

COMPARATIVE VITAMIN AND MINERAL PROFILES OF *DIOSCOREA VILLOSA* LEAF AND ROOT-EXTRACTS: AN ANALYTICAL REASSESSMENT OF EXTRACTION-SOLVENT AND PLANT-PART DIFFERENCES

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Abstract—*Dioscorea villosa* leaf and root-extracts contain measurable vitamins and minerals, but comparative compositional data across extraction solvents remain limited. This study compared vitamin and mineral concentrations in deionized-water and diethylether extracts of leaves and roots and assessed their correlation patterns and principal component structure. Original analytical records were reanalysed for four preparations: deionized-water leaf (DWL), deionized-water root (DWR), diethylether leaf (DEL) and diethylether-root (DER). Nine reported vitamins and eleven minerals were summarized as mean $\pm$ standard deviation from three recorded readings per analyte. Pearson correlations and standardized principal component analysis (PCA) were calculated from four extract-level profiles. Vitamin A was highest in DER (9.840 mg/100 g) and lowest in DWL (0.313 mg/100 g). Vitamin C was higher in DEL (4.813 mg/100 g) and DER (4.347 mg/100 g) than in DWL (1.867 mg/100 g) and DWR (1.640 mg/100 g). Calcium was highest in DWL (21.180 mg/100 g), while phosphorus peaked in DWR (29.507 mg/100 g). Manganese was highest in DEL (2.480 mg/100 g). Vitamin B4 and C correlated positively ($r = 0.994$); mineral correlations also showed strong contrasting patterns. The first two principal components explained 87.37% of vitamin variation and 93.27% of mineral variation. These findings identify distinct extract-specific compositional profiles. However, the four-profile multivariate analyses are exploratory, and discrepancies in the original potassium and phosphorus readings require verification before confirmatory interpretation.

Index Terms—*Dioscorea villosa*, vitamins, minerals, correlation heatmap, principal component analysis, solvent extraction

I. INTRODUCTION

The genus *Dioscorea* (Dioscoreaceae) includes plants of nutritional and pharmacological interest. Although several species are cultivated as edible tubers, others are studied for their specialized metabolites. *Dioscorea villosa* L. (wild yam) is associated with steroidal saponins, but its vitamin and mineral profiles, particularly those of separate leaf and root extracts, require further characterization. Such analyses distinguish the chemical composition of prepared extracts from the composition of intact plant tissues [1], [2].

Vitamins support metabolic regulation, enzymatic activity, cellular maintenance and antioxidant defence. Vitamin A contributes to immune function and cellular differentiation, B-complex vitamins participate in coenzyme-dependent metabolism, and vitamins C and E have distinct antioxidant roles. Their measured concentrations in botanical preparations can vary with tissue selection, solvent properties, and processing, chemical stability and assay conditions. Consequently, values determined in extracts should not be generalized to whole-plant nutritional content.

Mineral constituents, likewise contribute to biological functions. Calcium, magnesium, potassium, sodium and phosphorus are involved in structural, physiological and metabolic processes, while iron, zinc, manganese and selenium participate in essential enzyme systems. Elemental concentrations may vary across plant organs and preparation methods. Measurements of elements such as lead also warrant attention, although detection alone does not establish toxicological risk. Interpretation requires clear

analytical procedures, calibration, quality control and a defined concentration basis [3]. Comparative work on white- and orange-fleshed sweet potato cultivars has also documented variation in nutritional and anti-nutritional traits, supporting the value of organ- and preparation-specific compositional assessment [4], [5], [6].

Extraction solvent influences the recovery of plant constituents through differences in polarity and solubility. Water and diethylether may therefore produce contrasting chemical profiles from the same plant organ. Leaves and roots also differ in their physiological roles and constituent distributions. Comparing these two organs under the two extraction conditions provides a framework for identifying organ-associated and solvent-associated differences, without assuming that an observed contrast establishes its underlying biochemical mechanism [7].

