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VARIATION IN BIOACTIVE, NUTRIENT, AND ANTI-NUTRIENT COMPOSITION OF *GONGRONEMA LATIFOLIUM* PLANT PARTS

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Abstract: *Gongronema latifolium* is an important edible plant in West Africa; however, comparative compositional data across its edible parts remain scarce. This study evaluated the phytochemical, proximate, mineral, and vitamin composition of dried leaves, seeds, and fruit of *G. latifolium*. Phytochemicals were quantified using gas chromatography-flame ionization detection (GC-FID), proximate composition was determined with standard AOAC methods, and minerals and vitamins were analyzed using established spectrophotometric and chromatographic techniques. Data were expressed as mean ± SD and analyzed via one-way ANOVA ($p < 0.05$). The results showed significant variation across the different plant parts. *G. latifolium* leaves contained higher levels of kaempferol (22.32 µg/ml) and flavones (17.57 µg/ml), whereas *G. latifolium* seeds exhibited greater phenolic content (22.20 µg/ml) and quercetin (15.49 µg/ml). *G. latifolium* fruit was richer in protein (26.53%), fat (5.09%), and moisture (6.72%), while leaves had higher crude fiber (26.82%) and ash (13.66%). Calcium and potassium were more abundant in seeds, whereas magnesium and sodium were higher in leaves. Vitamin C (205.20 mg/100 g), carotenoids (46.45 mg/100 g), and B vitamins (notably B_3 and B_6) were more abundant in leaves, while seeds contained higher vitamin E (6.21 mg/g) and B_1. Anti-nutritional factors such as phytate and oxalate were present at varying concentrations across plant parts. These findings demonstrate organ-specific biochemical distributions in *G. latifolium*, highlighting complementary nutritional properties among leaves, fruits, and seeds and providing updated compositional data for future nutritional and functional studies.

Keywords: *Gongronema latifolium*, bioactive compounds, nutraceutical potential, mineral content, leaves and seeds

1. Introduction

Plants are an essential source of nutrients and bioactive compounds that significantly benefit human health and well-being. The medicinal properties of many plant species are strongly linked to their diverse phytochemicals, including flavonoids, alkaloids, phenolic acids, saponins, terpenoids, tannins, and glycosides (Wilson and Roberts, 2014). The therapeutic effects of these plant materials mainly come from interactions among the secondary metabolites they produce. These secondary metabolites possess key properties, including antioxidant, anti-inflammatory, antibacterial, and antidiabetic effects, making them essential

for disease prevention and health promotion (Airaodion et al., 2019; Ohiagu et al., 2021). The rising global interest in medicinal and nutraceutical plants over the past few decades underscores the importance of disease prevention. This trend is driven by the pursuit of safer, more cost-effective alternatives to synthetic medicines, alongside the growing demand for functional foods that provide both nutritional and therapeutic advantages.

Gongronema latifolium Benth., commonly known as "Utazi" in southeastern Nigeria, is a perennial climbing shrub in the family Apocynaceae and the genus *Gongronema*. This edible plant features green leaves, yellow flowers, and a milky latex that exudes when cut; it is high in nutritional value. It is characterized by a distinctive, sharp, bitter-sweet flavor, especially when consumed fresh. The leaves are rich in lipids, proteins, vitamins, minerals, and essential amino acids (Okonkwo et al., 2025), making them an important dietary addition. It is often used in soups as a vegetable or dried and ground into powder for use as a spice (Dalziel, 1937). It is also eaten fresh and can be added to salads (Anameze et al., 2023). *G. latifolium* plays a vital role in nutrition and traditional medicine, with its dietary and ethnomedical uses common in eastern Nigeria and West Africa. Traditional healers use the leaves, stems, seeds, and fruits of this plant to treat various conditions, highlighting its cultural significance and the region's rich ethnobotanical heritage (Ojo et al., 2020; Amrelia, 2022).

Most studies on *G. latifolium* have focused on its leaves, which are rich in flavonoids, phenolic acids, alkaloids, saponins, and terpenoids, and are known to have antioxidant, hepatoprotective, and antimicrobial effects (Olufunke, 2021). However, the seeds and fruits have received comparatively less attention. There is a notable research gap, given that secondary metabolites often vary across plant organs, potentially leading to distinct biological functions. Without comparative data across plant parts, it is difficult to fully assess the species' nutraceutical and pharmacological potential.

Members of the Apocynaceae family, including *G. latifolium*, are known to accumulate flavonols, anthocyanins, and saponins in their fruits and seeds, which have significant antioxidant properties (Okonkwo et al., 2025). Although there are some indications, a comprehensive comparison of phytochemical distributions across leaves, fruits, and seeds remains limited, particularly when combined with nutritional profiling of specific organs. Scientific validation of the phytochemical content in the leaves, fruits, and seeds is crucial to support their use in food, nutraceutical, and pharmaceutical industries.

Understanding how bioactive compounds are distributed in different plant parts is essential for validating traditional knowledge and promoting the careful use of *G. latifolium* in modern applications. Comparative studies can identify specific plant parts for targeted medicinal purposes, guide their use in functional foods, and open new avenues for pharmacological research. Additionally, in regions where the plant is cultivated or harvested, gaining detailed knowledge of its bioactive components in various parts could increase its economic value through diverse applications in the nutraceutical, pharmaceutical, and food industries.

This study aimed to compare the bioactive components of *G. latifolium* leaves, fruits, and seeds, and to examine the proximate, mineral, and vitamin contents of the leaves and seeds. The specific goals were to (i) measure major phytochemicals in each part of the plant to identify differences in bioactive compounds, and (ii) analyze the nutritional aspects of the leaves, fruits and seeds, including their proximate makeup, mineral content, and

selected vitamins. By combining phytochemical analysis with nutritional evaluation, this research provides detailed insights into the organ-specific nutritional and medicinal qualities of *G. latifolium*.

2. Materials and Methods

Sample collection and identification

The fruits, seeds, and leaves of *Gongronema latifolium* (**Fig. 1**) were collected from a local farm in Ntezi-Aba, Abakaliki, Ebonyi State, in eastern Nigeria during the early rainy season. The Department of Crop Science at Ebonyi State University, Abakaliki, performed scientific identification of *G. latifolium*.

Sample preparation

The fresh *Gongronema latifolium* samples (fruit, seeds, and leaves) were thoroughly washed with distilled water to remove dust and debris, then dried in the oven at a temperature of 105 °C for 3 hours. The dried samples were cooled in a desiccator, ground individually into a powder, and then stored in airtight containers at room temperature until analysis.

