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Phytochemical, Antioxidant, Vitamin, and Mineral Profiling of a Nigerian Herbal Tea: Nutritional and Safety Evaluation

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ABSTRACT

Introduction: Herbal teas have garnered significant attention for their therapeutic benefits and sensory appeal. This study aimed to assess the phytochemical constituents, antioxidant activity, and nutritional profile—particularly vitamins A and C—of a locally formulated herbal tea blend. The blend contained a variety of aromatic spices, including cinnamon, cloves, cardamom, lemongrass, black pepper, ginger, star anise, fennel seed, and doum palm fruit.

Methods: Dried tea samples were pulverized and subjected to cold maceration. The extracts were filtered, concentrated using a rotary evaporator, and stored for subsequent analyses. Phytochemical screening was conducted using standard qualitative colorimetric assays. Antioxidant activity was measured via the DPPH radical scavenging method. Vitamin A (as total carotenoids) and vitamin C (ascorbic acid) levels were determined using spectrophotometric and iodometric methods, respectively. Mineral content was analyzed using atomic absorption spectroscopy.

Results: The extract demonstrated 43.42% DPPH radical scavenging activity at a concentration of 2 mg/mL, compared to 91.41% for the vitamin C standard. Vitamin A content was recorded at 3.0132 mg/L Mineral analysis revealed concentrations of lead (71.85 mg/L), zinc (19.80 mg/L), iron (212.49 mg/L), copper (26.42 mg/L), potassium (6290.19 mg/L), magnesium (773.38 mg/L), calcium (2640.54 mg/L), and nickel (8.85 mg/L).

Conclusion: This study suggests that the herbal tea may play a dual role as both a flavorful beverage and a potential natural therapeutic agent. Its phytochemical and nutritional composition could support the value of traditional herbal formulations in modern preventive nutrition and wellness practices, though further research is needed to confirm these effects.

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Introduction

Herbal teas have long been cherished across cultures for their pleasant flavours and medicinal properties (Huda et al., 2024). In recent years, their consumption has surged due to growing interest in natural remedies and functional beverages (Sousa et al., 2024). Scientific research has increasingly explored the bioactive compounds in herbal ingredients, validating many traditional health claims (Chaachouay et al., 2024; Karimi et al., 2025; Farajzadeh Memari et al., 2025). This study examines the nutritional and therapeutic properties of a locally produced Nigerian herbal tea blend containing cinnamon, cloves, cardamom, lemongrass, black pepper, ginger, star anise, fennel seed, and doum palm fruit. A key advantage of this herbal blend is its positive impact on digestion. Cardamom, often referred to as the "queen of spices," has demonstrated anti-inflammatory effects and gastrointestinal benefits (Singletary, 2022). Similarly, fennel seeds are widely recognized for relieving bloating and indigestion (Divya, 2022). Ginger, a well-studied digestive aid, effectively reduces nausea and supports gut motility (Anh et al., 2020). Additionally, cloves contribute antimicrobial properties that may promote a balanced gut microbiome (Abdul Aziz et al., 2023). Together, these ingredients make the tea a potential remedy for common digestive ailments. Chronic inflammation and oxidative stress are linked to numerous diseases, and several components of this tea exhibit protective effects. Cinnamon, for instance, contains potent antioxidants that improve insulin sensitivity (Moridpour et al., 2024). Cloves are rich in eugenol, a compound with strong anti-inflammatory and antioxidant activity (Abdul Aziz etal., 2023). Black pepper enhances nutrient absorption through piperine while also reducing oxidative damage (Butt et al., 2013). Star anise and doum palm fruit further contribute antioxidants, which may help combat cellular damage (Zou et al., 2023; El-Gendy et al., 2008). These properties suggest that regular consumption of the tea could support overall metabolic health. Beyond digestion and inflammation, some of the ingredients offer cardiovascular and calming benefits. Cardamom extract has been associated with lowered blood pressure, indicating potential heart health benefits (Zhang et al., 2024). Lemongrass, traditionally used for relaxation, may reduce anxiety due to its soothing phytochemicals (Shah et al., 2011). Such effects make the tea a functional beverage for both physical and mental well-being.

