-loaded thimble into the Soxhlet liquid–solid extraction, and then precisely weigh a dry, clean 150ml round-bottom flask. Add approximately 90 mL of petroleum ether (boiling range 40-60°C) to the flask. Then, assemble the extraction apparatus over an electric water bath or heating mantle in a certified fume hood with appropriate ventilation. Apply heat to the flask until the solvent begins to boil, adjusting the temperature to ensure solvent drips from the condenser at a steady rate of roughly six drops per second into the sample chamber. Allow the extraction to proceed for 6 hours; afterwards, turn off the heat, remove the apparatus, carefully separate the condenser and extractor, and then return the flask to the heat source to evaporate the remaining solvent. Place the flask in an oven set at 60–80 °C and dry the residue to a constant weight, typically taking 1 to 2 hours. Let the flask cool in a desiccator, then measure its weight to determine the extracted fat content. Solvent was recovered post-extraction using a solvent recovery system, and all procedures were conducted with standard safety measures, including personal protective equipment (PPE) and adherence to fume hood certification.

$$\% \text{ Crude Fat} = \frac{(W1 - W2) \times 100}{Ws} \qquad \ldots(1)$$

Where:

W1 = Weight of Empty Flask (g)

W2 = Weight of flask and extracted fat (g)

Ws = Weight of Sample

2.2.2. Determination of Crude Protein

Weigh 0.5 g of the sample and place the weighed sample into a pre-labelled Kjeldahl digestion flask. Add 20 mL of concentrated sulfuric acid (H_2SO_4) to the digestion flask with the sample and catalyst (K_2SO_4 and $CuSO_4$). Giving the flask a little swirl is good to ensure everything is okay. Subsequently, the mixture will be heated in a digestion apparatus at 200 to 300°C for about 2 hours. After digestion, allow the flask to cool and dilute the content with distilled water to a suitable volume. Transfer 20 mL of the diluted solution into a 100 mL volumetric flask and top it off with distilled water up to the mark. In a separate conical flask, measure 30 mL of 4% boric acid solution and place it in a distillation apparatus. Add 10 mL of the diluted digested sample and 50 mL of 40% sodium hydroxide solution. Heat the mixture in the distillation unit until the ammonia is distilled and collected in the boric acid solution. After distillation, titrate the collected distillate with 0.1 N hydrochloric acid (HCl) using a burette. Add a few drops of a methyl red indicator to the distillate and continue titrating until the solution changes colour, indicating the endpoint. Note the last volume of HCl used in the titration. When the titration is finished, calculate the nitrogen percentage, from which the crude protein content can also be determined using the following formulas:

Calculating Nitrogen Percentage (%N):

$$\text{Nitrogen (\%)} = \frac{[(V_{blank} - V_{sample}) \times Nhcl \times 14.01 \times \left(\frac{V\_dilution}{V\_aliquot}\right)]}{Ws \times 100} \qquad \ldots(2)$$

Where:

- Vblank: volume of HCl used for blank titration (mL).

- Vsample: volume of HCl used for sample titration (mL).
- N*hcl*: normality of HCl (0.1 N).
- 14.01: atomic weight of nitrogen (g/mol).
- V_dilution: total volume after dilution (100 mL in the volumetric flask).
- V_aliquot: volume of diluted sample taken for distillation (10 mL).
- W*s*: weight of sample (0.5 g).

Crude Protein (%) = %N × 6.25 …(3)

(for most plant materials; may vary for specific proteins, e.g., 6.38 for dairy).

2.2.3. Determination of Fibre Content

The crude fibre content is determined using a dual-stage digestion process involving acid and alkali digestion. This method isolates the sample's fibrous, insoluble carbohydrate components, which are resilient against acid and alkaline treatments. It ultimately allows precise quantification of crude fibre.

In the initial acid digestion stage, weigh 2 grams of the dried vegetable leaf sample. Begin by removing fat content in the sample through sequential washes with 25 ml of petroleum ether, using a filtration assembly to ensure fat-free residue. After defatting, transfer the sample to a 500 ml conical or flat-bottom flask. Add 200 ml of 1.25% sulfuric acid (H2SO4) solution and set the flask on a hot plate until it boils. Attach a reflux condenser to the flask and allow the sample to reflux for 30 minutes. Once the acid digestion is complete, filter the contents using a Whatman No. 1 filter paper over a Buchner funnel and rinse thoroughly with boiling water. Confirm acid removal by testing the residue with litmus paper before proceeding to alkali digestion.

For the alkali digestion, prepare a new solution of 1.25% sodium hydroxide (NaOH) and add 200 mL to the same conical flask used in the acid digestion. Transfer the filtered and acid-free residue into this solution. Reflux the sample once again for 30 minutes under the same conditions. After refluxing, filter the sample through a Whatman No. 1 filter paper and wash it with boiling water until it is free of any remaining alkali.

The next step involves thoroughly rinsing the sample with hot water and a 15 ml rinse with ethyl ethanol to ensure no remaining impurities. Transfer the residue to a Gooch crucible that has been previously dried and weighed. Dry the crucible containing the residue in an oven set at 105°C for approximately 30 minutes. Allow it to cool, then weigh the crucible. Repeat the drying, cooling, and weighing steps until a constant weight is achieved.

In the final stage, place the Gooch crucible containing the dried residue into a muffle furnace set to 550°C for incineration. After the incineration, allow the crucible to cool, then weigh it again. Repeat this process as necessary until a stable weight is achieved. This final incineration step eliminates any remaining organic matter, leaving only the ash content used to calculate the crude fiber content.

The percentage fibre content is calculated as follows:

% Crude Fibre = $\frac{\mathrm{Wx-Wy}}{\mathrm{Ws}} \times 100$ …(4)

Where:

Wx = Weight of oven-dried residue (constant weight after drying at 105°C, including fiber and other organic matter)
Wy = Weight of ash residue (constant weight after incineration at 550°C, leaving only inorganic ash)
Ws = Original weight of sample (2 grams)

2.2.4. Determination of Moisture Content

Moisture content is determined by measuring the weight loss due to water evaporation under controlled heating conditions. To determine the moisture content of the dried waterleaf samples, clean and dry an empty petri dish, place the petri dish in an open position inside a hot air oven, and heat it at 110°C for 20 minutes. After drying, transfer the petri dish to a desiccator to cool, preventing it from absorbing ambient moisture, and then record its weight. Weigh 2 grams of the dried sample into the petri dish and place it in an oven set to 105°C for two hours to allow all water content to evaporate. After two hours, cool the petri dish and sample in the desiccator again, then note the weight. Repeat the drying, cooling, and weighing process in one-hour increments until a constant weight is achieved, indicating that all moisture has been removed. Finally, the percentage of moisture content can be calculated using the appropriate formula:

$$\% \text{ Moisture Content} = \frac{Wb - Wa}{Ws} \times 100 \qquad \ldots(5)$$

Where:

Wa = Weight of the petri dish + sample after drying.

