Assessment of Some Minerals and Proximate Composition Of Selected Vegetables Grown Around Gwaigwaye Dam in Katsina State, Nigeria

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Abstract

This study evaluated the mineral and proximate composition of cabbage, lettuce, and Moringa oleifera cultivated near Gwaigwaye Dam to assess their nutritional value and safety for human consumption. Mineral concentrations of calcium, potassium, iron, and zinc were determined using Atomic Absorption Spectroscopy, while proximate parameters including protein, fiber, lipid, ash, carbohydrate, and moisture were analyzed following standard AOAC procedures. Mineral contents (mg/100 g) ranged from 198.00–245.90 for calcium and potassium, 17.66–26.50 for iron, and 1.32–2.10 for zinc. The Ca: K ratios varied from 0.84 in cabbage to 1.00 in Moringa oleifera, indicating a balanced calcium–potassium relationship, while Fe: Zn ratios ranged from 9.75 in lettuce to 20.08 in Moringa, showing a predominance of iron relative to zinc. Proximate composition (%) ranged from 7.40–17.44 for protein, 17.43–32.88 for fiber, 4.90–5.30 for lipid, 4.42–10.46 for ash, 21.10–43.40 for carbohydrate, and 2.70–9.00 for moisture. The results demonstrate that the vegetables are nutrient-dense, with variations among samples that were statistically significant ($p > 0.05$). Favorable Ca: K ratios might support bone health, cardiovascular regulation, and electrolyte balance, whereas elevatedFe: Zn ratios suggest the need for dietary strategies to enhance zinc bioavailability.

Keywords: *Cabbage; Dam; Lettuce; Minerals; Moringa Oleifera and Proximate.*

1. Introduction

Vegetables are vital components of the human diet and are recognized globally as essential sources of nutrients necessary for growth, development, and the maintenance of health. They sustain nearly all land-dwelling organisms, including humans, by providing essential macronutrients and micronutrients that support survival and overall well-being [1]. Broadly, vegetables consist of various edible plant parts—including leaves, stems, roots, fruits, and seeds that may be consumed raw or cooked, either as staple foods or as complementary ingredients in diverse dishes worldwide[2].

Nutritionally, vegetables play a critical role in supplying carbohydrates, proteins, vitamins, minerals, and dietary fibres. They also serve as natural neutralizers of the acidic byproducts of digestion, thereby promoting metabolic balance and maintaining physiological health [3]. Moreover, most vegetables are excellent sources of minerals such as calcium, iron, magnesium, and potassium, alongside vitamins A, C, and K. Almost all varieties also provide antioxidants and dietary fibres that are strongly associated with reduced risks of non-communicable diseases[4]. For instance, consumption of green leafy vegetables has been linked with lower incidences of cardiovascular disease, while diets rich in fibre, vitamins, and minerals have proven particularly beneficial for individuals with type 2 diabetes by aiding in glycemic control [5]. Furthermore, increased consumption of nutrient-dense vegetables—especially those rich in energy, protein, iron, and vitamin A—has been recognized as a global strategy to combat malnutrition and its associated health challenges, particularly in low- and middle-income countries[1].

The nutritional value of vegetables varies according to their species, environmental conditions, and cultivation practices[6]. Globally, researchers have emphasized the importance of characterizing the chemical and biochemical composition of commonly consumed vegetables to ensure their contribution to balanced diets and public health [7]. In this regard, cabbage (Brassica oleracea), lettuce (Lactuca sativa), and moringa leaves (Moringa oleifera) are among the most widely consumed vegetables, valued not only for their culinary versatility but also for their rich profiles of essential nutrients and bioactive compounds.

Despite their significance, there remains limited data on the comprehensive nutritional and mineral composition of these vegetables within specific local contexts. Therefore, the present study aims to determine the levels of essential nutrients—calcium, potassium, iron, zinc, protein, carbohydrate, crude fat, crude fibre, moisture, and ash—in cabbage, lettuce, and Moringa oleifera leaves. By establishing whether

these nutrients are sufficiently present, this study provides valuable information for improving dietary guidelines, supporting nutrition education, and contributing to the global knowledge base on vegetable nutrition.

2. Material and Methods

All the Chemicals used were of Analytical grade purity. Distilled water was used for solution preparation. Analytical grade reagents and Deionized water were used throughout the study.
All the glassware and plastic Containers used were washed, cleaned, and dried in an oven at $105°C$. All weighing was carried out on an analytical weighing Balance [1].

2.1. Description of the area of study

In 2003, former President Chief Olusegun Obasanjo commissioned the Gwaigwaye Dam in Funtua, Katsina State, to provide reliable irrigation and domestic water to Funtua, Faskari, and Bakori Local Government Areas. Situated on the Gwaigwaye River (latitude 11°58′N, longitude 7°20′E), the embankment dam regulates the river's variable flow by capturing excess wet-season runoff (May–October) and releasing water steadily during the dry season (November–April), as illustrated in Figure 1. With a width exceeding 450 meters, a depth of approximately 130 meters, and a storage capacity of 130 million cubic meters, the reservoir's physical characteristics ensure consistent water availability, buffering seasonal shortages. Figure 1 also highlights the reservoir's integration into the local irrigation network, demonstrating efficient water distribution across the three LGAs. By stabilizing river fluctuations, the Gwaigwaye Dam enhances agricultural productivity and secures water supply in this savannah region [8], underscoring its dual role as both a hydrological buffer and critical infrastructure for regional water resource management.
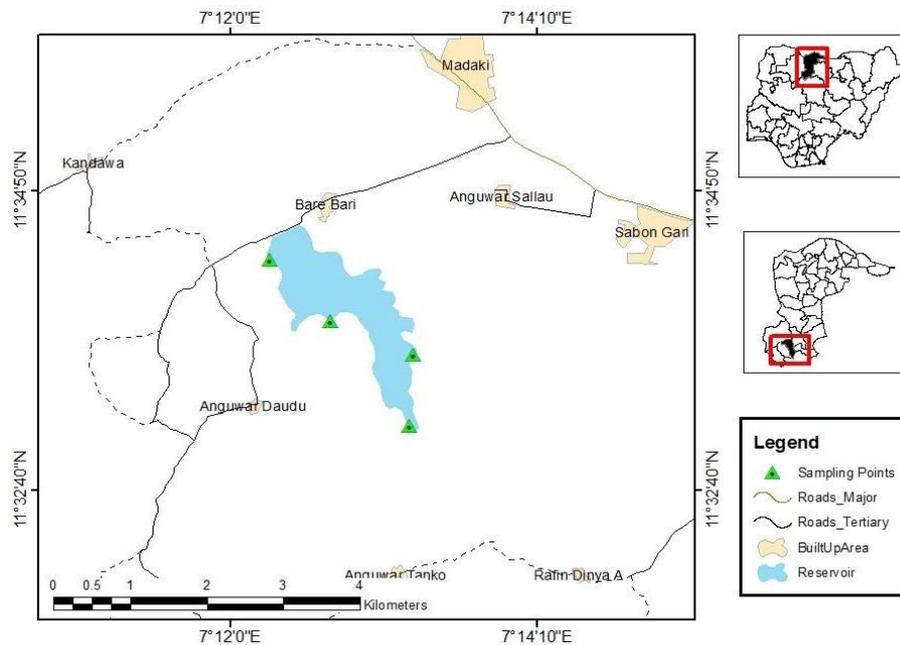