The common names, scientific names, family name, key bioactive compounds isolated and reported bioactivities of the components of the tea are outlined in table 1.

Table 1: Bioactive compounds and pharmacological properties of the herbal tea ingredients

Common Name	Scientific Name	Family	Key Bioactive Compounds	Reported Bioactivities	References
Cinnamon	*Cinnamomum verum*	Lauraceae	Cinnamaldehyde, Eugenol	Antioxidant, Anti-inflammatory, Antidiabetic	Kawatra & Rajagopalan, 2015
Cloves	*Syzygium aromaticum*	Myrtaceae	Eugenol, Acetyl eugenol	Antimicrobial, Analgesic	Pandey etal., 2023
Cardamom	*Elettaria cardamomum*	Zingiberaceae	α-Terpinyl acetate	Digestive, Cardiovascular	Khattabet al., 2020
Lemongrass	*Cymbopogon citratus*	Poaceae	Citral, Geraniol	Anxiolytic, Antimicrobial	Ekpenyong et al., 2014
Black Pepper	*Piper nigrum*	Piperaceae	Piperine	Enhances bioavailability, Antioxidant	Srinivasan, 2007
Ginger	*Zingiber officinale*	Zingiberaceae	Gingerol, Shogaol	Anti-nausea, Anti-inflammatory	Ali et al., 2008
Star Anise	*Illicium verum*	Schisandraceae	Anethole, Shikimic acid	Antimicrobial, Antifungal	Sharafan et al., 2022
Fennel Seed	*Foeniculum vulgare*	Apiaceae	Anethole, Fenchone	Digestive, Antispasmodic	Rather et al., 2016
Doum Palm	*Hyphaene thebaica*	Arecaceae	Phenolic acids, Flavonoids	Antioxidant, Anti-inflammatory	Dahiru & Nadro, 2022

The combination of these spices produces synergistic effect, enhancing their individual benefits. Studies suggest that herbal blends often exhibit greater bioactive potency than single ingredients (Das et al., 2022). Given the increasing demand for natural health products, analyzing this tea's nutritional and safety profile is essential. The herbal tea blend contains beneficial phytochemicals, antioxidants, and essential nutrients that may support overall health. However, the elevated lead content raises serious safety concerns. Therefore, despite its nutritional potential, rigorous quality control is necessary before recommending it for regular consumption.

Materials and Methods

Chemicals and Reagents

The following chemicals and reagents were used in this study:

Ethanol (Sigma-Aldrich, St. Louis, USA; purity: 99.9%)
Ferric chloride (Merck, Darmstadt, Germany; purity: 98%)
Chloroform (Fisher Scientific, Waltham, USA; purity: 99.8%)
Concentrated sulfuric acid (H_2SO_4) (Avantor, Radnor, USA; purity: 95–98%)
Sodium hydroxide (NaOH) (Sigma-Aldrich, St. Louis, USA; purity: 97%)
Dragendorff's reagent (Merck, Darmstadt, Germany)
2,2-Diphenyl-1-picrylhydrazyl (DPPH) (Sigma-Aldrich, St. Louis, USA; purity: 95%)
Ascorbic acid (Merck, Darmstadt, Germany; purity: 99%)
Nitric acid (HNO_3) (Fisher Scientific, Waltham, USA; purity: 70%)
Petroleum ether (Merck, Darmstadt, Germany; purity: 99%)
Acetic anhydride (Sigma-Aldrich, St. Louis, USA; purity: 98%)