In addition to individual constituent measurements, multivariate analysis can summarize compositional relationships. Pearson correlation coefficients describe linear associations between analytes, while principal component analysis (PCA) reduces a multivariable dataset to orthogonal components that capture dominant patterns of variation. PCA can aid visualization of similarities and differences among extract profiles, but its interpretation depends on sample size, scaling and data structure [8]. With only four extract-level profiles, correlations and component loadings are exploratory rather than confirmatory [9], [8].

The available analytical records provide vitamin and mineral measurements for aqueous and diethylether extracts of *D. villosa* leaves and roots. Integrating their descriptive

composition with correlation matrices and PCA may reveal patterns that are less apparent from individual measurements. Accordingly, this study aimed to compare vitamin and mineral concentrations among the four extract preparations, examine associations among the measured analytes using Pearson correlation analysis, and characterize their multivariate compositional differences using PCA.

II. MATERIALS AND METHODS

A. Study design and experimental material

The source was the thesis “Effects of Leaf and Root Extracts of *Dioscorea villosa* on Some Biochemical Parameters in Gentamicin-Induced Kidney Damage in Albino Rats” by V. U.-O. Nwankwo. The chemical-composition component used four preparations: deionized-water leaf (DWL), deionized-water root (DWR), diethylether leaf (DEL) and diethylether root (DER). This article reanalysed archived numerical records; it did not involve fresh collection, extraction or animal experimentation. Plant collection location, voucher accession and independent sampling units must be confirmed from the original laboratory documentation before submission. The roots and leaves of *Dioscorea villosa* were collected from Uffiboto 135 Amike Ezzangbo in Ohaukwu L. G. A. of Ebonyi State in September 2017 and were identified by a Taxonomist Prof. C. V. Nnamani of the Department of Applied Biology, Ebonyi State University, Abakaliki

B. Extract preparation

Leaf and root preparations were classified by the source thesis according to solvent (deionized water or diethyl ether). **Sample Preparation:** The leaves and roots were air dried at room temperature for 7-8 days. The dried samples were pulverized and stored in air-tight containers at 4 °C.

Extracts Preparation. The extraction method of Sofowora [10] was adopted.

Leaves: One thousand gram of the powdered leaves was soaked in 1500 ml of deionized water and diethylether separately for 48 hours with periodic stirring. Thereafter, the suspension was filtered using muslin cloth. The filtrates were evaporated using a rotary evaporator set at 30°C. The extracts were then divided into diethylether-leaf extract (DEL extract) and deionized water-leaf extract (DWL extract) and stored in air-tight containers at 4 °C for use. The same method was applied to the root.

Roots: Seven hundred and fifty grams of the powdered roots was soaked in 1000 ml of diethylether and deionized water separately for 48 hours with periodic stirring. Thereafter, the suspension was filtered using muslin cloth. The filtrates were evaporated using a rotary evaporator. The extracts were then divided into diethyl-root extract (DER extract) and deionized water-root extract (DWR extract) and stored in air-tight containers at 4 °C for use.

C. Vitamin determinations

The source thesis reports separate assays for retinol (vitamin A) [11], thiamin (B₁) [12], riboflavin (B₂) [12], niacin (B₃) [12], pyridoxine (B₆) [13], folate (B₉) [14], ascorbic acid (C) [15] and tocopherol (E) [16]. Its retinol protocol used 4 g of extract with ethanolic potassium hydroxide under reflux for 1 h. Its ascorbic-acid procedure extracted 3 g of material in metaphosphoric-acetic acid solution before analysis. These descriptions reflect the thesis, not independent method validation. The appendix additionally labels an analyte “B₄”; its chemical identity is unconfirmed, so that designation is retained as a source label and not interpreted as an established essential vitamin. A separate B₁₂ result could not be reconciled with the reanalysed appendix panel. The AOAC editions cited in the source include the 15th, 16th, 17th and 18th editions [11], [17], [13], [15].