Fig. 1: Map of Gwaigwaye Dam.

2.2. Sample collection and preparation

The representative samples of fresh cabbage, lettuce, and Moringa Oleifera leaves were randomly collected from farmlands around Gwaigwaye reservoir in Funtua local Government from Multiple locations, each separated by 30m and 50m from Roadsite in January 2024. The vegetable samples were carefully identified and authenticated by a botanist from the Department of Plant Science, Bayero University, Kano. Vegetables were washed with tap water and rinsed with de-ionized water to remove surface sand and dust. The samples were cut into smaller pieces and air-dried for 24 hours to reduce moisture. Each sample was dried in an oven at 80^{0c} for 3hours until constant weight was achieved. The samples were ground into powder using a mortar and pestle, sieved through a 2.0mm mesh size, and preserved until ready for analysis.

2.3. Sample digestion for elemental analysis

For digestion, 5g of powdered samples of each vegetable was mixed with 1.2 ml of of 70% perchloric acid, 1ml of 10% sulphuric acid, and 5ml of 10% Nitric acid. The mixtures were placed on a water bath and evaporated to dryness. The solution was cooled and filtered into 100ml standard flask and diluted to the mark with distilled water [9].

2.4. Instrumentation

Mineral elements (Ca, K, Fe, Zn) were determined in some vegetables(cabbage, lettuce, and moringa leaves cultivated in farmlands around Gwaigwaye dam by Agilent Atomic Absorption spectrophotometer (AAS), after appropriate digestion of samples to extract the minerals. Standard solutions with known concentrations and blanks are prepared. A calibration curve is created from the standards. The absorbance of the vegetable samples was measured and compared to the calibration curve to determine the concentration of each mineral. A blank is used to correct for background interference [10].

2.5. Determination of proximate composition

The proximate content of all the samples was analyzed. The gravimetric method was employed to determine the moisture and Ash content. Fibre content was determined by measuring the weight difference of the crucible and its contents before and after burning. The micro Kjeldahl method described by Pearson (1976) was employed to determine nitrogen content, a protein precursor. The process comprises three stages: digestion, distillation, and finally titration of the sample. To estimate protein, the nitrogen value was multiplied by 6.25. The percentage of carbohydrates was calculated by deducting the combined percentages of moisture, ash, protein, lipid, and fibre from 100. All the proximate values were obtained in percentage [11].

2.6. Statistical analysis

The results of statistical analysis revealed significant variations in heavy metal levels among the Vegetable samples analyzed, as p-values were less than the 0.05 significance level.

Table 1: Results of Statistical Analysis (ANOVA)

SUMMARY						
Groups	Count	Sum	Average	Variance		
Veg	12	24	2	0.727272727		
Minerals	12	30	2.5	1.363636364		
Elements		1445.65	120.4708	13123.10379		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	111810.8235	2	55905.41	12.77819027	7.77151E-05	3.284917651
Within Groups	144377.1417	33	4375.065			
Total	256187.9652	35				

SS= Sum of Squares, df= degree of freedom, Mean of square, F= Fischer variance ratio. Pvalue= probability value.

3. Results

Table 2: Concentrations of Some Minerals in Selected Vegetables (Mg/100g)

Minerals	Ca	K	Fe	Zn	Ca: K	Fe: Zn
Cabbage	198±0.00	235.01±0.01	21.5±0.01	2.1±0.01	0.84	10.24
Lettuce	210.19±0.01	240.2±0.01	17.66±0.01	1.81±0.01	0.87	9.75
Moringa	245.46±0.01	245.9±0.01	26.5±0.01	1.32±0.01	1.00	20.10

Table 3: Proximate Compositions of Some Vegetables in (%)

Vegetablesprotein	fibre	fat	Ash	Carbohydrate	Moisture
Cabbage	7.4	22.3	5.34	4.42	43.40	9.00
Lettuce	15.2.	17.43	4.9	6.20	3 2.40	7.43
Moringa leaves.	17.4.	32.88	1.72	10.46	21.10	2.70

3.1. Discussion

- **Calcium (Ca)**

Calcium concentrations ranged from 198 to 245.46 mg/100 g, with Moringa oleifera exhibiting the highest level and cabbage the lowest. All values were substantially below the maximum permissible limit of 3000 mg/100 g [12], confirming safety for consumption. Calcium is a structural macromineral essential for bone mineralization, neuromuscular transmission, vascular contraction, and enzymatic activation [13].