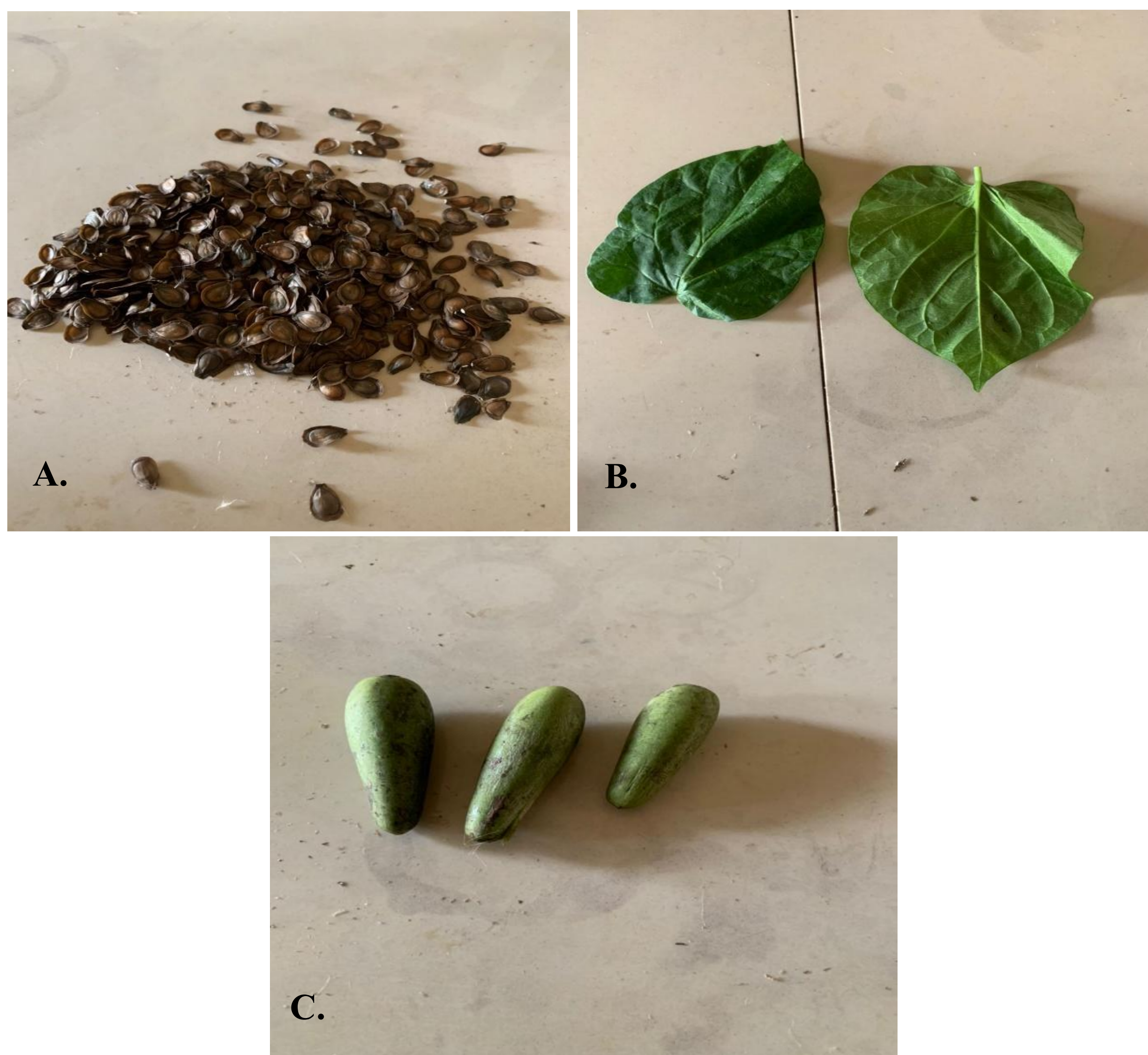

Fig. 1. *Gongronema latifolium*: **A.** seeds; **B.** leaves; **C.** fruits.

Determination of proximate composition

Using the method specified by AOAC (2023), the crude fiber, crude protein, crude fat, moisture, and ash contents of *Gongronema latifolium* fruit, seed, and leaf samples were measured in triplicate. Ebem et al. (2021) indicated that a different approach was employed to assess carbohydrate content. The carbohydrate amount was calculated using a formula.

Determination of moisture content

Approximately 2 g of each powdered sample was dried in a hot air oven at 105 °C until the weight remained constant. Moisture content was calculated as the percentage of weight lost after drying and was expressed as follows:

$$\%\ Moisture = \frac{W\ initial - W\ final}{W\ initial} x\ 100 \quad (1)$$

Determination of ash content

Ash was determined by incinerating 2 g of sample in a muffle furnace at 550 °C for 4–6 hours until light grey ash was produced. The ash percentage was calculated based on the initial sample weight as follows:

$$\%\ Ash = \frac{Weight\ of\ ash}{Dry\ weight\ of\ sample}\ x\ 100 \quad (2)$$

Determination of crude fat content

Crude fat was determined using Soxhlet extraction. Approximately 2 g of dried sample was extracted with petroleum ether (boiling point 40–60 °C) for 6 hours. The solvent was then evaporated, and the lipid was weighed. The fat content was expressed as a percentage of the dry sample weight.

$$\%\ Crude\ fat = \frac{(Extract\ cup + Residue\ weight) - Extraction\ cup\ weight}{Sample\ dry\ weight} x\ 100 \quad (3)$$

Determination of crude protein content

Crude protein was determined using the Kjeldahl method. Samples were digested with concentrated sulfuric acid in the presence of a catalyst, then distilled and titrated. Nitrogen content was multiplied by a conversion factor of 6.25 to compute the crude protein percentage:

$$\%\ Crude\ Nitrogen = \frac{14\ x\ N\ x\ X\ x\ 100}{1000\ x\ V\ x\ W} x\ 100 \quad (4)$$

Hence, % protein = % total nitrogen 6.25 (conversion factor). Where, N = normality of H_2SO_4, X = ml of standard H_2SO_4 required for titration of samples, V = aliquot (ml) of digested extract taken for distillation, W = weight (g) of sample.