Wb = Weight of the petri dish + sample before drying.

Ws = Initial weight of sample (i.e., weight of sample only).

2.2.5. Determination of Ash Content

An empty platinum crucible was washed and dried, and its weight was recorded. Approximately 2 g of the sample was measured and placed into the platinum crucible, which was then positioned in a muffle furnace set to 550°C for 2 hours. After the burning process, the sample was cooled in a desiccator for 30 minutes to prevent moisture absorption, and its weight was measured again. The ash content was determined as follows:

$$\% \text{ Ash content} = \frac{Wa - Wc}{Ws} \times 100 \qquad \ldots(6)$$

Where:

Wa = Weight of platinum crucible with ash.

Wc = Weight of empty platinum crucible.

Ws = Weight of sample.

2.2.6. Determination of Carbohydrate Content

Total carbohydrates were determined by deducting the moisture, lipid, ash, fibre, and protein percentages from the overall sample composition. Thus,

% Carbohydrate = 100% - % (Lipid + Protein + Fibre + Moisture + Ash) …(7)

2.2.7. Minerals and Heavy Metals Analysis

The minerals were analyzed by dry ashing the sample at a temperature of 500°C until a constant weight was achieved, with temperatures optimized to minimize metal volatilization. The resulting ash was dissolved in a 100 mL standard flask containing distilled deionized water and 3 mL of 3M HCl. Potassium and sodium concentrations were measured with a flame photometer (Model 405, Corning, U.K.), while the concentrations of other minerals were quantified using an Atomic Absorption Spectrophotometer (Perkin-Elmer Model 403, USA).

2.3. Statistical Analysis

The data were presented as mean ± standard deviation (SD) from three independent replicates (n = 3) and analyzed using one-way analysis of variance (ANOVA). Differences were considered statistically significant at $p < 0.05$. R statistical software guaranteed rigour in comparing the mineral composition between sample sites.

3. Results and Discussion

3.1. Proximate Analysis

The present study investigated the mineral and proximate analysis of *Talinum triangulare* (waterleaf) collected from two distinct locations—farmland in Igwuruta and quarry site in Eleme—to assess the impact of quarrying activities on the nutrient profile of this widely consumed vegetable in southern Nigeria. Leafy vegetables are important in human nutrition as dietary sources of proteins, carbohydrates, fibres, minerals, and vitamins, especially in rural communities where animal protein sources may be limited [27]. They add taste and variability to the diet and can be protective or medicinal foods as they have been reported to be responsible for preventing diseases and regulating physiology [28,29]. Green leafy vegetables like waterleaf are vital because they help restore metabolic functions, modulate appetite, and help maintain body composition, so they are critical components of a balanced diet.

The results obtained for the proximate analysis of *T. triangulare* cultivated and consumed within the environs of the quarries indicated that *T. triangulare* provides substantial levels of nutrients such as protein, dietary fibre, and carbohydrate. The proximate composition of the waterleaf samples is shown in Table 3 below:

Table 3. Proximate Composition of Waterleaf Samples (*Talinum triangulare*)

Component (%)	Control (Igwuruta) (%)	Quarry site (Eleme) (%)
Carbohydrates	54.10 ± 0.09[a]	56.34 ± 0.10[b]
Protein	13.30 ± 0.12[a]	11.85 ± 0.01[b]
Moisture	6.39 ± 0.12[a]	5.67 ± 0.01[b]
Ash	7.34 ± 0.09[a]	8.47 ± 0.10[b]

Fat	7.62 ± 0.19[a]	6.53 ± 0.10[a]
Fiber	11.25 ± 0.10[a]	11.14 ± 0.03[a]

Values are presented as mean ± standard deviation (n = 3). Values with different superscript letters within the same row differ significantly ($p < 0.05$).

Carbohydrates contribute to the plant's caloric value and serve as a primary energy source. The most occurring component of the plant was carbohydrates, with the values of 54.10 ± 0.09% in the control (Igwuruta) and 56.34 ± 0.10% in the quarry (Eleme), indicating the plant's potential as an energy-rich food source. These results are consistent with the high carbohydrate levels documented earlier by Mohammed et al. [30] in leafy vegetables such as *Vernonia amygdalina* (67.14%), *Telfairia occidentalis* (51.68%), and *Amaranthus tricolor* (49.66%). Despite being classified as non-starchy vegetables, the relatively high carbohydrate content in *Talinum triangulare* suggests that it is a good inclusion in feed formulations for livestock or as an adjunct to cereals in human food systems, especially in food-insecure areas [31].

The protein content of the farmland (13.30%) was slightly higher than that of the quarry-grown site (11.85%), indicating that the environmental stressors near quarry sites may influence the plant's biochemical synthesis. Nevertheless, these figures show that waterleaf is still a good source of vegetal protein, an important nutrient for growth, body tissue repair, and immune function. The concentrations, however, are lower than those of higher proteinaceous leaf veggies such as *Brassica nigra* and *Portulaca oleracea*, which have over 22% crude protein [32]. This variation may be due to differences in soil fertility, seed viability, and environmental conditions, including nutrient availability and uptake efficiency. Per nutritional guidelines, foods providing >12% of calories from protein are considered good sources [33]; therefore, waterleaf cultivated in Igwuruta conforms to good protein source values, reinforcing its aid for diets for protein-energy malnutrition.

The moisture content is a factor affecting enzymatic activity, microbial spoilage, and the overall shelf life of fresh produce [34]. This aligns with the study by Alp and Bulantekin [35], who posited that lower levels of moisture content limit spoilage organisms, which makes it longer-lasting. The moisture content in the non-quarry and quarry-grown hand samples was determined to be 6.39% and 5.67%, respectively, showing a minor change in the water content due to environmental factors, such as dust deposition and the soil drying effects of quarrying. These values are lower than the >10% reported for fresh samples [36, 37], reflecting the effect of sun-drying in this study; possibly due to variations in climatic conditions, harvesting practices, or processing methods across studies. Therefore, it could be expected that these waterleaf samples are less susceptible to microbial spoilage, hence making them a better fit for storability.