In Nigeria, calcium levels in Moringa oleifera leaves have been reported as high as 303 mg/100 g, while cabbage and lettuce typically contain lower concentrations [14], [15]. Across Africa, Moringa leaves in Botswana accumulated approximately 520 mg/100 g [16], reflecting species-specific mineral uptake under favorable soil conditions. lobally, studies from India and Europe reported calcium levels in leafy vegetables ranging from 350–450 mg/100 g [17], [18]. The comparatively lower values in this study likely originated from regional soil mineral content, genotype, and cultivation practices. Nevertheless, the vegetables analyzed remain nutritionally relevant sources of calcium, supporting skeletal health in local populations.

- **Potassium** (K)

Potassium concentrations varied slightly among the vegetables, ranging from 235.1 to 245.9 mg/100 g, with Moringa oleifera recording the highest and cabbage the lowest. All values were within recommended limits [12], confirming regulatory compliance. Potassium is the major intracellular cation, critical for osmotic balance, neuromuscular excitability, and blood pressure regulation [21].

In Nigeria, potassium content in cabbage has been reported as low as 12 mg/100 g, while lettuce levels can exceed 3000 mg/100 g depending on soil fertility and cultivar [22], [23]. Across Africa, leafy vegetables typically contain 200–500 mg/100 g of potassium, whereas global reports indicated substantially higher accumulation, with Moringa leaves in Brazil containing up to 4598 mg/100 g [24] and lettuce in China reaching 2800 mg/100 g [25]. These discrepancies are primarily due to soil potassium availability, agronomic practices, and moisture correction methods. Despite being lower than some global maxima, the potassium levels measured here remain physiologically relevant and may contribute meaningfully to cardiovascular health.

- **Iron (Fe)**

Iron concentrations exhibited the highest and lowest values in Moringa oleifera (26.5 mg/100 g) and lettuce (17.66 mg/100 g), respectively. All values were below permissible limits [12]. Iron is essential for haemoglobin synthesis, oxygen transport, mitochondrial respiration, DNA replication, and immune competence [13].

Within Nigeria, cabbage and lettuce have been reported to contain 6.99–24 mg/100 g of iron [26], [27], comparable to the present study. Across Africa, indigenous leafy vegetables in Ethiopia contained 15.7–31.2 mg/100 g [28], and globally, studies from India and Brazil reported iron in leafy vegetables ranging from 12.4 to 28.6 mg/100 g [29], [30]. The relatively elevated iron content in Moringa oleifera confirms its potential as a dietary source of iron, although non-haem iron bioavailability is influenced by dietary inhibitors such as phytates, highlighting the need for complementary food-based strategies to enhance absorption.

- **Zinc (Zn)**

Zinc concentrations in the analyzed vegetables were 1.32–2.1 mg/100 g, substantially lower than the regulatory threshold of 20 mg/100 g [12]. Cabbage had the highest zinc content, whereas Moringa oleifera had the lowest. Zinc is a catalytic and structural cofactor in numerous enzymes, essential for cellular growth, genomic stability, and immune function [13].

In Nigeria, zinc levels in leafy vegetables are typically 1.2–2.5 mg/100 g [31], [32], with similar ranges reported across Africa (0.9–2.8 mg/100 g) [33] and slightly higher values globally (1.1–3.2 mg/100 g in India; 1.6–2.9 mg/100 g in Turkey) [34], [35]. These results indicated that the vegetables analyzed are safe and can provide nutritionally relevant zinc levels.

Across all minerals, Moringa oleifera consistently demonstrated superior accumulation for calcium, potassium, and iron, reflecting species-specific nutrient uptake efficiency. Variation across studies is primarily attributable to edaphic conditions, agronomic practices, genotype, and methodological differences rather than intrinsic nutritional deficiency.

All vegetables were within regulatory safety thresholds [12] and can contribute meaningfully to recommended dietary intakes. Their consumption supports skeletal mineralization (Ca), cardiovascular regulation (K), haemopoiesis (Fe), and immune function (Zn). These findings reinforce dietary guidelines advocating ≥400 g/day vegetable intake and support community nutrition interventions and agricultural policies promoting nutrient-dense indigenous species. Integrating such vegetables into diets can enhance micronutrient adequacy, address deficiencies, and contribute to non-communicable disease prevention in both local and regional contexts.

Mineral Ratios: Calcium-to-Potassium (Ca: K) and Iron-to-Zinc (Fe: Zn)

- **Calcium-to-Potassium (Ca: K) Ratios**

As shown in Table 2, the Ca: K ratios of cabbage (0.84), lettuce (0.87), and Moringa oleifera (1.00) fall within the recommended nutritional range of 0.5–1.0 [44], which is widely used to assess mineral balance in foods. Ratios within this range indicate a favorable provision of calcium relative to potassium, essential for skeletal mineralization, muscle contraction, nerve impulse transmission, and cardiovascular regulation.

Among the vegetables analyzed, cabbage and lettuce, though slightly potassium-dominant, provide a favorable balance supporting electrolyte homeostasis, while Moringa oleifera, with a ratio near 1.0, offers an almost ideal mineral balance, particularly beneficial for populations at risk of calcium deficiency or osteoporosis. Regular consumption of these vegetables can thus contribute to bone health, the prevention of hypertension, and the maintenance of cardiovascular function.

Comparative studies show consistency across Nigeria and other regions. In Jos, Plateau State, Ca: K ratios in leafy vegetables ranged from 0.78 to 0.92, consistent with the present study [19]. Similarly, in Kano Metropolis, cabbage and lettuce exhibited ratios of 0.80–0.95 [29]. Across Africa, indigenous leafy vegetables in Ethiopia display ratios of 0.75–0.97 [34], while internationally, Moringa oleifera in India ranged from 0.85–1.05 [45] and leafy vegetables in Brazil from 0.80–0.98 [27]. These findings confirmed that well-balanced Ca: K ratios are a consistent feature of leafy vegetables globally.

The Ca: K ratios observed in cabbage, lettuce, and Moringa oleifera indicated that these vegetables can meaningfully support skeletal health, muscle function, and cardiovascular regulation when included regularly in diets, reinforcing their role in community nutrition programs and dietary guidelines promoting mineral adequacy.