D. Mineral determinations

According to the thesis, sodium and potassium were measured by flame photometry after acid digestion [17]; calcium and magnesium were assessed by EDTA titration; phosphorus by a molybdate-based colorimetric procedure; iron by a phenanthroline method; and zinc by a dithizone procedure. Manganese and selenium were described following nitric-acid wet digestion [18]. The thesis reports additional cobalt and lead results, but complete instrument-specific quality-control records were not available in the extracted dataset. Calibration, blank correction, certified reference materials, detection limits and analyte recovery therefore remain unverified. All reported concentrations retain the appendix unit of mg/100 g pending confirmation of the exact sample-mass basis.

E. Statistical Analysis

Data were summarized as mean ± sample standard deviation (SD) from three recorded readings per analyte and extract. Extract-level means were used to calculate Pearson correlation matrices and standardized principal component analyses (PCA) separately for vitamins and minerals. PCA was performed after centering and scaling each analyte; PC1 and PC2 explained variance was reported as percentages. Within-analyte letters indicate descending mean ranks only, not statistical significance. Correlation and PCA results were interpreted descriptively because only four extract profiles were available and independence of the recorded triplicates was unconfirmed. Analyses were reproducible using the accompanying R script.

III. RESULTS

A. Vitamin Concentrations and Descriptive Mean Grouping

Table I summarizes the concentrations of nine vitamins in aqueous leaf (DWL), aqueous root (DWR), diethylether leaf (DEL) and diethylether root (DER) extracts. Vitamin A ranged from 0.313 ± 0.012 mg/100 g in DWL to 9.840 ± 0.030 mg/100 g in DER; the corresponding concentrations in DWR and DEL were 5.450 ± 0.036 and 3.370 ± 0.010

mg/100 g. Vitamin C was 1.867 ± 0.015 , 1.640 ± 0.040 , 4.813 ± 0.015 and 4.347 ± 0.035 mg/100 g in DWL, DWR, DEL and DER, respectively. The analyte recorded as B₄ ranged from 0.020 ± 0.010 mg/100 g in DWL to 1.123 ± 0.012 mg/100 g in DEL. Vitamin B₆ was highest in DER (0.923 ± 0.021 mg/100 g), whereas vitamin E was highest in DWR (0.240 ± 0.036 mg/100g). Table I provides the remaining concentrations and within-analyte descriptive mean rankings.

TABLE I
VITAMIN COMPOSITION OF DWL, DWR, DEL AND DER EXTRACTS

Analyte	DWL	DWR	DEL	DER
A	0.313 ± 0.012	5.450 ± 0.036	3.370 ± 0.010	9.840 ± 0.030
B ₁	0.040 ± 0.020	0.020 ± 0.010	0.047 ± 0.015	0.053 ± 0.012
B ₂	0.053 ± 0.021	0.023 ± 0.015	0.107 ± 0.031	0.110 ± 0.010
B ₃	0.043 ± 0.025	0.027 ± 0.006	0.130 ± 0.010	0.107 ± 0.012
B ₄	0.020 ± 0.010	0.023 ± 0.015	1.123 ± 0.012	1.080 ± 0.010
B ₆	0.080 ± 0.010	0.073 ± 0.015	0.827 ± 0.117	0.923 ± 0.021
B ₉	0.023 ± 0.012	0.030 ± 0.010	0.147 ± 0.220	0.043 ± 0.025
C	1.867 ± 0.015	1.640 ± 0.040	4.813 ± 0.015	4.347 ± 0.035
E	0.113 ± 0.025	0.240 ± 0.036	0.220 ± 0.020	0.170 ± 0.010

Vitamin composition (mg/100 g; mean $\pm$ sample SD, three recorded readings per cell). Letters a–d indicate descriptive within-row mean rank only (a = highest); they are not inferential significance groupings. Independent extraction replicates were not documented.