Ash content, an indicator of total mineral composition [38], in the quarry site sample (8.47%) was less than that of the farmland sample (7.34%), indicating that the quarry area may have a higher accumulation of minerals. This increase reflects greater mineral accumulation, potentially driven by environmental exposure to quarry-related particulate matter (airborne dust and metal particles) and soil enrichment from industrial activities. Comparable ash content levels have been documented by Asaolu et al. [39] in other leafy vegetables like *Hibiscus sabdariffa*

(7.50%) and *Telfairia occidentalis* (8.54%), corroborating ash as a dependable parameter for estimating mineral abundance in edible plants.

According to Ganugpichayagrai and Suksaard [40], total fat is the sum of all fat components, including steriods, fat-soluble vitamins, oil-soluble dyes, fatty acids. Fat content was moderate in both sample groups, with values of 7.62% in the control and 6.53% in the quarry site samples. These levels are consistent with commonly reported fat content in leafy greens but remain significantly lower than those found in oil-rich seeds such as calabash seed, soybean, and groundnut, with fat content typically around 40-56% [41, 42]. This finding confirms that *Talinum triangulare* is not a significant source of dietary fats. However, it goes well with its long-standing position as a low-calorie, nutrient-dense vegetable suitable for weight management and cardiovascular health.

Dietary fibre content was in a consistent range in both sample types, with the control group showing 11.25% and the quarry site group recording 11.14%. Fibre diet, especially soluble fibre, is known to have great significance for human health, as it reduces cholesterol, regulates blood glucose, and improves gut health [43]. Soluble fibre binds to bile acids in the small intestine, reducing their reabsorption and lowering circulating cholesterol levels [44, 45]. Fibre also helps support digestion by giving stool bulk, which makes bowel movements regular and prevents constipation and associated disorders. Diets with a high fibre content have even been associated with greater insulin sensitivity and thus with a protective effect against type 2 diabetes [46].

These observations emphasize the need to include waterleaf in the diets of people at risk of lifestyle-related diseases as part of a routine.

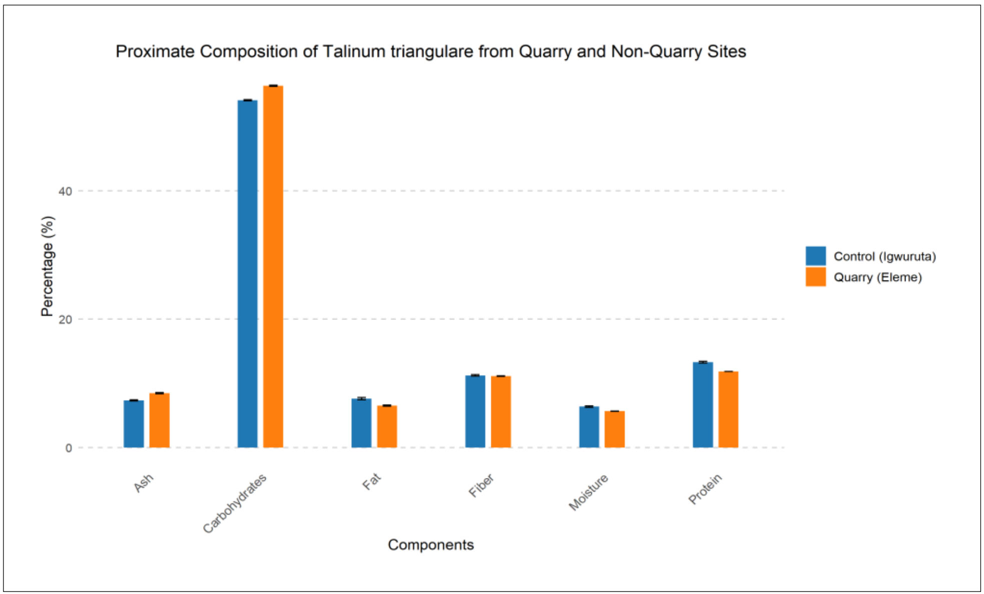

Figure 1. Proximate composition (% dry weight) of *Talinum triangulare* from control (Igwuruta) and quarry (Eleme) sites in Port Harcourt, Nigeria. Values are means ± SD (n=3). Different superscript letters in Table 3 indicate significant differences ($p < 0.05$)

The mineral composition of *Talinum triangulare* (waterleaf) from a control site (Igwuruta) and a quarry site (Eleme) is presented in Table 4, highlighting significant variations in macro- and micro-nutrient content, as well as the presence of toxic heavy metals. Twelve minerals were quantified, revealing potassium as the predominant mineral, followed by calcium, magnesium, and sodium. Concurrently, trace elements including manganese, copper, zinc, phosphorus, iron, lead, nickel and cadmium were also detected.

Table 4. Mineral Composition of Waterleaf Samples (*Talinum triangulare*)

Composition	Control (Igwuruta) (mg/100g)	Quarry site (Eleme) (mg/100g)
Phosphorus (P)	0.07 ± 0.002[a]	0.05 ± 0.002[b]
Potassium (K)	1,903.80 ± 68.06[a]	1,646.50 ± 47.40[b]
Calcium (Ca)	394.36 ± 7.49[a]	293.12 ± 6.75[a]
Magnesium (Mg)	248.17 ± 7.19[a]	131.52 ± 0.07[a]
Sodium (Na)	114.42 ± 4.87[a]	81.67 ± 1.65[b]
Copper (Cu)	0.74 ± 0.05[a]	1.58 ± 0.03[b]
Manganese (Mn)	1.08 ± 0.05[a]	5.35 ± 0.39[b]
Zinc (Zn)	7.30 ± 0.53[a]	4.84 ± 0.35[b]
Iron (Fe)	39.64 ± 2.67[a]	25.19 ± 2.49[b]
Lead (Pb)	0.04 ± 0.045[a]	0.21 ± 0.01[b]
Cadmium (Cd)	BDL	0.52 ± 0.02[b]
Nickel (Ni)	BDL	0.38 ± 0.05[b]

Values are presented as mean ± standard deviation (n = 3). Values with different superscript letters within the same row differ significantly ($p < 0.05$). BDL: Below Detectable Limit.