- **Iron-to-Zinc (Fe: Zn) Ratios**

The Fe: Zn ratios of cabbage (10.24), lettuce (9.75), and Moringa oleifera (20.08) reflect the proportion of iron relative to zinc in these vegetables (Table 2). According to [12], maintaining a balanced Fe: Zn ratio is crucial because excessive iron can inhibit zinc absorption, potentially reducing bioavailability and affecting growth, immune function, and enzymatic activity.

Cabbage and lettuce, with moderate Fe: Zn ratios (~10), provide a favorable balance to support hemoglobin synthesis, enzymatic reactions, immune competence, and overall growth. Moringa oleifera, with a higher ratio, is particularly iron-rich, but its consumption should be complemented with zinc-rich foods such as legumes, nuts, or seeds to optimize zinc absorption and maintain mineral balance.

Comparisons across Nigeria show general consistency. In Benue State, Fe: Zn ratios in cabbage and spinach ranged from 8.5 to 12.3 [46], while in Kaduna State, lettuce and amaranth ranged from 9.0 to 11.5 [47]. Across Africa, Ethiopian leafy vegetables reported ratios of 10–18 [49], and globally, green leafy vegetables in India and Mexico ranged from 7.8–13.5 [48] and 8.5–15.2 [50], respectively. These data demonstrated that moderate Fe: Zn ratios are typical in leafy vegetables worldwide, while iron-rich species like Moringa oleifera may require dietary pairing to optimize zinc intake.

Maintaining appropriate Fe: Zn ratios is particularly important for vulnerable populations, including children, pregnant women, and the elderly. The ratios observed in this study indicated that cabbage, lettuce, and Moringa oleifera can effectively contribute to balanced dietary mineral intake, supporting hematological health, enzymatic function, and immune defense, while informing public health interventions aimed at preventing mineral deficiencies.

Proximate Composition of Leafy Vegetables

- **Protein Content**

As detailed in Table 3, protein content varied among the vegetables, with Moringa oleifera leaves exhibiting the highest value (17.44%), followed by lettuce (15.23%), while cabbage recorded the lowest (7.40%). Lettuce and Moringa oleifera exceed 12%, considered nutritionally significant for leafy vegetables [51], indicating their potential as meaningful dietary protein sources. High protein content supports muscle maintenance, tissue repair, satiety, and overall metabolic health.

Variation in protein levels can be attributed to soil fertility, environmental conditions, cultivar differences, and agronomic practices influencing nitrogen uptake and protein biosynthesis. Nigerian studies confirm these trends: Enugu State reported 6.8–8.2% protein in cabbage and 14.5–16.8% in lettuce [52], while Oyo State documented 17% in Moringa oleifera leaves [32]. Across Africa, Ghana and Kenya reported comparable protein contents in Moringa oleifera (16.8–18.1%) and lettuce (14.2–15.5%) [53], [54], aligning with the present study. In Thailand, cabbage showed lower protein (7–8%), reflecting global trends of moderate protein in cabbage [55].

These results indicate that including Moringa oleifera and lettuce in regular diets can significantly enhance protein intake, particularly for populations relying on plant-based nutrition. Cabbage, while lower in protein, remains valuable for micronutrients and dietary diversity.

- **Crude Fiber**

Crude fiber content ranged from 17.43% to 32.88%, with Moringa oleifera leaves having the highest (32.88%), followed by cabbage (22.30%) and lettuce (17.30%) (Table 3). High fiber intake promotes digestive health, regulates blood sugar, reduces cholesterol, prevents constipation, and lowers the risk of metabolic disorders [56,57].

Regional comparisons in Nigeria are consistent: Ondo State reported 25% fiber in Moringa oleifera and 18.5% in cabbage [58], while Ekiti State documented 16.8–21.2% in lettuce and 23.5% in cabbage [59]. Kaduna State also reported 31.5% in Moringa oleifera, 20.5% in cabbage, and 18.7% in lettuce [60]. Across Africa and globally, Moringa and other leafy vegetables in the Philippines, Kenya, Egypt, Bangladesh, Ethiopia, and Thailand showed similarly high fiber content (16–34%) [61–64], highlighting their consistent role in promoting gut health.

These findings underscore the importance of including fiber-rich vegetables like Moringa oleifera and cabbage in daily diets to enhance nutrient density and support digestive and metabolic health.

- **Crude Fat**

Crude fat content was low in all vegetables: cabbage (5.3%), lettuce (4.9%), and Moringa oleifera (1.72%) (Table 3). Low lipid content indicates that these vegetables are poor sources of dietary fat but remain important for providing proteins, fiber, and micronutrients [12]. Comparative studies in Nigeria reported similarly low values: Lagos markets recorded 0.08–0.14% in cabbage and lettuce [60], while Moringa in Kaduna showed 1.5–2% [47]. Globally, crude fat in leafy vegetables ranges from 0.9–4.5% in China and Indonesia [66], [68], while mature Moringa leaves in India contained 18–20% fat [67], emphasizing the influence of leaf maturity and agro-climatic conditions. Although low in fat, the inclusion of these vegetables contributes to nutrient adequacy and supports low-calorie dietary patterns.

- **Ash Content**

Ash content, reflecting total mineral accumulation, varied from 4.42% in cabbage to 10.46% in Moringa oleifera, with lettuce at 6.2% (Table 3). Higher ash content indicates greater provision of essential minerals, important for electrolyte balance, bone health, and enzymatic function [12], [51].

Nigerian studies support these findings: Oyo State reported 9.8% ash in Moringa oleifera and 5.5% in cabbage [32], Northern Nigeria reported 6% in lettuce [40]. Internationally, North American studies recorded 10–11% in Moringa leaves, 4.8–6% in cabbage and lettuce [69–73], demonstrating consistent patterns of higher mineral accumulation in Moringa oleifera.

These results highlight the potential of these vegetables, particularly Moringa, to contribute to mineral intake and support dietary interventions targeting micronutrient adequacy.

- **Carbohydrate Content**

Carbohydrate content ranged from 21.10% in Moringa oleifera to 43.40% in cabbage, with lettuce at 32.40% (Table 3). Cabbage is a notable source of dietary energy, whereas lettuce and Moringa oleifera provide moderate contributions [58].