B. Mineral Concentrations and Descriptive Mean Grouping

Table II presents mean $\pm$ SD of concentrations of eleven mineral elements across the four extracts. Calcium concentrations were 21.180 ± 0.010 mg/100 g in DWL, 20.617 ± 0.015 mg/100 g in DWR, 3.187 ± 0.015 mg/100 g in DEL and 3.667 ± 0.015 mg/100 g in DER. Iron ranged from 7.813 to 7.913 mg/100 g in aqueous extracts and from 1.270 to 1.363 mg/100 g in ether extracts. Phosphorus was highest in DWR (29.507 ± 0.031 mg/100 g) and lowest in DER (10.020 ± 0.020 mg/100 g). Manganese was 0.467 ± 0.015 , 0.410 ± 0.010 , 2.480 ± 0.010 and 2.390 ± 0.010 mg/100 g in DWL, DWR, DEL and DER, respectively. Lead concentrations ranged from 0.023 to 0.030 mg/100 g. Potassium, magnesium, sodium, cobalt, selenium and zinc values, together with the descriptive mean rankings, are reported in Table II.

TABLE II
MINERAL COMPOSITION OF DWL, DWR, DEL AND DER EXTRACTS

Analyte	DWL	DWR	DEL	DER
Ca	21.180 ± 0.010	20.617 ± 0.015	3.187 ± 0.015	3.667 ± 0.015
Co	0.017 ± 0.006	0.020 ± 0.010	0.060 ± 0.020	0.107 ± 0.031
Fe	7.813 ± 0.186	7.913 ± 0.012	1.270 ± 0.020	1.363 ± 0.015
K	2.537 ± 3.432	8.280 ± 0.020	8.787 ± 0.015	8.930 ± 0.030
Mg	7.083 ± 0.021	7.863 ± 0.012	5.293 ± 0.067	6.477 ± 0.015
Mn	0.467 ± 0.015	0.410 ± 0.010	2.480 ± 0.010	2.390 ± 0.010
Na	7.367 ± 0.015	8.170 ± 0.020	2.467 ± 0.025	2.477 ± 0.021
P	28.333 ± 0.025	29.507 ± 0.031	13.093 ± 5.211	10.020 ± 0.020
Pb	0.030 ± 0.010	0.027 ± 0.015	0.023 ± 0.012	0.027 ± 0.015
Se	0.023 ± 0.012	0.020 ± 0.010	0.190 ± 0.020	0.117 ± 0.015
Zn	0.233 ± 0.031	0.270 ± 0.010	1.120 ± 0.020	1.067 ± 0.015

Mineral composition (mg/100 g; mean $\pm$ sample SD, three recorded readings per cell). Letters a–d indicate descriptive within-row mean rank only (a = highest); they are not inferential significance groupings. Independent extraction replicates were not documented.

C. Lower-triangular Correlation Matrices of Vitamin and Mineral Profiles

Fig. 1 displays the lower-triangular Pearson correlation matrix for nine vitamin measurements across the four extract-level mean profiles. Each off-diagonal coefficient appears once, and the diagonal and upper half are omitted. The association between the analyte designated B₄ and vitamin C was positive ($r = 0.994$), while that between vitamins B₁ and E was negative ($r = -0.436$). Additional coefficients included A–C, $r = -0.175$; B₂–B₃, $r = +0.963$; B₆–C, $r = +0.964$; A–E, $r = +0.014$. Correlation coefficients are displayed numerically in the corresponding matrix cells, with the colour gradient representing their direction and magnitude. The underlying sample size for every coefficient was four extract profiles (DWL, DWR, DEL and DER). These coefficients describe between-profile variation in mean concentrations; the figure does not display correlations calculated from independently replicated biological samples.