Determination of crude fiber content

Crude fiber was determined using AOAC Method. The defatted sample was first digested with dilute sulfuric acid and sodium hydroxide, then filtered, dried, weighed, and incinerated. The fiber content was calculated from the difference in weight before and after ashing:

$$\%\ Crude\ fiber = \frac{Weight\ of\ fiber}{Weight\ of\ sample} x\ 100 \quad (5)$$

Determination of carbohydrate

Carbohydrate content was determined by subtracting the sum of other proximate parameters, such as Nitrogen Free Extract (NFE), from 100% to find the weight by difference.

$$Carbohydrate\ (\%) = 100 - \%\ Moisture - \%\ Ash - \%\ Crude\ Faber - \%\ Crude\ Protein - \%\ Fat \quad (6)$$

Extraction of bioactive compounds

Exactly 20 g of each *Gongronema latifolium* sample was extracted with 100 ml of 95% ethanol using a Soxhlet apparatus for 6 hours. The extracts were filtered through Whatman No. 1 filter paper and concentrated to

dryness under reduced pressure with a rotary evaporator at 40-60 °C. The extracted oil was collected and stored in a reagent bottle for bioactive analysis by gas chromatography.

Analysis of bioactive compounds by gas chromatography flame ionization detector (GC-FID)

The bioactive components were analyzed using a BUCK M910 Gas Chromatograph with an FID detector as described by Imo and Uhegbu FO (2015). A RESTEK 15-metre MXT-1 column (15m x 250µm x 0.15µm) was employed. The injector temperature was set to 280°C, with a 2µl splitless injection of the sample and a linear velocity of 30 cm/s. Helium 5.0 purity served as the carrier gas, flowing at 40 ml/min. The oven temperature was set to 200°C and increased at 30°C/min to 330°C, where it was held for 5 minutes. The detector was maintained at 320°C. Exactly 0.5 µL of the sample was injected via the injector, and the analysis of *Gongronema latifolium* components lasted 45 minutes. Identification of bioactive constituents was based on the ratio of the internal standard's area to its mass relative to the detected compounds' areas. The concentrations of the bioactive components are expressed in µg/ml.

Antinutrient analysis determination

Tannin content

Tannin content was determined following the method outlined by Burns (1971). Exactly 2 g of the sample flour was extracted for 24 hours at room temperature using a mechanical shaker with 10 ml of methanol containing 1% HCl. After centrifuging at 1000 rpm for 5 minutes, 1 ml of the supernatant was collected and combined with 5 ml of vanillin-HCl reagent, prepared by mixing equal volumes of 8% HCl and 4% vanillin in methanol.

Using D-catechin as a standard (0.0–1.4 mg/ml, $R^2 = 0.995$), the absorbance of both the standard and sample solutions was measured after 20 minutes at 500 nm with a UV-Vis spectrophotometer.

Oxalate content

The total oxalate was determined using the Munro and Bassir (1969) method, a modification of the Dye (1956) method. Exactly 1 g ground sample was extracted three times by heating and stirring for 1 hour each in 20 cm^3 of 0.3 $mol \cdot dm^{-3}$ HCl. The combined extract was then diluted to 100 cm^3 with distilled water. From this, 5 cm^3 was taken and made alkaline with 1.0 cm^3 of 5 $mol \cdot dm^{-3}$ ammonium hydroxide. After adding a few drops of glacial acetic acid and phenolphthalein indicator until the solution turned colorless, 1.0 cm^3 of 5% $CaCl_2$ was added. The mixture was left for 3 hours, then centrifuged at 3000 rpm for 15 minutes. The supernatant was discarded, and the precipitate was washed with hot water, then dissolved in 2.0 cm^3 of warm 1.5 $mol \cdot dm^{-3}$ H_2SO_4 in a water bath. The solution was titrated with freshly prepared 0.01 $mol \cdot dm^{-3}$ $KMnO_4$ at room temperature until it turned pink throughout. After standing until colorless, it was warmed again and titrated until a persistent pink stain lasting at least 30 seconds appeared. These values were used to calculate the sample's oxalate content.

Phytate determination

About 0.2 g of the sample was weighed into 250 ml conical flasks. The sample was allowed to soak in 100 ml of 2% concentrated HCl for 3 hours, then filtered. 50 ml of the sample filtrate was placed in a 250 ml beaker, and 100ml of distilled water was added. 10 ml of 0.3% ammonium thiocyanate solution was used as an indicator and was titrated with a standard iron (111) chloride solution containing 0.00195g of iron per ml.

The following formula was used:

$$Phytic\ acid = \frac{Titre\ value\ x\ 0.00195\ x\ 1.19}{Weight\ of\ sample} x\ 100 \quad (7)$$

Quantification of mineral content

Mineral elements (Ca, K, Na, Mg, Fe, and Zn) were determined following AOAC (2006) procedures with slight modifications.

Sample Digestion: About 1 g of dried sample was wet-digested with a mix of concentrated nitric and perchloric acids under controlled heating until the solution became clear.

Quantification: Calcium, magnesium, iron, and zinc levels were determined via Atomic Absorption Spectrophotometry (AAS). Sodium and potassium concentrations were assessed with a flame photometer. Calibration curves were prepared using certified standard solutions. All results are reported in mg.

Determination of vitamin content

The analysis was conducted according to the Official Methods of Analysis published by the Association of Official Analytical Chemists (AOAC, 2005). Beta-carotene concentrations were determined following Zakaria et al. (1979). The vitamins examined include A, C, E, and the B group vitamins.

Vitamin A (retinol)

Exactly 1 g of the sample and the standard were mixed with 30 ml of absolute alcohol. Then, 3 ml of the 50 ml KOH solution was added, and the mixture was gently refluxed for 30 minutes. After washing with distilled water, vitamin A was extracted using 3 × 50 ml of diethyl ether. The extract was evaporated to dryness at low temperature and then dissolved in 10 ml of isopropyl alcohol. About 1 ml of standard vitamin A solution was prepared, and the dissolved extract was transferred to separate cuvettes. Their respective absorbances were measured using a Thermo Fisher Scientific spectrophotometer at 325 nm, with a reagent blank set to zero.

$$Calculation = \frac{Absorbance\ of\ sample\ x\ Concentration\ of\ standard}{Absorbance\ of\ standard} \quad (8)$$

Vitamin B1 (thiamine) and B2 (riboflavine) determination

Approximately 1 g of the sample was weighed into a conical flask, dissolved in 100 ml of deionized water, shaken well, heated for 5 minutes, then cooled and filtered. The filtrate was transferred to a cuvette, and the spectrophotometer was set to the specific wavelengths for each vitamin are; 261 nm for B1 and 242 nm for B2 to measure absorbance. Mineral elements (Ca, K, Na, Mg, Fe, and Zn) were determined following AOAC (2006) procedures with slight modifications.

$$Concentration\ (mg\ \%) = \frac{A\ x\ DF\ x\ Volume\ of\ cuvette}{E} \quad (9)$$

Where A = Absorbance, E = extinction coefficient (25 for B_1 and B_2), and DF = dilution factor (5)

Vitamin B_3 (niacin)

To determine Vitamin B_3 (Niacin), exactly 5 g of the sample was dissolved in 20 ml of anhydrous glacial acetic acid and gently heated. Then, about 5 ml of acetic anhydride was added, and the mixture was stirred until homogeneous. A few drops of crystal violet solution served as an indicator, and titration was performed with 0.1 M perchloric acid until a greenish-blue color appeared. The Vitamin B_3 content was calculated using the formula:

$$Vitamin\ B_3 (Niacin)\ (g) = \frac{Titre\ value\ x\ 0.0122}{0.1} \quad (10)$$

Vitamin B_5 (pantothiamine)

Standard Preparation: 0.25 ml of the vitamin B5 working standard was transferred to a 25 ml volumetric flask containing a 1:9 (v/v) mixture of chloroform and methanol. The solution was gently shaken to ensure thorough mixing, then made up to the mark. Sample Preparation: 0.25 ml of the sample was measured into a 25 ml volumetric flask containing the same chloroform-methanol mixture (1:9). The flask was gently shaken to mix, and absorbance was measured at 246 nm against the blank.