Comparative studies show similar trends: Cameroon reported 46.2% in cabbage [74]; the Central African Republic reported 33.5% in lettuce [75]; Moringa in the Democratic Republic of Congo contained 25.6% [76]. European studies reported 42.5% in cabbage (France) and 34% in lettuce (Germany) [77], [78], while Italy reported 23.5% in Moringa [79]. North American and Mexican studies confirm moderate carbohydrate content in leafy vegetables (12–19%) [81–83].

These findings indicate that cabbage can significantly support dietary energy intake, while lettuce and Moringa oleifera provide complementary energy contributions.

- **Moisture Content**

Moisture content varied, with cabbage highest (9%), followed by lettuce (7.43%), and Moringa oleifera lowest (2.70%) (Table 3). Moisture affects freshness, microbial stability, storage potential, and shelf life [12], [50], [80].

Nigerian studies show variability: Ekiti State reported 24.3% in cabbage [80], Niger State 4.5% in lettuce [47], Kano State 4.42% in Moringa [84]. West African, Indian, Pakistani, Bangladeshi, and Southeast Asian studies reported similar patterns, highlighting the influence of climate, cultivation, and leaf maturity [53], [66], [85–88].

Low moisture in Moringa oleifera suggests better storage stability, while cabbage's higher moisture supports freshness. These results emphasize the role of moisture in post-harvest handling and dietary quality.

Variations in proximate composition reflect species, cultivar, plant maturity, soil nutrients, environmental conditions, agronomic practices, and analytical methods [89].

4. Conclusion

Proximate and mineral analyses are essential for assessing the nutritional quality of leafy vegetables. This study indicated that cabbage, lettuce, and Moringa oleifera are nutrient-dense, providing appreciable amounts of calcium, potassium, iron, zinc, protein, fiber, and carbohydrates. These nutrients may support bone and teeth strength, muscle function, nerve transmission, hemoglobin synthesis, immune function, and energy provision. The Ca: K ratios were within the recommended range of 0.5–1.0, suggesting a relatively balanced intake that may aid bone health, blood pressure regulation, and muscle function. Similarly, the Fe: Zn ratios highlight the potential benefits of consuming these vegetables alongside zinc-rich foods to optimize mineral absorption and reduce the risk of deficiencies that can affect growth, immunity, and cognitive development. Regular inclusion of these vegetables in the diet may therefore contribute to improved nutritional status and overall health.

Recommendations

1) Regular consumption of cabbage, lettuce, and Moringa oleifera should be encouraged due to their high nutritional value and potential to improve micronutrient intake and overall health.
2) Dietary strategies that combine these leafy vegetables with zinc-rich foods are recommended to enhance iron and zinc bioavailability, particularly among vulnerable populations.
3) Routine monitoring of the proximate and mineral composition of leafy vegetables is advised to ensure nutritional quality and safety amid environmental and agronomic variations.
4) Future studies should expand mineral and trace element profiling to provide a more comprehensive assessment of the health benefits of commonly consumed leafy vegetables.

Conflict of Interest

The Authors wish to declare that no conflict of interest exists between them.

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References

[1] M.I., Mohammed, N., Kabir, A., Mustapha, Comparative Study on some mineral compositions of seeds extract of Cassia Occidentalis, Ocimum gratissum and Senna tora obtained from Kafur local government Area of Katsina State, Nigeria. International Journal of Scholarly and Educational Research, 13(2024),13-23.

[2] J.R., Dhellot, E., Matouba, M.G., Maloumbi, J.M., Nzioku, D.G., Safou-Ngaoma, M., Linderon, S., Desobrys, M., Parmentier, Extraction, Chemical composition and nutritional characteristics of vegetable oil; A case study of Amaranthus hybridus(val1and2) of congo brazeville. Afr. J. Biotechnol, 2006 5(2006),1095-1101.

[3] Z.N., Ali, F.M., Abdulkadir, M.M., Imam, Determination of some heavy metals in spinach and lettuce from selected markets in kaduna metropolis. Nigerian Journal of chemical research, 17(2012),23-29.

[4] D.,Kumar, S., Kumar, C., Shekhar,Nutritional components in green leafy vegetables.Journal of pharmacognosy and phytochemistry 9(2020),2498-2502.

[5] N.A., Aduke, K.A., Ekowe, Proximate and mineral composition of five leafy vegetables commonly consumed in ogun state. In the proceeding of international conference held on 9th-10th december, 2020.

[6] N.S., Chauhan, Medicinal and Aromatic plants of himachal pradesh. Indus pub.co. New delhi: wealth of india. A dictionary of raw materials and industrialn products, publiction and information directorate C.S.I.R.2020 1(2020),368-370

[7] A., Delgado, M., Issaoui, M., Vieira, I., Saraiva de Carvalho, A., Fardet, Food Composition Databases: Does It Matter to Human Health?. Nutrients, 13(2021), 2816. https://doi.org/10.3390/nu13082816.

[8] N., Lawal, M.I., Nafiu, T.S., Kuiwa, A.M., Aminu, Phyto-plankton Population in Relation to physiccochemical parametres of Gwaigwaye Rresevoir Katsina state, Nigeria.J. Appl. Sci. Environ. Manage 24(2020),73-78. https://doi.org/10.4314/jasem.v24i1.10.

[9] C.E., Achikanu, C.E., Eze- steven, P.E., Ude, C.M., Ugwuokoie, Determination of vitamin and mineral composition of common leafy vegetables in south eastern Nigeria. Int J. Curr. Microbiol. Appl Sci, 2013 2(2013),347-353.

[10] A., Mustapha, A., Dahiru, K. R.,Zainab, Determination of some heavy metals in some vegetables grown around Gwaigwaye dam, Katsina state, Nigeria. 12(2024),67-70. https://doi.org/10.14419/kbwp8v23.

[11] AOAC, (2005). Official methods of Analysis of the Analytical chemist 18th edition, Washington D.C. U.S.A.