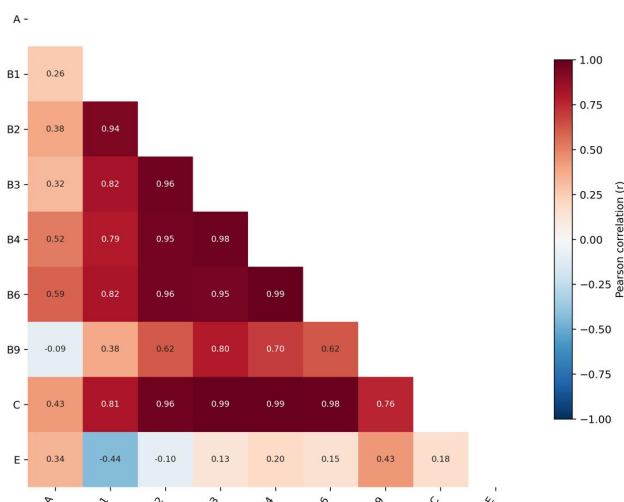


Fig. 1. Lower-triangular Pearson correlation matrix for vitamin analytes across four extract-level mean profiles (n = 4). Each correlation is displayed once; the diagonal and redundant upper triangles are omitted. Correlations are descriptive and exploratory.

Fig. 2 shows the lower-triangular Pearson correlation matrix for eleven minerals measured in four extract-level mean profiles. Calcium and iron showed a positive association ($r = 0.999$), whereas iron and manganese showed a negative association ($r = -1.000$, rounded to three decimal places). Other coefficients were Ca–P, $r = +0.999$; Ca–Mg, $r = +0.987$; Fe–Na, $r = +1.000$; K–Zn, $r = +0.952$; Se–Mn, $r = +0.995$. The matrix presents each mineral pair once and excludes the self-correlations along the diagonal. Cell annotations give Pearson's r and colour intensity distinguishes positive from negative coefficients. All values were calculated across DWL, DWR, DEL and DER (n = 4 profiles). The analysis used the extract-level mean concentrations rather than the three individual analytical readings per cell; no correlation significance levels are assigned in Fig. 2.

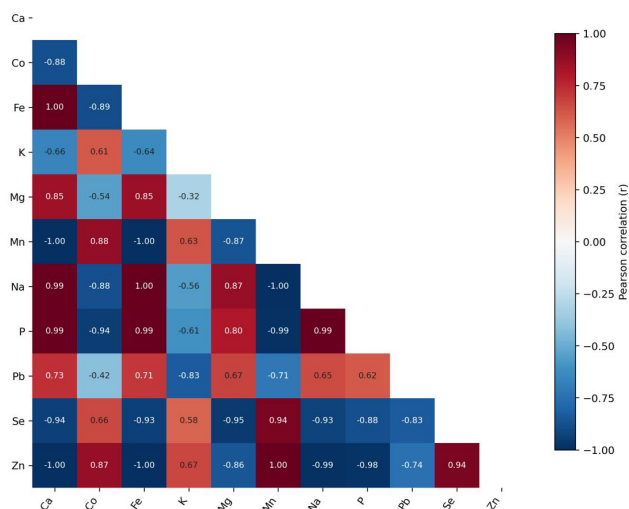


Fig. 2. Lower-triangular Pearson correlation matrix for mineral analytes across four extract-level mean profiles ($n = 4$). Each correlation is displayed once; the diagonal and redundant upper triangles are omitted. Correlations are descriptive and exploratory.

D. Principal Component Analysis

Fig. 3 presents the principal component analysis of the nine standardized vitamin variables for the four extract profiles. The first principal component (PC1) accounted for 70.23% of the total variance, and the second component (PC2) accounted for 17.14%. Together, these axes explained 87.37% of the variance; the remaining components accounted for 12.63%. The biplot places DWL, DWR, DEL and DER in the PC1–PC2 coordinate space and overlays vectors representing vitamins A, B₁, B₂, B₃, B₄, B₆, B₉, C and E. The relative positions of the extract labels and the directions of the vitamin vectors are shown in Fig. 3. The analysis was performed on the standardized extract-level mean matrix, comprising four observations and nine variables. No additional biological observations or confidence regions are represented in the plot.