Vitamin B_6 (pyridoxine)

A precise 5 g sample was dissolved in a mixture of 5 ml anhydrous glacial acetic acid and 6 ml mercury (II) acetate solution. Two drops of crystal violet served as an indicator, and titration was performed with 0.1 M perchloric acid until the green endpoint was reached. Calculation: 1 ml of 0.1 M perchloric acid equals 0.02056 g of $C_8H_{11}NO_3 \cdot HCl$.

Vitamin B_7 (biotin)

Sample Preparation involved taking 0.1 ml of the sample into a separator, adding 5 ml of water, mixing thoroughly, then adding 5 ml of chloroform. The chloroform layer was discarded, and the water layer was transferred to a 50 ml volumetric flask, filtered through anhydrous sodium sulfate, and adjusted to 50 ml with water. Aliquots of 2 ml from both the sample and blank solutions were placed into test tubes. To each, 2 ml of a 0.2% phenylhydrazine solution (in hydrochloric acid and alcohol, 1.5 v/v) was added, and the mixture was mixed well. The mixtures were heated on a water bath until nearly dry, then cooled to room temperature. Approximately 2 ml of a mixture of ammonia and alcohol (1:1 ratio) was added to each test tube, followed by 1 ml of pyridine. Absorbance was measured at 548 nm against the blank. Standard cobalamin was processed and analyzed in a similar manner to the sample.

Vitamin B_9 (folic acid)

Exactly 0.4 ml of the sample was measured and transferred to a separator. Approximately 5 ml of water was added, mixed thoroughly, followed by 5 ml of chloroform to extract the sample. The water layer was discarded, and the chloroform was collected in a dry 50 ml volumetric flask by passing it through anhydrous sodium sulphate. Then, the flask was adjusted to 50 ml with chloroform. The sample and blank solutions were placed in separate test tubes. Each received exactly 2 ml of a 0.2% phenylhydrazine solution (containing hydrochloric acid and 1.5 v/v alcohol), which was thoroughly mixed. They were heated in a water bath until nearly dry, then cooled to room temperature. About 15 ml of the mixture (ammonia and alcohol in a 1:1 ratio) was added to each test tube. Absorbance was measured at 635 nm against a blank.

Vitamin B_{12} (cobalamine)

Exactly 30 mg of the sample was dissolved in 250 ml of deionized water. The absorbance was read at 361nm:

$$Concentration\ (mg\ \%) = \frac{A\ x\ DF\ x\ Volume\ of\ cuvette}{E} \quad (11)$$

Where A = Absorbance, E = Extinction coefficient = 25, DF = dilution factor = 5.

Vitamin C (ascorbic acid)

Approximately 3 g of the sample were homogenized in a 6% EDTA/TCA solution. The homogenate was then filtered and analyzed. To the homogenate, 20 ml of 30% KI solution was added, followed by 100 ml of distilled water. Then, 1 ml of a 1% starch solution was added, and titration was performed with 0.1 M $CuSO_4$ solution. The

endpoint was indicated by a black coloration. A reagent blank was also titrated for comparison. The vitamin content was calculated using the following relationship:

$$Vitamin\ C\ (mg/100\ g) = \frac{100\ x\ 0.88\ x\ Titre - Blank}{Weight} \quad (12)$$

Vitamin E

Total vitamin E levels were measured according to the AOAC (2023) method.

Beta-carotene

Beta-carotene was determined following Zakaria et al. (1979). Samples were extracted with acetone–petroleum ether (1:1 v/v), and absorbance was measured at 450 nm. The beta-carotene content was calculated using the extinction coefficient for β-carotene and expressed as mg/100 g.

Statistical analysis

All analyses were conducted in triplicate (n = 3). Results were expressed as mean ± standard deviation (SD). A one-way ANOVA was used to compare means across different plant parts. Differences were considered significant at $p < 0.05$. Statistical analyses were performed using SPSS software (version 23, SPSS Inc., Chicago, IL, USA).

3. Results

Bioactive composition of *Gongronema latifolium* seed, leaf, and fruit

The results in **table 1** show the concentrations of bioactive compounds in *Gongronema latifolium* seed extract. The seed contains various levels of phenolic and flavonoid compounds. Phenol was present at the highest level (22.20 ± 0.14 µg/ml), followed by gallic acid (17.39 ± 0.02 µg/ml) and quercetin (15.49 ± 0.05 µg/ml). Other significant phytochemicals present in notable amounts include catechin (12.60 ± 0.00 µg/ml) and sapogenin (11.62 ± 0.05 µg/ml). Epicatechin (14.52 ± 0.02 µg/ml) and flavone (8.64 ± 0.01 µg/ml) were also present, although phytate levels were notable (9.68 ± 0.11 µg/ml). Kaempferol and anthocyanin were among the least abundant compounds, at 5.88 ± 0.10 µg/ml and 3.90 ± 0.05 µg/ml, respectively.

The high levels of total phenols and phenolic derivatives (such as phenol, gallic acid, quercetin, catechin, and epicatechin) indicate that *G. latifolium* seed has a strong phenolic profile, which is important because phenols are key contributors to antioxidant capacity. The elevated concentrations of flavonoids (quercetin, catechin, epicatechin) suggest that *G. latifolium* seed may have significant free radical scavenging activity. The presence of sapogenins indicates potential anti-inflammatory and steroidogenic effects, whereas phytate suggests mineral chelating properties. Overall, the composition shows that *G. latifolium* seeds are a rich source of phytochemicals, potentially enhancing their ethnomedicinal significance.