[12] FAO/WHO. (2004). Vitamin and mineral requirements in human nutrition (2nd ed.). Geneva: World Health Organization.

[13] K.O., Soetan, C.O., Olaiya, O.E., Oyewole, you the importance of mineral elements for humans, domestic animals and plants: A review. African Journal of Food Science, 4(2010),200–222.

[14] I.I., Nkafamiya, S.A., Osemeahon, U.U., Modibbo, A., Aminu, Nutritional status of non-conventional leafy vegetables consumed in Mubi, Nigeria. African Journal of Food Science, 4(2010), 104–108.

[15] M.G., Mokganya, L.R., Motadi, M.A., Selepe, . Mineral composition and nutritional potential of Moringa oleifera leaves grown in Botswana. Food Production, Processing and Nutrition, 5(2023), 1–10. https://doi.org/10.1186/s43014-023-00183-8.

[16] L., Gopalakrishnan, K., Doriya, D.S., Kumar, Moringa oleifera: A review on nutritive importance and its medicinal application. Food Science and Human Wellness, 5(2016) 49–56. https://doi.org/10.1016/j.fshw.2016.04.001.

[17] A., Aberoumand, S.S., Deokule, Determination of elements profile of some wild edible plants. Food Analytical Methods, 2(2009), 116–119. https://doi.org/10.1007/s12161-008-9057-9.

[18] United States Department of Agriculture (USDA). FoodData Central. U.S. Department of Agriculture, Agricultural Research Service. https://fdc.nal.usda.gov,2019.

[19] B.A., Akinwande, S.J., Olatunde, Comparative evaluation of mineral composition of some leafy vegetables consumed in Jos, Plateau State, Nigeria. International Journal of Science and Research, 4(2015), 143–147.

[20] M.C., Martínez-Ballesta, R., Dominguez-Perles, D.A., Moreno, B., Muries, C., Alcaraz-López, E., Bastías, C., García-Viguera, M., Carvajal, (Minerals in plant food: Effect of agricultural practices and role in human health. Agronomy, 11(2021), 1–21. https://doi.org/10.3390/agronomy11040684.

[21] T.A., Oyewale, O.N. Oyewale, A.E. Falodun, Cassia fistla seeds nutritional profile and therapeutic potentials. Insight in chemistry and biochemistry 2022, 2(2022),1-7

[22] O.A., Babatunde, D.O., Ojo, D.F., Adewumi, Evaluation of mineral elements in selected vegetables cultivated in Ekiti State, Nigeria. International Journal of Agriculture and Environmental Research, 5(2019), 45–53.

[23] O.B. Ajayi, T.J., Bamidele, O.I. Malachi, A.A. Oladejo, Comparative proximate minerals and anti nutrient analysis of selected nigerian leafy vegetables. Journal of Applied life sciences international, 16(2018),1-8. https://doi.org/10.9734/JALSI/2018/26666.

[24] S.J., Olatunde, B.A., Akinwande, O., Ogunyemi, Proximate and mineral composition of leafy vegetables sold in Jos North Local Government Area, Plateau State, Nigeria. International Journal of Nutrition and Food Sciences, 6(2017), 123–129. https://doi.org/10.11648/j.ijnfs.20170603.15.

[25] A., Ibrahim, B., Suleiman, H., Musa, Proximate composition of lettuce (Lactuca sativa) from Minna, Niger State, Nigeria. Journal of Food Science and Technology, 57(2020), 1453–1460.

[26] A.C., Akinmoladun, E.O., Ibukun, E., Afor, Mineral composition and nutritional evaluation of selected leafy vegetables consumed in Nigeria. Journal of Food Composition and Analysis, 96(2021),103735.

[27] M.S., Calvo, C., Lamberg-Allardt, T., Pham, Minerals in plant food: Effect of agricultural practices and role in human health. Agronomy, 11(2021), 1–21. https://doi.org/10.3390/agronomy11040684.

[28] Y., Zhang, X., Li, J., Wang, Q., Chen, Mineral accumulation and dietary contribution of leafy vegetables grown under different cultivation systems in China. Journal of Food Science, 87(2022), 4021–4032. https://doi.org/10.1111/1750-3841.16234.

[29] A., Abdullahi, M., Bello, I., Garba, Mineral composition of leafy vegetables consumed in Kano Metropolis, Nigeria. International Journal of Food Science and Nutrition, 3(2018), 45–52.

[30] M., Yusuf, A., Ibrahim, S., Aliyu, Nutrient profiling of leafy vegetables from Bauchi State, Nigeria. African Journal of Food Science, 13(2019), 98–104.

[31] C., Ogbunugafor, P., Nwankwo, C., Eze, Nutritional and mineral composition of leafy vegetables in Anambra State, Nigeria. Journal of Food Composition and Analysis, 90(2020), 103498.

[32] O., Adewumi, T., Ogunleye, A., Olawale, Nutrient and protein content of Moringa oleifera leaves in Oyo State, Nigeria. Journal of Food Science and Nutrition, 10(2020), 1–8.

[33] R., Singh, S., Sharma, P., Kaur, Mineral composition of commonly consumed leafy vegetables in India. Journal of Food Science and Technology, 57(2020); 3482–3490.

[34] W.,Abebe, T., Mekonnen, K., Desta, Nutritional evaluation and mineral composition of indigenous leafy vegetables in Ethiopia. Heliyon, 7(2021): e07033. https://doi.org/10.1016/j.heliyon.2021.e07033.

[35] L.F., Silva, R.A., Pereira, M. A., Costa, Iron and other mineral contents in commonly consumed leafy vegetables in Brazil. Food Chemistry, 367(2022); 130727. https://doi.org/10.1016/j.foodchem.2021.130727.

[36] M., Abubakar, A., Musa, H., Bello, Zinc concentration in leafy vegetables from Hunkuyi, Kaduna State, Nigeria: Influence of agricultural practices. International Journal of Food Science and Nutrition, 2(2017), 45–51.