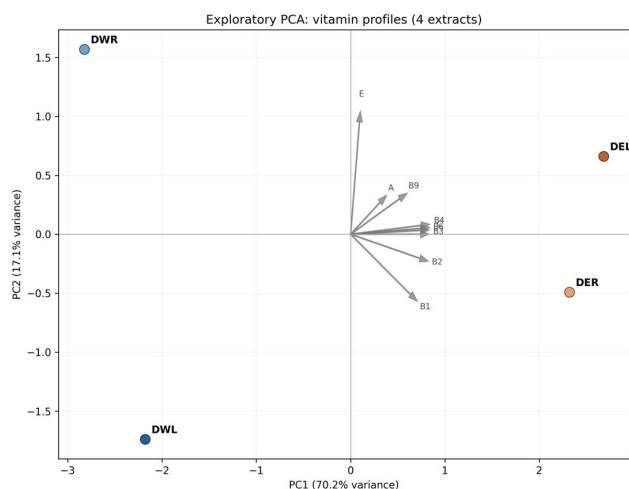


Fig. 3. Exploratory Standardized PCA Biplot for Vitamin Mean Profiles. Only four extract profiles were available; loading interpretation is provisional.

Fig. 4 presents the principal component analysis of eleven standardized mineral variables across the four extract profiles. PC1 explained 84.87% of the total variance, while PC2 explained 8.39%; their combined contribution was 93.27%. The remaining principal components therefore represented 6.73% of the variance. The biplot includes the four extract profiles (DWL, DWR, DEL and DER) and loading vectors for calcium, cobalt, iron, potassium, magnesium, manganese, sodium, phosphorus, lead, selenium and zinc. The plotted extract scores describe their positions on the first two principal components, while the loading vectors identify the directions associated with the measured minerals. Fig. 4 displays these scores and vectors on the same two-dimensional ordination. PCA was applied to the standardized four-by-eleven extract-level mean matrix, without adding the individual laboratory readings as independent observations.

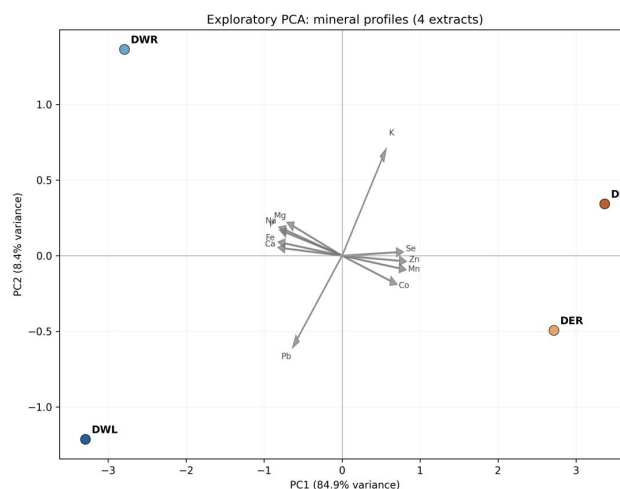


Fig. 4. Exploratory Standardized PCA Biplot for Mineral Mean Profiles. Only four extract profiles were available; loading interpretation is provisional.

IV. DISCUSSION

The vitamin data reveal marked differences between plant parts and solvents, but the direction of these differences varies by analyte. Vitamin A was greatest in DER (9.840 mg/100 g) and lowest in DWL (0.313 mg/100 g), whereas vitamin E peaked in DWR (0.240 mg/100 g). The higher reported vitamin C concentrations in DEL and DER than in the aqueous preparations deserve particular scrutiny because ascorbic acid is strongly hydrophilic. Extraction recovery, oxidation during processing, matrix effects or nonspecific assay response may contribute to an unexpected solvent pattern, but the available records cannot distinguish among these explanations. The reported B₄ designation also lacks an unambiguous chemical identity and should not be interpreted as a specific established vitamin until the original assay target is confirmed. Solvent-dependent recovery is well recognized in botanical extraction, although the phenolic-extraction review by Alara et al. [7] provides general methodological context rather than direct validation of these vitamin measurements. Related botanical-extract studies using *Annona muricata*

examined biochemical responses in paracetamol-exposed rats [19]–[21]. Those animal findings concern a different plant and injury model and do not establish the biological effects of the *D. villosa* extracts assessed here [1], [2].