3.2. Macronutrients: Potassium, Sodium, Calcium, Magnesium, and Phosphorus

Potassium was a rich mineral at both sites, with 1,903.80 ± 68.06 mg/100g concentrations in Igwuruta and 1,646.50 ± 47.40 mg/100g in Eleme. However, they are less than the values obtained by Folarin et al. [47] (5,471.25 mg/100g). Potassium is the most abundant intracellular cation important for nerve impulse transmission, acid-base balance, and cellular hydration [48]. Sodium, which is present at 114.42 ± 4.87 mg/100g in Igwuruta and 81.67 ± 1.65 mg/100g in Eleme, is the central extracellular cation and it controls blood pressure, extracellular fluid volume, and neuromuscular excitability [49]. The sodium-to-potassium (Na/K) ratio, a very important bioindicator of cardiovascular health, measured 0.0601 in Igwuruta and 0.0496 in Eleme, both of which recorded values well below the recommended threshold of <1 for reducing hypertension risk [50,51]. These low ratios suggest that *T. triangulare* from both sites may contribute to improved blood pressure control when incorporated into diets.

Calcium and magnesium were also prominent, with Igwuruta samples containing 394.36 ± 7.49 mg/100g Ca and 248.17 ± 7.19 mg/100g Mg, compared to 293.12 ± 6.75 mg/100g Ca and 131.52 ± 0.07 mg/100g Mg in Eleme samples. Calcium is critical for bone mineralisation, vascular function, and cellular signalling, with over 99% of body calcium stored as hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) in bones and teeth [52]. Magnesium is a cofactor for enzymes that depend on ATP (adenosine triphosphate), supporting energy metabolism and nucleic acid synthesis [53,54]. The significantly lower Ca and Mg levels in quarry site samples ($p < 0.05$) may reflect altered soil chemistry or reduced nutrient uptake due to environmental stressors.

Phosphorus, essential for ATP synthesis and bone mineralisation, was present at low concentrations (0.07 ± 0.002 mg/100g in Igwuruta and 0.05 ± 0.002 mg/100g in Eleme); Phosphorus levels were unexpectedly low, possibly due to soil depletion or analytical limitations. One major factor that contributes to bone health is the ratio of calcium to

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phosphorus (Ca/P); higher values represent standard quality (around 1), and low values indicate poor (less than 0.5) in nutritive value [55]. The Ca/P ratios (5,633 for Igwuruta and 5,862 for Eleme) of *T. triangulare* in this study are well above the optimum level, thus indicating the adequacy of *T. triangulare* as a dietary source for these minerals. Low Ca/P ratios can stimulate the secretion of parathyroid hormone, which results in urinary calcium excretion and subsequent bone demineralisation, thus causing osteoporosis and osteomalacia [56,57].

3.3. Trace Elements: Copper, Manganese, Zinc, and Iron

Trace elements, including iron, zinc, magnesium, and copper, exhibited significant differences between sites. Copper and manganese levels were higher in Eleme samples (1.58 ± 0.03 mg/100g Cu and 5.35 ± 0.39 mg/100g Mn) compared to Igwuruta (0.74 ± 0.05 mg/100g Cu and 1.08 ± 0.05 mg/100g Mn), while zinc and iron were higher in Igwuruta (7.30 ± 0.53 mg/100g Zn and 39.64 ± 2.67 mg/100g Fe) compared to Eleme (4.84 ± 0.35 mg/100g Zn and 25.19 ± 2.49 mg/100g Fe). These variations likely reflect differences in soil composition, quarry-related contamination, or plant bioaccumulation [58]. Copper contributes to efficient cellular respiration and maintains the strength of connective tissues, being, among others, a coenzyme of cytochrome c oxidase [59]. Manganese contributes to metabolic and antioxidant functions via enzymes such as manganese superoxide dismutase [60]. Zinc is critical in wound healing, DNA synthesis, and immune function, serving as a cofactor for over 300 enzymes. [61]. Iron, essential for haemopoiesis and cellular respiration, is a key component of cytochromes and immune defence mechanisms [62].

The levels of these trace elements are within safe dietary limits, with copper (RDA: 0.9 mg/day), manganese (AI: 1.8–2.3 mg/day), zinc (RDA: 8–11 mg/day), and iron (RDA: 8–18 mg/day) posing no immediate toxicity risk per 100 g of dry weight [63]. However, the elevated Cu and Mn in quarry site samples suggest potential environmental contamination, warranting further investigation into long-term dietary safety.

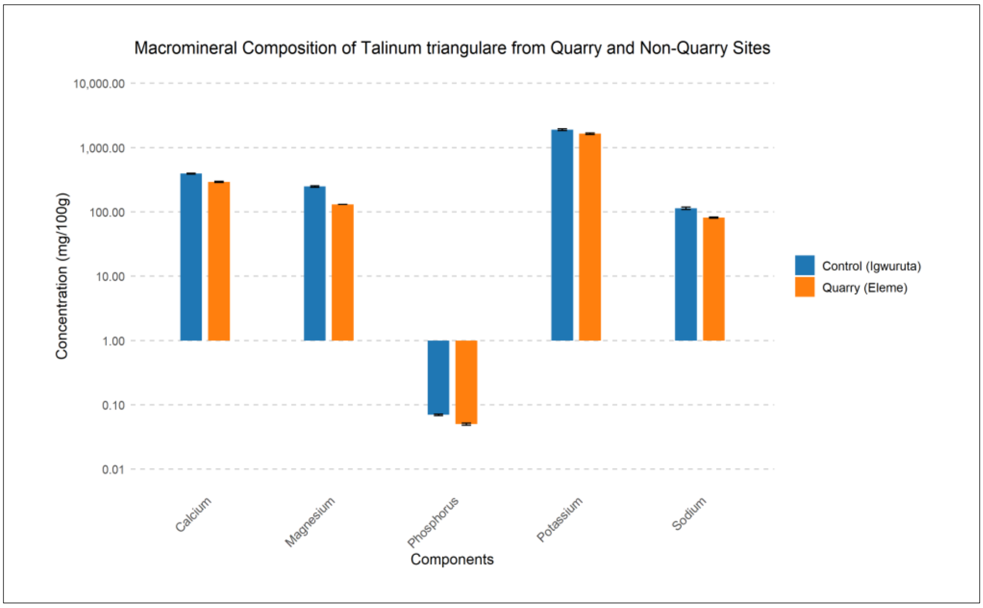

Figure 2. Macromineral composition (mg/100g dry weight) of *Talinum triangulare* from control (Igwuruta) and quarry (Eleme) sites in Port Harcourt, Nigeria. Values are means ± SD (n=3). Different superscript letters in Table 4 indicate significant differences ($p < 0.05$)