[37] E.N., Onyeike, P.C., Ojimelukwe, Mineral composition of leafy vegetables sold in Kakuri Market, Kaduna State, Nigeria. African Journal of Food Science, 9(2015): 215–220.

[38] F.A., Oluwole, T.M., Adepoju, O.O., Oladipo, Zinc and other trace elements in leafy vegetables grown in Southern Nigeria. Journal of Food Composition and Analysis, 86(2020): 103378.

[39] C.N., Eze, E.C., Okoye, C.I., Chukwu, Nutritional evaluation of leafy vegetables in Enugu State, Nigeria. Food Science and Nutrition, 7(2019): 1934–1941. https://doi.org/10.1002/fsn3.1165.

[40] A.R., Bello, T.A., Lawal, K.S., Adeyemi, Mineral content of cabbage and lettuce cultivated in Lagos State, Nigeria. Journal of Nutrition and Food Sciences, 11(2021): 1–9.

[41] P., Sharma, R., Singh, S., Gupta, Zinc and other minerals in commonly consumed green leafy vegetables in India. Journal of Food Science and Technology, 57(2020):1498–1505.

[42] D., Tadesse, M., Bekele, K., Alemayehu, Nutritional and mineral composition of indigenous leafy vegetables in Ethiopia. Heliyon, 7(2021), e07790. https://doi.org/10.1016/j.heliyon.2021.e07790.

[43] M., Yildiz, H., Kaya, F., Demir, Zinc content and mineral composition of commonly consumed leafy vegetables in Turkey. Food Chemistry, 353(2021): 129487. https://doi.org/10.1016/j.foodchem.2021.129487.

[44] R., Rizzoli, J.Y., Reginster, J. F., , Arnal, I., Bautmans, C., Beaudart, H., Bischoff-Ferrari, J.A., Kanis, Nutritional intake and bone health. Osteoporosis International, 25(2014): 1–21.

[45] S., Sreelatha, P.R., Padma, (2009).Antioxidant activity and total phenolic content of Moringa oleifera leaves in two stages of maturity.Plant Foods for Human Nutrition, 64(2009):303–311. https://doi.org/10.1007/s11130-009-0141-0.

[46] P.N., Okafor, C.O., Eze, P.I., Nwankwo, Iron and zinc contents and Fe:Zn ratios of selected leafy vegetables cultivated in Benue State, Nigeria. African Journal of Food Science, 11(2017):65–72.

[47] M., Ibrahim, A., Musa, H., Lawal, (2019). Mineral composition and Fe:Zn ratios of leafy vegetables from Kaduna State, Nigeria. Journal of Nutrition and Food Sciences, 9(2019); 1–7.

[48] R., Patel, S., Sharma, A., Singh, . Iron and zinc content and Fe:Zn ratios in commonly consumed leafy vegetables in India. Journal of Food Science and Technology, 57(2020):1985–1993.

[49] T., Bekele, W., Abebe, T., Mekonnen, Mineral composition and Fe:Zn ratios of indigenous leafy vegetables in Ethiopia. Heliyon, 7(2021); e08123. https://doi.org/10.1016/j.heliyon.2021.e08123.

[50] R., González, M., Torres, F., Pérez, Mineral content and Fe:Zn ratios in local leafy vegetables consumed in Mexico. Food Chemistry, 260(2018):36–42. https://doi.org/10.1016/j.foodchem.2018.03.021.

[51] I.A., Onimawo, E.I., Akubugwo, Nutritional composition of selected leafy vegetables in Nigeria. African Journal of Food, Agriculture, Nutrition and Development, 12(2012):5689–5703.

[52] C.C., Okeke, C.N., Eze, C.O., Nwachukwu, Proximate composition of leafy vegetables cultivated in Enugu State, Nigeria. International Journal of Food Science and Nutrition, 3(2018), 89–95.

[53] J.K., Mensah, H., Amaglo, O.I., Oladele, E., Owusu, Nutritional composition of Moringa oleifera and commonly consumed leafy vegetables in Ghana. Journal of Food Composition and Analysis, 80(2019):1–8. https://doi.org/10.1016/j.jfca.2019.02.006.

[54] L.W., Wambui, P.N., Kamau, C.K., Mwangi, . Proximate analysis of leafy vegetables grown in central Kenya. African Journal of Food Science, 14(2020): 123–130. https://doi.org/10.5897/AJFS2020.1935.

[55] V., Chavasit, N., Rojroongwasinkul, S., Siriamornpun, Proximate and mineral composition of commonly consumed vegetables in Thailand. Food Chemistry, 229(2017):488–495. https://doi.org/10.1016/j.foodchem.2017.02.018.

[56] J. L., Slavin, B., Lloyd, Health benefits of fruits and vegetables. Advances in Nutrition, 3(2012), 506–516. https://doi.org/10.3945/an.112.002154.

[57] P., Kumar, S., Mishra, A., Malik, S., Satya, Nutritional and medicinal properties of Moringa oleifera: A review. Journal of Food Science and Nutrition, 8(2020):67–75.

[58] I.O., Akinyele, T. S., Olatunde, T. M., Adepoju, Proximate composition and nutrient evaluation of leafy vegetables in Ondo State, Nigeria. African Journal of Food Science, 12(2018); 103–110.

[59] A.I., Olagunju, A.A., Adebayo, O.O., Adeola, Nutritional evaluation of selected leafy vegetables consumed in Ekiti State, Nigeria. International Journal of Food Science and Nutrition, 4(2019);45–52.

[60] A.O., Abiodun, T.M., Ogunleye, K.S., Adeyemi, Nutritional quality and proximate composition of cabbage and lettuce sold in Lagos markets, Nigeria. Journal of Food and Nutrition Research, 8(2020);145–152.

[61] P.U., Rao, M.K., Devi, V.S., Reddy, Dietary fiber content of selected vegetables and their role in human nutrition. Food Research International, 105(2018);400–406.

[62] M.M., Rahman, M.A., Hossain, M.S., Islam, Nutritional composition of selected leafy vegetables available in Bangladesh. Journal of Food Composition and Analysis, 67(2018);14–20.