The mineral measurements show a clearer solvent-associated contrast for several elements. Calcium and iron were substantially higher in the aqueous preparations, while manganese was higher in the ether preparations. These differences may reflect tissue composition, sample preparation, solvent-dependent transfer or analytical matrix effects; they do not establish that ether preferentially extracts elemental minerals in a chemically direct manner. Phosphorus was highest in DWR, but the inconsistent DEL phosphorus readings limit the reliability of its reported variability. Similarly, the DWL potassium readings contain an outlying value pattern that materially changes the calculated mean and SD. Both records require checking against laboratory notebooks or instrument outputs before interpretation. Detection of lead at low reported concentrations is analytically relevant, yet health-risk conclusions require validated quantification, exposure estimates and appropriate regulatory comparison. AOAC International [3] documents the importance of validated analytical methods, although no specific historical method can be certified from this reanalysis. The observed variation in mineral composition can be considered alongside reported nutritional differences among sweet potato genotypes [4], although the crops, tissues and analytical designs are not directly comparable [5], [6].

The vitamin correlation matrix displays several near-perfect positive relationships, including B₄–C ($r = 0.994$) and B₂–B₃ ($r = 0.963$). These correlations indicate that the corresponding measured concentrations followed similar patterns across the four preparations; they do not demonstrate shared biosynthetic regulation or direct chemical interactions. The B₁–E relationship was negative ($r = -0.436$), illustrating that not all vitamins varied in parallel. Because each coefficient was calculated from only four extract means, small changes in any one profile could substantially alter its magnitude or direction. The lower-triangular display removes duplicated entries without changing the underlying calculations. Consequently, the heatmap is best understood as a compact description of the observed extraction profiles, not as evidence of statistically established biochemical associations.

The mineral correlation matrix likewise reflects common between-extract contrasts. Calcium, iron and phosphorus were strongly positively associated, while iron and manganese were nearly perfectly negatively correlated. These results align with the opposing aqueous–ether concentration patterns in Table II. The K–Zn and Se–Mn associations suggest further co-variation among the four measured profiles, but the potassium discrepancy could influence correlations involving K. With eleven minerals and only four observations, a large number of pairwise coefficients are calculated from very limited information.

Extreme correlations may therefore arise from shared solvent contrasts or individual influential profiles rather than stable physiological relationships. Independent plant samples and replicated extraction batches would be necessary to evaluate whether these associations persist.

The PCA results reinforce the descriptive separation of the four preparations. The first two vitamin components accounted for 87.37% of standardized variance, while the corresponding mineral components accounted for 93.27%. These percentages describe the fitted four-profile matrices rather than the proportion of biological variation explained in a wider population. With four observations, the centered data matrix has ranked no greater than three, and its high-dimensional loading structure is sensitive to individual measurements and scaling. As Jolliffe and Cadima [8] explain, PCA summarizes variance and facilitates visualization but does not independently establish causal effects. Accordingly, the biplots complement the composition tables and correlation heatmaps without replacing experimental replication. The present findings support a descriptive analytical comparison and define testable priorities for future work: independently replicated extraction, unambiguous analyte identification, validated recoveries and corrected source records [9].

V. CONCLUSION

The four *Dioscorea villosa* extracts differed in their recorded vitamin and mineral profiles. Diethyl-ether root-extract had the highest vitamin A concentration, whereas aqueous leaf-extract had the highest calcium concentration and aqueous root-extract had the highest phosphorus concentration. Correlation analysis identified contrasting associations among analytes, and the first two principal components accounted for 87.37% and 93.27% of variation in vitamin and mineral profiles, respectively. These findings describe extract-level patterns rather than statistically confirmed treatment effects. Verification of discrepant potassium and phosphorus readings, analyte identity and independent replication is necessary before drawing broader nutritional or biological conclusions.

ETHICAL APPROVAL

Ethical approval for this study was obtained from the Research Ethics Committee, Department of Biochemistry, Ebonyi State University, Abakaliki, Nigeria (Approval No. EBSU/BCH/ET/21/006), subject to confirmation that this approval covers the present animal experiment.

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CONFLICTS OF INTEREST STATEMENT

The author declares no conflict of interest.

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