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3.4. Heavy Metals: Nickel, Lead, and Cadmium

The presence of heavy metals—nickel, lead, and cadmium—in *T. triangulare* from the quarry site raises significant public health concerns. Lead was detected at 0.04 ± 0.045 mg/100g in Igwuruta and 0.21 ± 0.01 mg/100g in Eleme, while cadmium (0.52 ± 0.02 mg/100g) and nickel (0.38 ± 0.05 mg/100g) were detected only in Eleme samples. These values are reported on a dry weight basis. Converting to approximate fresh weight, assuming a 90% moisture content (as typical for fresh waterleaf), cadmium equates to approximately 0.052 mg/100g and nickel to 0.038 mg/100g. These levels exceed WHO/FAO permissible limits for fresh weight (Pb < 0.1 mg/kg, Cd < 0.02 mg/100g, Ni < 0.1 mg/100g), suggesting potential health risks with regular consumption. These non-essential metals, linked to quarry activities such as rock blasting and machinery emissions, are toxic even at low concentrations. Lead is known to cause neurological, renal, and haematological damage, especially in children and pregnant women [64]. Cadmium, a known carcinogen, accumulates in the kidneys and liver, causing organ dysfunction and skeletal damage [65]. Nickel, while having minor biological roles, can induce oxidative stress and pulmonary complications at elevated levels [66].

The elevated heavy metal levels in Eleme samples have indicated the risk of bioaccumulation in plants cultivated around quarry sites and possibly enhanced by dust fall and soil pollution [24]. In humans, over 90% of human intake of these metals is obtained from diet and is a source of potential risk for chronic toxicity through food chain bioaccumulation of the metals [67, 68]. These findings underscore the need for strict environmental regulatory and monitoring measures to diminish contamination risks in agricultural areas near quarry sites. Further testing is recommended to evaluate these heavy metals' bioavailability and long-term health implications in *T. triangulare* consumed from quarry-adjacent regions.

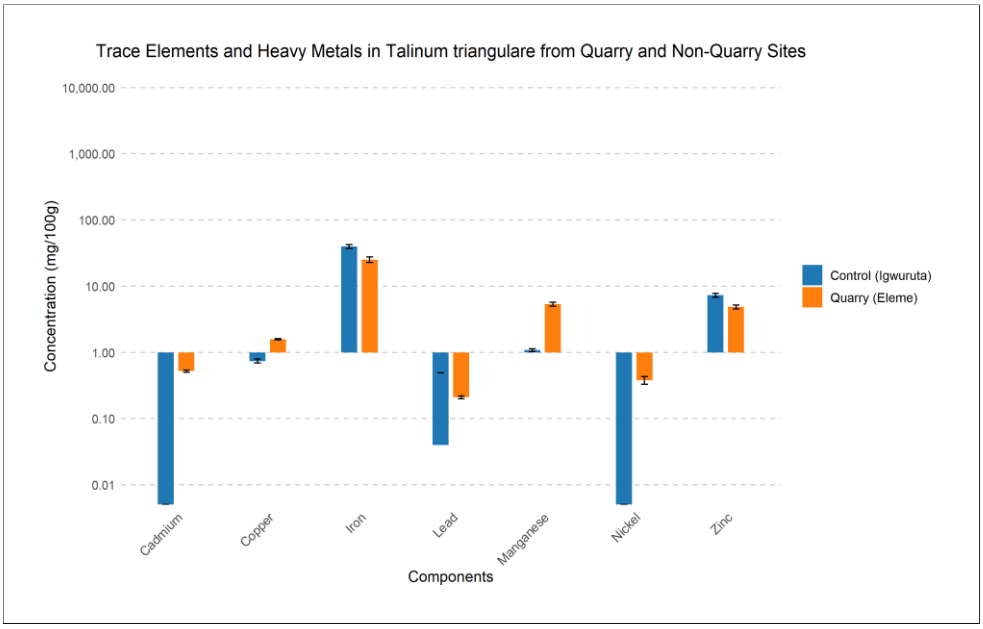

Figure 3. Trace element and heavy metal composition (mg/100g dry weight) of *Talinum triangulare* from control (Igwuruta) and quarry (Eleme) sites in Port Harcourt, Nigeria. Values are means ± SD (n=3). ND: Not Detected (plotted as 0.001 for log scale). Different superscript letters in Table 4 indicate significant differences ($p < 0.05$)

4. Conclusion

This study showed that *Talinum triangulare* (waterleaf) is rich in essential mineral elements (such as Ca, Zn, K, Mg, and Fe) that are important for various physiological functions and overall health. The plant also exhibited high levels of heavy metals such as nickel, lead, and cadmium—particularly in samples collected near quarry activities—indicating possible environmental contamination. Although the nutrient profile indicates that the plant may serve as a functional food, the increased levels of toxic heavy metals in samples from the quarry site indicate that consumption could risk food security and environmental safety. These findings highlight the need for ongoing surveillance of edible plants cultivated in industrially affected regions and validate that planting *T. triangulare* in non-contaminated areas is recommended as a healthy, nutrient-rich vegetable. Further studies are warranted to assess the bioavailability of these nutrients, the possible health Implications of the consumption over time, and the effectiveness of post-harvest handling techniques in reducing heavy metal content.

5. Further Suggestions and Recommendations

In light of the outcomes from this study, the following actions are proposed to guide future research, agricultural practices, and public health policy:

a. Routine Monitoring of Heavy Metal Levels in Vegetables Grown Near Quarry Sites

Given the observed accumulation of heavy metals—particularly cadmium, nickel, and lead—in waterleaf samples from the quarry site, it is recommended that regulatory agencies implement regular monitoring of heavy metal content in leafy vegetables cultivated near industrial and quarrying zones. This will help prevent long-term dietary exposure and reduce the local populations' risk of chronic toxicity.

b. Environmental Impact Assessment for Quarrying Activities

The significant mineral and heavy metal composition differences between quarry and farmland samples suggest that quarrying activities alter soil chemistry and plant nutrient uptake. Accordingly, complete environmental impact assessments (EIAs) are recommended before and during quarrying operations to determine their impact on the proximate natural agricultural ecosystem.