The results from **table 2** show the levels of bioactive compounds in *Gongronema latifolium* leaf extract. The leaf contains various phytochemicals, with kaempferol at the highest level (22.32 ± 0.42 µg/ml), followed by flavone (17.57 ± 0.21 µg/ml) and alkaloids (14.40 ± 0.02 µg/ml). Tannins are present in significant amounts (13.46 ± 0.09 µg/ml), while terpenoids and epicatechin are moderate (8.55 ± 0.13 µg/ml and 5.77 ± 0.03 µg/ml, respectively). Other bioactive compounds detected, including rutin (5.59 ± 0.17 µg/ml), quercetin (4.89 ± 0.03 µg/ml), and phenol (2.81 ± 0.10 µg/ml), are found at lower concentrations.

Table 1. Bioactive composition of *Gongronema latifolium* seed

Bioactive Components	**Concentration (ug/ml)**
Kaempferol	5.88±0.10
Phenol	22.20±0.14
Gallic Acid	17.39±0.02
Flavone	8.64±0.01
Epicatechin	14.52±0.02
Sapogenin	11.62±0.05
Anthocyanin	3.90±0.05
Quercetin	15.49±0.05
Catechin	12.60±0.00

Values represent mean ± standard deviation (n = 3).

Table 2. Bioactive composition of *Gongronema latifolium* leaf

Bioactive Components	**Concentration (ug/ml)**
Kaempferol	22.32±0.42
Anthocyanin	3.71±0.22
Flavone	17.57±0.21
Tannin	13.46±0.09
Rutin	5.59±0.17
Terpenoid	8.55±0.13
Phenol	2.81±0.10
Quercetin	4.89±0.03
Alkaloid	14.40±0.02
Epicatechin	5.77±0.03

Values represent mean ± standard deviation (n = 3).

Table 3. Bioactive composition of *Gongronema latifolium* fruit

Bioactive Components	**Concentration (ug/ml)**
Anthocyanin	7.67±0.02
Gallic Acid	4.70±0.17
Sapogenin	18.20±0.06
Epicatechin	0.94±0.04
Isoflavone	2.02±0.02
Catechin	11.81±0.23
Quercetin	25.80±0.19
Kaempferol	11.78±0.24

Values represent mean ± standard deviation (n = 3).

Table 4. Proximate composition of *Gongronema latifolium* leaf, fruit and seed (%)

Parameter	**Leaf**	**Fruit**	**Seed**
Ash	13.66 ± 0.22^{a}	5.25 ± 0.30^{c}	8.57 ± 0.17^{b}
Moisture	1.93 ± 0.05^{c}	6.72 ± 0.24^{a}	2.49 ± 0.16^{b}
Fat	1.14 ± 0.04^{c}	5.09 ± 0.13^{a}	3.81 ± 0.15^{b}
Fiber	26.82 ± 0.20^{a}	13.64 ± 0.62^{c}	18.99 ± 0.08^{b}
Protein	17.04 ± 0.14^{c}	26.53 ± 0.31^{a}	21.14 ± 0.19^{b}
Carbohydrate	39.23 ± 0.09^{c}	42.77 ± 0.11^{b}	44.76 ± 0.12^{a}

Values are mean ± SD (n = 3). Different superscript letters within a row indicate significant differences ($p < 0.05$).

Oxalate (3.76 ± 0.12 µg/ml), anthocyanin (3.71 ± 0.22 µg/ml), and phytate (2.79 ± 0.11 µg/ml) are the least abundant components in the leaf sample.

The results from **table 3** show the levels of key bioactive compounds in *G. latifolium* fruit extract. Quercetin was the most abundant compound (25.80 ± 0.19 µg/ml), followed by sapogenin (18.20 ± 0.06 µg/ml). Catechin and kaempferol appeared at moderate concentrations of 11.81 ± 0.23 µg/ml and 11.78 ± 0.24 µg/ml, respectively. Anthocyanin concentration was 7.67 ± 0.02 µg/ml, and gallic acid concentration was 4.70 ± 0.17 µg/ml; both were low. Isoflavone (2.02 ± 0.02 µg/ml) and epicatechin (0.94 ± 0.04 µg/ml) were among the least abundant bioactive compounds.

The presence of quercetin and catechin emphasizes that *G. latifolium* fruit is particularly rich in flavonoids, consistent with the identified antioxidant-related metabolites. The elevated sapogenin levels imply potential steroidogenic or anti-inflammatory effects. The noticeably lower levels of epicatechin and isoflavone, compared to the seed and leaf profiles, indicate that the fruit selectively accumulates certain flavonoid groups. The phytochemical profile reveals that *G. latifolium* fruit possesses significant bioactive potential, primarily driven by its quercetin-related antioxidant activity.

Proximate composition of *Gongronema latifolium* leaf, fruit and seed

Table 4 shows the proximate composition of *Gongronema latifolium* leaves, fruits, and seeds. Significant differences ($p < 0.05$) were observed among the three plant parts analyzed. The leaf exhibited notably higher ash and crude fiber levels, indicating greater mineral and structural carbohydrate content. Conversely, the fruit contained significantly more protein and lipid, while the seed was abundant in carbohydrate fractions, reflecting its role as a nutrient reserve. Moisture content also varied significantly across tissues. These results emphasize a functional nutritional distinction: leaves are richer in minerals and fiber, whereas seeds are more energy-dense in macronutrients.

Mineral composition of *Gongronema latifolium* leaf, fruit and seed

The mineral profile (**Fig. 2**) showed statistically significant differences ($p < 0.05$) between the fruits, leaves and seeds.