[63] H.S., El-Beltagi, A.A., Mohamed, G., Safwat, Evaluation of nutritional quality and antioxidant properties of Moringa oleifera leaves. Asian Journal of Biological Sciences, 12(2019); 151–159.

[64] J.W., Kamau, F.K., Mutua, S.N., Wambugu, Nutritional composition of Moringa oleifera and selected vegetables consumed in Kenya. African Journal of Food Science, 14(2020);274–281.

[65] A.A., Adebayo, A.I., Olagunju, O.O., Adeola, Proximate composition and crude fiber content of selected leafy vegetables consumed in southwestern Nigeria. Nigerian Journal of Nutritional Sciences, 42(2021);45–52.

[66] W., Chai, F., Li, H., Zhang, Proximate composition and fatty acid profile of selected leafy vegetables in China. Journal of Food Composition and Analysis, 49(2016):10–18. https://doi.org/10.1016/j.jfca.2015.12.006.

[67] S., Ghosh, A., Roy, S., Dey, Nutritional and proximate analysis of Moringa oleifera leaves in India: Effect of maturity on nutrient composition. Journal of Food Measurement and Characterization, 12(2018):2005–2012.

[68] S.R., Dewi, M.A., Sari, Nutritional evaluation of leafy vegetables in Indonesia: Proximate and lipid content analysis. Asian Journal of Food and Agro-Industry, 10(2017); 67–75.

[69] R.L., Smith, P.K., Johnson, T., Nguyen, Proximate and mineral composition of Moringa oleifera leaves grown in Florida, USA. Journal of Food Composition and Analysis, 62(2017); 34–40. https://doi.org/10.1016/j.jfca.2017.02.006.

[70] D., Johnson, S., Lee, Mineral and proximate composition of cabbage and lettuce in Ontario, Canada. Canadian Journal of Plant Science, 98(2018);1092–1098. https://doi.org/10.1139/cjps-2018-0123.

[71] M., Torres, C., Ramirez, J., Lopez, Nutritional analysis of Moringa oleifera leaves in Mexico: Ash and carbohydrate content. Journal of Food Quality, 42(2019); 25–32.

[72] A., Davis, H., Miller, K., Thompson, Proximate analysis of leafy vegetables grown in California, USA. Food Science and Nutrition, 8(2020); 3502–3509.

[73] L., Martin, J., Robertson, P., Clark, Nutrient composition of Moringa oleifera and other leafy vegetables cultivated in Quebec, Canada. Journal of Food Composition and Analysis, 97(2021);103727.

[74] F.A., Nguema, P., Mbougueng, M., Tchouanguep, Nutritional composition of cabbage cultivated in Cameroon: Proximate and mineral analysis. Journal of Food Composition and Analysis, 77(2019);45–52.

[75] P., Mbougueng, F.A., Nguema, M., Tchouanguep, Proximate analysis of lettuce (Lactuca sativa) cultivated in Central African Republic. African Journal of Agricultural Research, 15(2020); 347–353.

[76] F., Kalonji, J., Mukendi, D., Tshibangu, Nutritional profiling of Moringa oleifera leaves in the Democratic Republic of Congo. Food Science & Nutrition, 6(2018); 725–732. https://doi.org/10.1002/fsn3.615.

[77] F., Dupont, M., Bernard, J., Leroy, Proximate composition of cabbage cultivated in France. European Food Research and Technology, 243(2017);1425–1432.

[78] H., Fischer, K., Müller, S., Weber, Nutrient composition of lettuce varieties grown in Germany. Journal of Applied Botany and Food Quality, 91(2018); 120–126.

[79] G., Rossi, L., Bianchi, M., Conti, Proximate and carbohydrate composition of Moringa oleifera leaves grown in Italy. Journal of Food Composition and Analysis, 79(2019); 41–48. https://doi.org/10.1016/j.jfca.2019.03.002.

[80] O.A., Adeyemi, O.T., Omotoso, T., Fadeyi, Moisture content and proximate analysis of selected leafy vegetables in Ekiti State, Nigeria. Nigerian Journal of Nutrition Science, 40(2019);55–62.

[81] S., Miller, R., Brown, D., Wilson, Carbohydrate and nutrient content of leafy vegetables grown in California. Journal of Agricultural and Food Chemistry, 67(2019); 5920–5928.

[82] T., Roberts, M., Evans, G., Harrison, Proximate analysis and nutrient profiling of leafy vegetables in Ontario, Canada. Canadian Journal of Food Science, 103(2020); 502–510.

[83] P., Hernandez, R., Castillo, A., Flores,Proximate composition of commonly consumed leafy vegetables in Mexico. Food Chemistry, 239(2018); 123–130. https://doi.org/10.1016/j.foodchem.2017.06.045.

[84] S., Musa, I., Abdullahi, M.S., Bello, Nutritional evaluation of Moringa oleifera leaves from Kano State, Nigeria. African Journal of Food Science, 12(2018); 215–222.

[85] V., Reddy, S., Kumar, P., Sharma, Proximate composition of cabbage and lettuce grown in India. International Journal of Food Science and Nutrition, 68(2017); 841–847.

[86] R., Khan, S., Ahmed, M., Ali, Proximate analysis of Moringa oleifera leaves in Pakistan: Moisture and nutrient content. Pakistan Journal of Nutrition, 17(2018); 472–478.

[87] M.R., Islam, M.M., Hossain, M., Rahman, Nutrient composition of cabbage and lettuce cultivated in Bangladesh. Journal of Food Measurement and Characterization, 13(2019); 1204–1211.

[88] T.P., Nguyen, H.M., Le, H. Q.V., Tran, Proximate composition of leafy vegetables in Vietnam: Effects of climate and cultivation methods. Food Science & Nutrition, 8(2020):895–902. https://doi.org/10.1002/fsn3.1402.

[89] M., Ali, M., Sajad, N., Akhtar, Nutritional and mineral composition variability among selected leafy vegetables. Journal of Food Composition and Analysis, 82(2019),103231. https://doi.org/10.1016/j.jfca.2019.06.003.