c. Public Health Awareness Campaigns

Health educational programs should be implemented to enlighten farmers and consumers about the possible health hazards of consuming vegetables from contaminated environments. Such campaigns should highlight the need to wash vegetables thoroughly using methods such as soaking in a 2% vinegar solution for 10 minutes or boiling for 2-3 minutes to remove surface contaminants, and to use filtering systems where water sources may become mixed with potentially harmful substances, employing filters such as activated carbon or reverse osmosis systems to ensure water safety.

d. Soil Remediation and Buffer Zone Establishment

Remediation methods, including phytoremediation with high biomass non-edible hyperaccumulator plants such as *Phytolacca americana* (for lead), *Thlaspi caerulescens* (for zinc and cadmium), and *Brassica juncea* (for multiple metals), should be tested to reduce soil contamination of agricultural lands from heavy metals. Furthermore, buffer zones should be created between quarries and agricultural lands to mitigate dust deposition and soil pollution.

e. Further Research on Bioavailability and Toxicological Effects

Although we determined the total mineral and heavy metal content in waterleaf in this study, there is a need to assess the bioavailability of these elements in human beings. In vivo and in vitro toxicological assessments are also needed to better understand the health implications of long-term, low-dose dietary exposure to heavy metals.

f. Promotion of Waterleaf as a Nutritional Resource in Safe Environments

Although the danger posed by other contaminants near quarrying is apparent, waterleaf growing in non-contaminated sites is still a good source of essential elements like zinc, calcium, potassium, iron, and magnesium. It is important to encourage its cultivation and consumption in a safe area to contribute to food security and nutrition, particularly in agrarian areas.

g. Integration of Local and Scientific Knowledge for Sustainable Agriculture

Promoting collective efforts among local farmers, environmental scientists, and public health workers will contribute to developing sustainable agricultural practices that can accommodate industrial development, food safety, and environmental protection.

Declarations

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Competing Interests Statement

The authors declare that they have no competing interests related to this work.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Availability of data and materials

Authors are willing to share data and material on request.

Institutional Review Board Statement

Not applicable for this study.

Informed Consent

Not applicable for this study.

References

[1] National Bureau of Statistics (2021). Gross Domestic Product Report 2021. Punch Newspapers, March 7. https://punchng.com/mining-quarrying-sector-contributed-n5-37tn-to-gdp-in-2021/.

[2] Lad, R.J., & Samant, J.S. (2014). Environmental and social impacts of stone quarrying: A case study of Kolhapur District. Int J Curr Res., 6(3): 5664–5669.

[3] Oshim, F., Chukwuemeka, E., Amaefule, W.A., Ayajuru, N.C., Amaeful, E.O., & Anumaka, C.C. (2024). Socioeconomic and environmental impacts of quarrying in Nigeria: A comprehensive review of sustainable quarrying practices and innovative technologies. SSRN. https://doi.org/10.2139/ssrn.4925021.

[4] Akanwa, A.O., Onwuemesi, F.E., Chukwurah, G.O., & Officha, M.C. (2016). Effects of open cast quarrying technique on vegetation cover and the environment in South-Eastern Nigeria. Am Sci Res J Eng Technol Sci., 21(1): 227–240.

[5] Ogbonnaya, J.E., & Phil-Eze, P.O. (2020). Challenges of quarrying activities for sustainable quality water resources in Abakaliki and Environs. J Geogr Meteorol Environ., 3(1): 61–83.

[6] Osioma, E., Iniaghe, P.O., & Chibogu, I.F. (2018). Evaluation of heavy metals content in soil and *Talinum triangulare* from Kolo Creek, Bayelsa State, Nigeria. J Sci Environ., 26(5): 1–26.

[7] Kumar, D., Kumar, S., & Shekhar, C. (2020). Nutritional components in green leafy vegetables: A review. J Pharmacogn Phytochem., 9(5): 2498–2502.

[8] Mepba, H.D., Eboh, L., & Banigo, E.B. (2007). Effect of processing treatments on the nutritive composition and consumer acceptance of some Nigerian edible leafy vegetables. Afr J Food Agric Nutr Dev., 7(1): 23–26.

[9] Anjorin, T.S., Ikokoh, P., & Okolona, S. (2010). Mineral composition of *Moringa oleifera* leaves, pods and seed from two regions in Abuja, Nigeria. Int J Agric Biol., 12: 431–434.

[10] Ojeilua, C.H., Folorunso, A.E., Eze, F.N., Okaah, E.L., & Alonge, O.R. (2025). Evolutionary Adaptations in Drought-Resilient Crops and Their Impact on Agricultural Sustainability in Nigeria. Afr J Agric Sci Food Res., 19(1): 44–64. https://doi.org/10.62154/ajasfr.2025.019.01014.

[11] Ezekwe, M., Besong, S.A., & Igbokwe, P.E. (2001). Beneficial influence of purslane and waterleaf supplement to human. FASEB J., 16: a639.

[12] Onophurhi, G.A., & Ojeilua, C.H. (2025). A Decade of Plant Conservation and Diversity: Eco-Taxonomic Insights from the University of Benin Botanical Garden. Afr J Agric Sci Food Res., 19(1): 281–309. https://doi.org/10.62154/ajasfr.2025.019.01028.

[13] Fasuyi, A.O. (2007). Bio-nutritional evaluations of three tropical leaf vegetables (*Telfairia occidentalis*, *Amaranthus cruentus* and *Talinum triangulare*) as sole dietary protein sources in rat assay. Food Chem., 103(3): 757–765. https://doi.org/10.1016/j.foodchem.2006.09.030.

[14] Musefiu, T.A., & Yinka, O.D. (2022). *Talinum triangulare* (Water leaf): What a wonderful plant? J Biotechnol Res., 8(2): 26–31. https://doi.org/10.32861/jbr.82.26.31.

[15] Edwards, I.S., & Edwards, E.J. (2020). Crassulacean acid metabolism. Curr Biol., 30(2): r57–r62. https://doi.org/10.1016/j.cub.2019.11.073

[16] Harbourne, N.V. (1993). Phytochemical methods: A guide to modern techniques of plant analysis (2nd Eds.). London: Fakenham Press Ltd.

[17] Ezekwe, M., Uzomba, C.R., & Ugwu, O.P.C. (2013). The effect of methanol extract of *Talinum triangulare* (water leaf) on the hematology and some liver parameters of experimental rats. Glob J Biotechnol Biochem., 8: 51–60.

[18] Sofowora, A.E. (1993). Medicinal plants and traditional medicines in Africa (2nd Eds.). Ibadan, Nigeria: Spectrum Books.