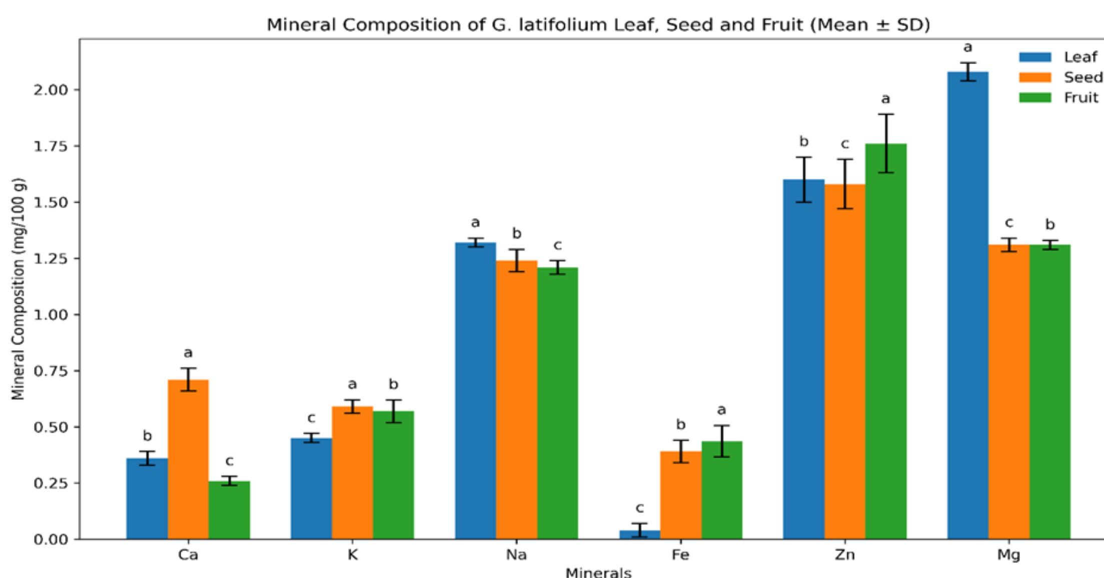

Fig. 2. Mineral composition of *Gongronema latifolium*

The leaves had a higher magnesium content, while the seeds contained greater concentrations of calcium, potassium, iron, and zinc. Sodium levels showed minimal variation between the two tissues. The results demonstrate organ-specific mineral distribution within *Gongronema latifolium*.

Vitamins composition of *Gongronema latifolium* leaf, fruit and seed

Table 5 shows a statistically significant difference ($p < 0.05$) in vitamin profiles between leaf, fruits and seed tissues. Leaves contained higher levels of antioxidant vitamins, especially vitamin C and carotenoids, while seeds had comparatively higher amounts of vitamin B_1 and vitamin E. Vitamins B_2 and B_{12} were similar in both parts. This pattern indicates organ-specific vitamin distribution within *Gongronema latifolium*.

Phytate and oxalate content

The results in **table 6** showed the distribution of antinutritional factors. Phytate is mainly present in seeds, which gives them their distinct nutritional properties, while oxalate is confined to leaves and affects their composition. Notably, the levels of these compounds differ significantly ($p < 0.05$) across plant parts, highlighting variation in their accumulation across organs.

Table 5. Vitamin composition of *Gongronema latifolium*

Vitamin Composition	*G. latifolium* Leaf	*G. latifolium* Seed	*G. latifolium* Fruit
Vitamin B_1 (mg/g)	0.42 ± 0.02^b	0.51 ± 0.00^a	0.10 ± 0.00^c
Vitamin B_2 (mg/g)	0.43 ± 0.02	0.45 ± 0.03	0.54 ± 0.01^a
Vitamin B_3 (mg/g)	0.68 ± 0.02^a	0.61 ± 0.02^b	0.33 ± 0.03^c
Vitamin B_6 (mg/g)	0.66 ± 0.01^a	0.20 ± 0.00^b	0.05 ± 0.00^c
Vitamin B_{12} (mg/g)	0.31 ± 0.01	0.33 ± 0.01	0.11 ± 0.02^c
Folic acid (mg/g)	4.45 ± 0.11	4.30 ± 0.12	1.25 ± 0.12^c
Biotin (mg/g)	2.35 ± 0.15^a	1.46 ± 0.14^b	0.63 ± 0.03^c
Vitamin A (mg/g)	8.57 ± 0.08^a	5.11 ± 0.02^c	7.03 ± 0.11^b
Vitamin E (mg/g)	5.11 ± 0.02^b	6.21 ± 0.07^a	3.09 ± 0.42^c
Carotenoids (mg/100 g)	46.45 ± 0.47^a	36.83 ± 0.06^c	41.32 ± 0.64^b
Vitamin C (mg/100 g)	205.20 ± 1.82^a	135.25 ± 0.40^b	122.65 ± 1.07^c

Values are mean ± SD (n = 3). Different superscript letters within a row indicate significant differences ($p < 0.05$).

Table 6. Antinutritional factors in *Gongronema latifolium* leaf and seed

Parameter	Leaf	Seed	Fruit
Phytate (µg/ml)	2.79 ± 0.00^b	9.68 ± 0.11^a	0.82 ± 0.10^c
Oxalate (mg/100 g)	3.76 ± 0.12^a	0.02 ± 0.00^c	0.03 ± 0.00^b
Tannin (%)	1.59 ± 0.00^b	3.59 ± 0.01^a	0.22 ± 0.00^c

Values are mean ± SD (n = 3). Different superscript letters within a row indicate significant differences ($p < 0.05$).

4. Discussions

Bioactive composition of *Gongronema latifolium*

The study of the bioactive components in *Gongronema latifolium* revealed notable differences in secondary metabolite levels among seed, leaf, and fruit samples. These differences suggest a varied distribution of phytochemicals, likely due to the plant's adaptive metabolism, tissue-specific functions, and growth stages.

Phenolic compounds and flavonoids

The study revealed distinct organ-specific differences in the distribution of phenolic and flavonoid compounds in *Gongronema latifolium*. The seed exhibited the highest total phenolic content at 22.20 µg/ml, significantly exceeding the leaf's level of 2.81 µg/ml, while the fruit showed moderate gallic acid levels at 4.70 µg/ml. Their variation indicates tissue-specific regulation of the phenylpropanoid pathway, which is vital for phenolic biosynthesis.

The increased phenolic content observed in the seed may contribute to oxidative defence during dormancy and early germination. Seeds are particularly vulnerable to the accumulation of reactive oxygen species (ROS) during desiccation and metabolic reactivation. Phenolic compounds act as hydrogen-donating antioxidants, stabilizing lipid membranes and reducing peroxidative damage (Rajashekar, 2023). Recent studies in seed metabolomics have shown that higher phenolic levels are positively associated with improved seed viability and stress resilience under environmental stresses such as drought and temperature fluctuations (Ware et al., 2024; Dossou et al., 2023). However, the considerable build-up of phenolics in *G. latifolium* seeds may represent an adaptive biochemical strategy to ensure reproductive success.

Kaempferol was the most abundant flavonoid in the leaves at 22.32 µg/ml, while quercetin was the dominant one in the fruit at 25.80 µg/ml. Flavonols, such as kaempferol, tend to accumulate in photosynthetic tissues, where they act as UV-B protectors and help regulate photooxidative stress (Moustaka and Moustakas, 2025). Their presence in leaves helps defend against high light levels and environmental oxidative stress. A recent study shows that increased leaf flavonol levels enhance photoprotection by interacting with ROS generated in chloroplasts and modulating redox signaling pathways (Postiglione et al., 2024). The high levels of quercetin in the fruit may relate to its roles in pigmentation, defence against pathogens, and fruit ripening regulation. Quercetin and its derivatives are linked to fruit protection through antimicrobial effects and modulation of oxidative bursts during ripening (Zheng et al., 2025; Aghababaei and Hadidi, 2023). This variation in flavonoid distribution highlights functional specialization among different plant organs.