[19] Tiamiyu, A.M. (2019). Feed additive potentials and antibacterial effects of *Allium sativum, Chromolaena odorata* and *Talinum triangulare* against Pseudomonas aeruginosa infection in Clarias gariepinus Burchell, 1822. PhD Thesis, University of Ibadan, Post Graduate School.

[20] Barman, D., Puro, K.N., Boruah, J.L.H., Kumar, D., Medhi, K., Mazumder, B., & Baishya, R. (2024). *Talinum triangulare* (Jacq.) Willd: A review of its traditional uses, phytochemistry, and pharmacology along with network pharmacology analysis of its components and targets. Food Chem Adv., 5: 100768. https://doi.org/10.1016/j.focha.2024.100768.

[21] Ikewuchi, C.C., Ikewuchi, J.C., & Ifeanacho, M.O. (2016). Bioactive phytochemicals in an aqueous extract of the leaves of *Talinum triangulare*. Food Sci Nutr., 5(3): 696–701. https://doi.org/10.1002/fsn3.449.

[22] Tongprung, S., Wibuloutai, J., Dechakhamphu, A., & Samaneein, K. (2024). Health risk assessment associated with consumption of heavy metal-contaminated vegetables: A case study in the southern area of Northeast Thailand. Environ Challenges, 14: 100845. https://doi.org/10.1016/j.envc.2024.100845.

[23] Vasilachi, I.C., Stoleru, V., & Gavrilescu, M. (2023). Analysis of heavy metal impacts on cereal crop growth and development in contaminated soils. Agriculture, 13(10): 1983. https://doi.org/10.3390/agriculture13101983.

[24] Nkwunonwo, U.C., Odika, P.O., & Onyia, N.I. (2020). A review of the health implications of heavy metals in food chain in Nigeria. Sci World J., 2020: 6594109. https://doi.org/10.1155/2020/6594109.

[25] Mapanda, F., Mangwayana, E.N., Nyamangara, J., & Giller, K.E. (2005). The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agric Ecosyst Environ., 107(2–3): 151–165.

[26] Hosen, A., Jahan, R.A., Simol, H.A., Kabir, M.H., Hossain, M.M., & Rahman, M.A. (2024). Assessing heavy metal contamination in leafy vegetables and associated health risks in Dhaka, Bangladesh. CABI Agric Biosci., 5: 116. https://doi.org/10.1186/s43170-024-00317-z.

[27] Morka, W.E., Amitaye, A.N., & Okhifo, A. (2019). Proximate and vitamin C composition of some selected leafy vegetables grown in Burutu Town, Delta State, Nigeria. Niger Res J Eng Environ Sci., 4(1): 383–388.

[28] Aregheore, E.A. (2012). Nutritive value and inherent anti-nutritive factors in four indigenous edible leafy vegetables in human nutrition in Nigeria: A review. J Food Resour Sci., 1(1): 1–14.

[29] Omoyeni, O.A., Olaofe, O., & Akinyeye, R.O. (2015). Amino acid composition of ten commonly eaten indigenous leafy vegetables of South-West Nigeria. World J Nutr Health, 3(1): 16–21.

[30] Mohammed, H.A., Mada, S.B., Muhammad, A., Olagunju, A., Garba, A., Mohammed, A., Garba, Y., & Joseph, A.D. (2012). Comparative proximate analysis of three edible leafy vegetables commonly consumed in Zaria, Nigeria. Int J Mod Biol Med., 1(1): 82–88.

[31] Ekine, O.A., Orindu, A.N., & Ukanwoko, A.I. (2020). Responses of broiler chickens fed varying levels of dietary waterleaf (*Talinum triangulare*). J Biosci Agric Res., 24(1): 1999–2005. https://doi.org/10.18801/jbar.240120.244.

[32] Mengisteab, M., Tekle, R., & Gebreyohannes, D. (2023). Comparing proximate composition of three green leafy vegetables, Eritrea. Int J Curr Sci., 13(1): 240–246.

[33] Food and Nutrition Board. (2001). Dietary reference intakes: Elements. Institute of Medicine, National Academy of Sciences, Washington, D.C.

[34] Jibrin, M., Micah, R.M., & Omotehinwa, F.H. (2024). Comparative evaluation of the proximate, phytochemical, and antioxidant properties of selected leafy vegetables (bitter, pumpkin, and spinach leaves). Lafia J Sci Ind Res., 2(1): 60–64. https://doi.org/10.62050/ljsir2024.v2n1.293.

[35] Alp, D., & Bulantekin, Ö. (2021). The microbiological quality of various foods dried by applying different drying methods: A review. Eur Food Res Technol., 247(6): 1333–1343. https://doi.org/10.1007/s00217-021-03731-z.

[36] Ogungbenle, H.N., Akinsola, A.F., Olatunde, O.C., & Lijoka, A.O. (2018). Chemical, functional properties and amino acid composition of water leaf (*Talinum triangulare*). Chem Res J., 3(3): 7–16.

[37] Tiamiyu, A.M., & Oluwafemi, D.Y. (2022). *Talinum triangulare* (Water Leaf): What a wonderful plant? J Biotechnol Res., 8(2): 26–31. https://doi.org/10.32861/jbr.82.26.31.

[38] Ismail, B.P. (2017). Ash content determination. In Food analysis laboratory manual, Pages 117–119, Springer. https://doi.org/10.1007/978-3-319-44127-6_11.

[39] Asaolu, S.S., Adefemi, O.S., Oyakilome, I.G., Ajibulu, K.E., & Asaolu, M.F. (2012). Proximate and mineral composition of Nigerian leafy vegetables. J Food Res., 1(3): 214. https://doi.org/10.5539/jfr.v1n3p214.

[40] Ganogpichayagrai, A., & Suksaard, C. (2020). Proximate composition, vitamin and mineral composition, antioxidant capacity, and anticancer activity of *Acanthopanax trifoliatus*. J Adv Pharm Technol Res., 11: 179–183.

[41] Apata, D.F., & Ologhobo, A.D. (1994). Biochemical evaluation of some Nigerian legume seeds. Food Chem., 49: 333–338.

[42] Akubugwo, I.E., Obasi, N.A., Chinyere, G.C., & Ugbogu, A.E. (2007). Nutritional and chemical values of *Amaranthus hybridus* L. leaves from Afikpo, Nigeria. Afr J Biotechnol., 6(24): 2833–2839.

[43] Alahmari, L.A. (2024). Dietary fiber influence on overall health, with an emphasis on CVD, diabetes, obesity, colon cancer, and inflammation. Front Nutr., 11: 1510564. https://doi.org/10.3389/fnut.2024.1510564.

[44] Soliman, G.A. (2019). Dietary fiber, atherosclerosis, and cardiovascular disease. Nutrients, 11(5): 1155. https://doi.org/10.3390/nu11051155.

[45] Yang, J., Wang, H.P., Zhou, L., & Xu, C.F. (2012). Effect of dietary fiber on constipation: A meta-analysis. World J Gastroenterol., 18(48): 7378–7383. https://doi.org/10.3748/wjg.v18.i48.7378.

[46] Liu, J., An, Y., Yang, N., et al. (2024). Longitudinal associations of dietary fiber and its source with 48-week weight loss maintenance, cardiometabolic risk factors and glycemic status under metformin or acarbose treatment: A secondary analysis of the March randomized trial. Nutr Diabetes, 14: 81. https://doi.org/10.1038/s41387-024-00340-z.

[47] Folarin, O.M., Bamiro, F.O., & Esuoso, K.O. (2001). Distribution of nutritive elements in waterleaf (*Talinum triangulare*) and juice mallow (*Corchorus olitorus*). Glob J Pure Appl Sci., 7(2): 285–290.

[48] Mohamed, E.T., Mahmood, F.N., Merie, G.M.S., & Saadi, A.M. (2025). The medical importance of sodium and potassium. Int J Future Eng Innov., 2(2): 1–10. https://doi.org/10.54660/ijpgrr.2025.2.2.01-10.

[49] Pirahanchi, Y., Jessu, R., & Aeddula, N.R. (2023). Physiology, sodium potassium pump. In StatPearls, StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/nbk537088/.

[50] Zheng, H., Wang, Y., Yang, B., Wu, J., Qian, Y., Wang, W., & Wang, X. (2023). Interaction of dietary sodium-to-potassium ratio and dinner energy ratio on prevalence of hypertension in Inner Mongolia, China. J Epidemiol., 33(11): 547–555. https://doi.org/10.2188/jea.je20220045.

[51] Palmer, B.F., & Clegg, D.J. (2020). Blood pressure lowering and potassium intake. J Hum Hypertens., 34(10): 671–672. https://doi.org/10.1038/s41371-020-00396-1.

[52] Yu, E., & Sharma, S. (2023). Physiology, calcium. In StatPearls. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/nbk482128/.

[53] Jomova, K., Makova, M., Alomar, S.Y., Alwasel, S.H., Nepovimova, E., Kuca, K., Rhodes, C.J., & Valko, M. (2022). Essential metals in health and disease. Chem Biol Interact., 367: 110173. https://doi.org/10.1016/j.cbi.2022.110173.

[54] Pilchova, I., Klacanova, K., Tatarkova, Z., Kaplan, P., & Racay, P. (2017). The involvement of Mg^{2+} in regulation of cellular and mitochondrial functions. Oxid Med Cell Longev., 2017: 6797460. https://doi.org/10.1155/2017/6797460.

[55] Nieman, D.C., Butterworth, D.E., & Nieman, C.N. (1992). Nutrition. Brown Publishers.

[56] Adeyeye, E.I., & Fagbohun, E.D. (2005). Proximate, mineral and phytate profiles of some selected spices found in Nigeria. Pak J Sci Ind Res., 48: 14–22.

[57] Higdon, J., Drake, V.J., & Delage, B. (2017). Calcium. Linus Pauling Institute, Oregon State University. https://lpi.oregonstate.edu/mic/minerals/calcium.

[58] Adu, A.A., Aderinola, O.J., & Kusemiju, V. (2020). Comparative assessment of heavy metals concentration in leaf, stem and root of water leaf (*Talinum triangulare*) (Jacq Willd, 1799) grown on the soil of Cassidy's dumpsite and farmland in Ojo, Lagos State. J Med Plants Stud., 8(3): 80–84.

[59] Fu, Y., Hou, L., Han, K., Zhao, C., Hu, H., & Yin, S. (2025). The physiological role of copper: Dietary sources, metabolic regulation, and safety concerns. Clin Nutr., 48: 161–179. https://doi.org/10.1016/j.clnu.2025.03.023.

[60] Li, L., & Yang, X. (2018). The essential element manganese, oxidative stress, and metabolic diseases: Links and interactions. Oxid Med Cell Longev., 2018: 7580707. https://doi.org/10.1155/2018/7580707.

[61] Read, S.A., Obeid, S., Ahlenstiel, C., & Ahlenstiel, G. (2019). The role of zinc in antiviral immunity. Adv Nutr., 10(4): 696–710. https://doi.org/10.1093/advances/nmz013.

[62] Cappellini, M.D., Santini, V., Braxs, C., & Shander, A. (2022). Iron metabolism and iron deficiency anemia in women. Fertil Steril., 118(4): 607–614. https://doi.org/10.1016/j.fertnstert.2022.08.014.

[63] Institute of Medicine (US) Panel on Micronutrients (2001). Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc (Chapter 7, Copper). National Academies Press. https://www.ncbi.nlm.nih.gov/books/nbk222312/.

[64] Institute for Health Metrics and Evaluation (2024). Lead exposure – Level 3 risk. University of Washington. https://www.healthdata.org/research-analysis/diseases-injuries-risks/factsheets/2021-lead-exposure-level-3-risk.

[65] Lin, H.C., Hao, W.M., & Chu, P.H. (2021). Cadmium and cardiovascular disease: An overview of pathophysiology, epidemiology, therapy, and predictive value. Rev Port Cardiol., 40(8): 611–617. https://doi.org/10.1016/j.repce.2021.07.031.

[66] Genchi, G., Carocci, A., Lauria, G., Sinicropi, M.S., & Catalano, A. (2020). Nickel: Human health and environmental toxicology. Int J Environ Res Public Health, 17(3): 679. https://doi.org/10.3390/ijerph17030679.

[67] Shahid, M., Dumat, C., Pourrut, B., Abbas, G., Shahid, N., & Pinelli, E. (2015). Role of metal speciation in lead-induced oxidative stress to *Vicia faba* roots. Russ J Plant Physiol., 62(4): 448–454.

[68] Kabir, M., Aziz, N., Hammad, M., Iqbal, M.Z., & Tariq, M.A. (2025). Toxicity of heavy metals in vegetables and their impacts on human health. In Sustainable and innovative vegetable production in times of climate change (Chapter 19), Springer. https://doi.org/10.1007/978-981-96-6283-8_19.