Furthermore, the high levels of phenolics and flavonoids across all organs support the traditional use of *G. latifolium* for conditions linked to oxidative stress. The variety of flavonoid subclasses indicates the potential for synergistic antioxidant effects, as polyphenol mixtures generally show stronger radical-scavenging capacity than individual compounds.

Tannins, alkaloids, and terpenoids

The alkaloid concentration in the leaves (14.40 µg/ml) aligns with previous studies on *Gongronema latifolium* leaves by Okochi et al. (2024) and Okonkwo et al. (2025), which reported the presence of nitrogen-based secondary metabolites in these leaves. The recorded alkaloid level slightly exceeds that of various tropical medicinal plants. This difference is likely due to ecological factors

such as soil type, climatic stress, plant age, or extraction methods, as reported by Isah (2019). These environmental and methodological factors significantly influence secondary metabolite production. The detection of both tannins (13.46 µg/ml) and alkaloids supports the Optimal Defence Theory, which proposes that plants mainly allocate defensive compounds to tissues most vulnerable to herbivores and environmental stress (Isah, 2019). *G. latifolium* and other medicinal plants demonstrate similar organ-specific accumulation patterns (Edeoga et al., 2005; Ezeani et al., 2022), indicating adaptive metabolic distribution. Their higher concentrations in leaves probably reflect their role as the primary site for biotic interactions. From an ethnopharmacological perspective, the high alkaloid content may partly explain the traditional use of "Utazi" for hypertension and malaria. Although pharmacological testing was not performed in this study, plant alkaloids are recognized for their antihypertensive properties through calcium channel modulation and for their anti-plasmodial activity via DNA intercalation and disruption of parasitic metabolism (Rajabian et al., 2022). The abundance of alkaloids in the leaves provides a biochemical basis for their medicinal properties. Additionally, terpenoids (8.55 µg/ml) identified in the leaves are known to play roles in defence and anti-inflammatory actions, possibly working synergistically with polyphenols, as suggested by prior phytochemical studies (Ojo et al., 2020). However, further chromatographic and bioassay-guided research is necessary to identify specific active compounds.

Catechin, epicatechin, and sapogenin

The distinct patterns of catechin and epicatechin distribution in seeds, fruit, and leaves indicate organ-specific regulation of the phenylpropanoid pathway. The much higher epicatechin level in seeds (14.52 µg/ml) compared to fruit (0.94 µg/ml) suggests its possible role in proanthocyanidin synthesis, which may help reinforce and protect seed coats during dormancy. The fruit exhibited the highest sapogenin concentration (18.20 µg/ml), indicating its potential as a source of triterpenoid derivatives. Since sapogenins are precursors to steroidal compounds and are linked with hypoglycemic activity, this supports the findings of Ogunyemi et al. (2022) and Okonkwo et al. (2025), who reported that triterpenoid saponins from *Gongronema latifolium* inhibited α-amylase and α-glucosidase. Although enzyme assays were not performed in this study, the elevated sapogenin levels could partly explain the fruit's reported antidiabetic properties.

Phytate, oxalate and tannin

The high phytate levels in the seeds (9.68 µg/ml) highlight their role as the main phosphorus reserve in reproductive tissues. During germination, phytate provides essential phosphorus and energy, supporting early seedling development (Isah, 2019). This accumulation pattern is common in leguminous and medicinal plant seeds, where phytic acid functions as both a nutrient store and mineral regulator. Although elevated phytate levels can hinder the absorption of minerals such as iron and zinc by forming insoluble complexes, this presents a trade-off between plant health and human nutrition; however, the levels measured are comparable to those in edible tropical plant seeds (Ukorebi, 2021). Traditional processing methods, such as cooking or fermentation, may reduce mineral-binding effects. Oxalate was detected only in the leaves (3.76 µg/ml), likely as calcium oxalate crystals, which protect the plant by deterring herbivores, causing mechanical irritation, and helping to regulate calcium and ion-balance. While moderate, oxalate remains nutritionally significant

because excessive intake can increase the risk of kidney stones in sensitive individuals. However, oxalate levels are similar to those in common leafy vegetables (Okonkwo et al., 2025). The leaves possess notable phytochemical and medicinal properties, and proper processing, along with moderate consumption, can ensure safety. Overall, the distinct distribution of phytate in seeds and oxalate in leaves reflects the plant's specialized functions, balancing growth needs with potential human health risks.

Proximate composition of *Gongronema latifolium*

The proximate analysis showed distinct nutrient distributions among the leaves, fruits, and seeds of *Gongronema latifolium*. The leaves have a significantly higher ash content (13.66%) than the seeds (8.57%) and the fruits (5.25%), indicating greater mineral accumulation in the leaves. Recent studies report ash contents in *G. latifolium* leaves ranging from 8.5% to 12.4% (Adeyeye & Olaleye, 2020; Nneoyi-Egbe et al., 2024), with the current value at the upper end of this range. Their variation could result from differences in soil, environmental factors, or sample processing techniques. The higher ash content observed in the leaves likely reflects their active metabolism, as minerals are essential for photosynthesis and enzymatic functions.

The fruit samples exhibited significantly higher levels of protein (26.53%), lipids (5.09%), and moisture (6.72%) compared to leaf and seed samples ($p < 0.05$). This elevated protein content indicates that the fruit could serve as a valuable dietary source. While Okochi et al. (2024) reported lipid levels of approximately 8%, the lower lipid content observed in this study may be attributed to varietal differences or the sensitivity of the extraction method. The dominance of macromolecular reserves in seeds reflects typical seed physiology, where storage compounds accumulate to support germination. Therefore, the distribution pattern observed suggests functional specialization rather than random nutrient allocation.

The leaves exhibited significantly higher ash (13.66%) and fiber (26.82%) contents than both fruit and seed samples ($p < 0.05$), indicating a richer mineral and structural carbohydrate profile. Previous research on *G. latifolium* leaves reported lower fiber levels, ranging from 2% to 12% (Adeyeye & Olaleye 2020; Okochi et al., 2024; Joshua Ndukwe et al., 2024). The higher fiber content observed here could be due to genetic differences, environmental factors, or variations in analytical methods. Besides their dietary role, the increased fiber in the leaves likely contributes to structural and protective functions, helping to reinforce vegetative tissues against mechanical stress and environmental challenges.

Mineral composition of *Gongronema latifolium*

The mineral analysis confirms the organ-specific distribution of nutrients. Magnesium levels were significantly higher in leaves (2.08 mg/100 g) compared to seeds (1.31 mg/100 g) and fruit (1.37 mg/100 g). Recent studies on tropical leafy vegetables (Alabi et al., 2022; Nneoyi-Egbe et al., 2024) have also reported similar values. Since magnesium is essential for chlorophyll formation and ATP-dependent processes, its higher concentration in leaves reflects its vital role in photosynthesis.

Gongronema latifolium seeds contained higher levels of calcium (0.71 mg/100 g) and potassium (0.59 mg/100 g). While earlier studies reported higher iron content in *G. latifolium* leaves (Edeoga et al., 2005), the current results indicate that iron is more abundant in fruits (0.44 mg/100 g). This discrepancy could be due to differences in soil

mineral composition or regional factors. The elevated iron in seeds likely supports mitochondrial respiration during embryo development.

The similar zinc levels in both plant parts examined suggest a regulated overall distribution rather than localized accumulation. The zinc content, 1.60 mg/100 g in leaves and 1.58 mg/100 g in seed, reported in this study, differs markedly from the estimated average daily dietary zinc intake range of 5.6 to 13 mg/day in infants and children and 8.8 to 14.4 mg/day in adults aged 20 to 50 years (FAO, 1990). Recent phytochemical studies (Okochi et al., 2024; Oko et al., 2018) also noted minimal variation in zinc across different plant organs, supporting the idea of strict homeostatic regulation. Understanding these mineral concentrations requires caution. Although the differences are statistically significant, the actual values are relatively low compared to dietary recommendations. Therefore, while *G. latifolium* can contribute to mineral intake, it should not be regarded as a primary mineral source without considering bioavailability.

Vitamins composition of *Gongronema latifolium*

The vitamin profile of *Gongronema latifolium* varies across plant parts (leaves, fruits, and seeds), suggesting specialized metabolism rather than a consistent distribution. The leaves have higher levels of water-soluble vitamins such as B_3, B_6, and vitamin C, along with carotenoids, while the seeds are comparatively richer in vitamin E and show a slight increase in vitamin B_1.

Vitamins B Complex

The high levels of vitamins B_3 (niacin) and B_6 (pyridoxine) in the leaves are probably related to their functions in primary metabolism and enzymatic redox reactions within photosynthetically active tissues. Recent research on tropical leafy vegetables has also noted similar increases in B-complex vitamins (Nneoyi-Egbe et al., 2024; Okochi et al., 2024). The variation in B_6 levels observed in this study exceeds that previously reported, indicating that environmental factors or different varieties may affect B_6 concentrations.

The levels of vitamins B_1 (thiamine) and B_2 (riboflavin) were similar in both leaves and seeds of the plant. However, the seed had slightly higher B_1 (0.51 mg/g) than the leaf (0.42 mg/g). The marginal increase in vitamin B_1 in seeds may suggest its role in carbohydrate metabolism during germination. Thiamine-dependent enzymes are essential for glycolysis and the pentose phosphate pathway, both active during early seed development. The consistent riboflavin (B_2) levels across tissues, especially in the fruit, indicate uniform distribution, underscoring its importance in oxidative metabolism (Aminul et al., 2025). Vitamin B_{12} levels were low and stable in both plant parts. As higher plants do not synthesize cobalamin, its presence may result from microbial associations or environmental contamination; therefore, these findings should be interpreted with caution.

Biotin and folic acid

Folate and biotin levels were slightly higher in the leaves compared to the fruits and seeds. This pattern indicates a greater need for folate in rapidly dividing and metabolically active tissues, especially for nucleic acid synthesis. While previous studies on *Gongronema latifolium* confirmed the presence of folate (Balogun et al., 2016; Edelman and Colt, 2016), recent research has provided few direct quantitative comparisons, highlighting a gap in comprehensive micronutrient data. Although the differences observed are statistically significant, they are relatively minor in practical terms. While *G. latifolium*

leaves may contribute to dietary folate intake, further studies on bioavailability are necessary before conclusive nutritional claims can be made.

Carotenoids and fat-soluble vitamins A and E

Significant levels of carotenoids, vitamins A and E were found in the plant parts, highlighting the role *of Gongronema latifolium* as a natural antioxidant source. The leaves exhibited higher concentrations of carotenoids (46.45 mg/100 g) and vitamin A (8.57 mg/g) compared to the seeds, which contained 5.11 mg/g and 36.83 mg/100 g for leaves and seeds, respectively. Vitamin A and its precursors, the carotenoids, are essential for vision, immune system function, and epithelial tissue health (Maqsood et al., 2020; Okochi et al., 2024). The reported values are among the highest for tropical medicinal plants, suggesting vigorous pigment production in *G. latifolium* leaves. However, *G. latifolium* seeds showed higher vitamin E (tocopherol) levels, which is consistent with their physiological role in protecting polyunsaturated fatty acids in oil-rich tissues (Okonkwo et al., 2025). The increased vitamin E in seeds aligns with their higher lipid content, as confirmed by proximate analysis, suggesting a coordinated antioxidant response in storage tissues.

Vitamin C (ascorbic acid)

Vitamin C levels were significantly higher in the leaves compared to the seeds. However, high levels of ascorbic acid have been reported in fresh *Gongronema latifolium* leaves (Nneoyi-Egbe et al., 2024; Alabi et al., 2022), although the exact values vary depending on processing and testing methods. The increased ascorbate levels in leaves likely play a role in reducing photooxidative stress during photosynthesis. However, high vitamin C levels can enhance antioxidant capacity; this study did not specifically assess its bioactivity or therapeutic effects.

Conclusions

This study highlights notable differences in the nutritional content and bioactive compounds among dried *Gongronema latifolium* leaves, seeds, and fruit. The leaves contain higher levels of vitamins, crude fiber, and certain phytochemicals, whereas the seeds are richer in protein, carbohydrates, and specific minerals. This demonstrates the functional specialization within the plant. These findings deepen our understanding about the biochemical composition of *G. latifolium* and offer valuable insights into its potential health benefits. However, it is essential to acknowledge the study's limitations, particularly the lack of information on bioavailability and therapeutic efficacy. Therefore, further research is necessary to explore how these compositional differences influence dietary and therapeutic applications. The comparative data presented support more detailed investigations into the nutritional and pharmacological significance of *G. latifolium*, paving the way for its potential use in dietary and medicinal contexts.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Conceptualization: Emmanuel C. Ebem and Joshua Ndukwe; Data analysis: Emmanuel C. Ebem and Joshua Ndukwe; Interpretation of data: Emmanuel C. Ebem and Joshua Ndukwe; Drafting the original manuscript: Emmanuel C. Ebem; Review and editing: Emmanuel C. Ebem and Joshua Ndukwe. All authors

contributed to the article and approved the submission.

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