Sample Collection and Preparation

The herbal tea sample was collected from Kaduna town, Kaduna, Nigeria. The herbal tea ingredients were locally made by the vendor and identified to comprise of aromatic spices including cinnamon, cloves, cardamom, lemongrass, black pepper, ginger, star anise, fennel seed, and doum palm fruit. The herbal tea materials were shade-dried to preserve their phytochemical content for approximately 7 days. The materials were weighed periodically until a constant mass was achieved, indicating complete drying. The materials were dried in a well-ventilated room at ambient temperature (25–30°C). The dried materials was pulverized using a Philips HR2115 blender (Philips, Amsterdam, Netherlands). The ground material was sifted through a 60-mesh sieve (250 μm particle size). The powdered material was stored in airtight containers at 4°C until extraction.

Extraction

The process used was cold maceration involved using ethanol. In a glass jar with a stopper, 2kg of the herbal tea were combined with exactly 6 L of 60% ethanol and sealed tightly. After the mixture was stirred occasionally each day for 72 hours at room temperature, the extract was finally filtered using cotton wool and Whatman 125 mm filter paper No. 1. A Stuart RE 300B W13 rotary evaporator was used to condense the resulting ethanol extract at low pressure. To acquire the sample's crude ethanolic extract, the extract was dried out by evaporating it completely and then distilling out the ethanol at 40oc. Thereafter, the dry extract was stored in a refrigerator in bottles with tight stoppers until it was needed for analysis (Afolayan et al., 2023).

Phytochemical Screening

Phytochemical screening was carried out for the qualitative determination of major phytoconstituents using standard methods (Shaikh and Patil, 2020).

Test for Phenols

Extract solution + few drops of 5% ferric chloride solution. The presence of dark green/bluish black colour proves positive.

Test for Sterols

Crude extract + chloroform + few drops of concentrated H2SO4, shake well and allow to standing. A red colour at the lower layer of test tube proves positive.

Test for Glycosides

Alcoholic extract dissolved in 1 mL of water + few drops of aqueous NaOH solution. A yellow colour proves positive.

Test for Flavonoids

1 mL of extract + 2 mL of 2% NaOH solution + few drops of dilute HCl. An intense yellow colour which becomes colourless on addition of diluted acid indicates positive.

Test for Alkaloids
Few mL of extract + 1 to 2 mL of dragendorff's reagent. A reddish-brown precipitate indicates presence of alkaloids.

Test for Carbohydrates
Aqueous extract + 5 mL of 5% KOH solution. A cinary colouration indicates positive.

Test for Saponins
0.2 g of extract shaken with 5 mL of distilled water in a test tube. Frothing which persist on warming indicates positive.

Test for Tannins
1 mL of extract + 3 mL of distilled water + 3 drops of 10% Ferric chloride solution. Blue-green colour proves positive.

Test for Resins
1 mL of plant extract + acetic anhydride solution + 1 mL of concentrated H2SO4. An orange to yellow change in colour indicates positive.

Test for Triterpenoids
1 mL of extract + few drops of concentrated H2SO4 (Shake well and allowed to stand). A golden yellow layer (at the bottom) indicates positive.

Test for Terpenoids
2 mL chloroform + 5 mL plant extract, (evaporated on water bath) + 3 mL concentrated H2SO4 (boiled on water bath). A grey coloured solution shows presence of terpenoids.

Antioxidant Activity
The free-radical antioxidant activities of the sample was investigated using 2,2-diphenyl-1-picrylhydrozyl radical (DPPH) in methanol as adopted by Jibrin et al. (2022) with slight modification. Thus, 1 mL of 1 mM of DPPH in methanol was prepared under dark condition and 2 mL of this solution was added to 1 mL of various concentrations (0.5, 0.25, 0.425, 0.0625, and 0.03125 mg/mL) of the extracts. The tests were conducted in triplicates. The test tubes were left to incubate at room temperature for duration of 30 minutes, after which the absorbance was measured at a wavelength of 517 nm. Ascorbic acid was used as a standard. DPPH radical scavenging activity percentage was calculated by the following equation:

% inhibition = [A control –A extract) ÷ (A control)] x 100

A: Absorbance

Mineral Content Analysis
Some portion of the dried powder sample was digested as reported by (Soylak et al. 2003). 1 g of the sample was weighed into a beaker and treated with 20 mL of concentrated HNO3. The mixture was digested at 130 ℃. After digestion, the sample was cooled, then, filtered into 100 mL volumetric flask and made up with deionized water. The digest sample were analyzed for the minerals and trace metals content using ThermoScientific ICE 3000 Atomic Absorption Spectrophotometer.

Analysis of Vitamin A (Total Carotenoids)
Total carotenoids are extracted from the sample using acetone and petroleum ether. The absorbance of the carotenoid layer is measured spectrophotometrically at 452 nm, and the concentration is calculated using a standard formula. Soak 5 g of the sample in 20 mL of Ar grade acetone for 12 hours at room temperature in the dark to ensure complete extraction of carotenoids. Separate the carotenoid layer using petroleum ether in a separating funnel. Adjust the volume to 50 mL with petroleum ether. Pass the solution through anhydrous sodium sulfate to remove moisture. Measure the optical density of the carotenoid layer at 452 nm using petroleum ether as a blank. Calculate the total carotenoid content using the formula:

Total carotenoids (mg/100g) = 3.85 × optical density × volume made up (mL) × 100 ÷ weight of sample (g) × 1000

Analysis of Vitamin C (Ascorbic Acid)
Vitamin C is determined by iodometric titration, where ascorbic acid reduces iodine to iodide. The endpoint is detected using a starch indicator, which forms a blue complex with excess iodine. Dissolve 0.50 g of soluble starch in 50 mL of near-boiling distilled water. Mix well and cool before use. Dissolve 5.00 g of potassium iodide (KI) and 0.268 g of potassium iodate (KIO_3) in 200 mL of distilled water. Add 30 mL of 3M sulfuric acid. Dilute to 500 mL with distilled water and mix thoroughly. Dissolve 0.250 g of ascorbic acid in 100 mL of distilled water. Dilute to 250 mL in a volumetric flask and label as the standard solution. Add 25 mL of the vitamin C standard solution to a

125 mL erlenmeyer flask. Add 10 drops of 1% starch solution. Titrate with iodine solution until a persistent blue color appears (endpoint). Record the volume of iodine solution used and repeat the titration for consistency. Perform the titration on the sample using the same procedure as for the standard solution.

Results

Qualitative phytochemical analysis of the herbal tea indicated that it is a rich source of phytochemical constituents (Table 2). The results showed that the tea extract exhibited significant antioxidant activity, with a 43.42% DPPH radical scavenging capacity at a concentration of 2 mg/mL (Table 3). The vitamin A and C contents were measured at 3.0132 mg/L and 0.00404 mg/L, respectively.

Mineral analysis of the herbal tea revealed considerable amounts of minerals, including lead, zinc, iron, copper, potassium, magnesium, calcium, and nickel (Table 4). Detailed results are presented in the tables.

Table 2: Qualitative phytochemical analysis of herbal tea sample

Phytochemical constituents	Qualitative result
Tannins	+
Steroids	+
Triterpenoids	+
Glycosides	+
Saponins	+
Phenols	+
Alkaloids	+
Terpenoids	+
Flavonoids	+
Carbohydrate	-
Resins	+

(+) = Present (-) = Absent

Table 3: Antioxidant activity of herbal tea

Concentration (mg/mL)	Herbal tea scavenging capacity (%)	Vitamin C scavenging capacity (%)
2	43.42	91.41
1	19.52	91.50
0.5	18.81	91.32
0.1	0.26	90.47
0.05	4.97	90.19

The free-radical antioxidant activities of the samples was investigated using 2,2-diphenyl-1-picrylhydrozyl radical (DPPH).

Table 4: Mineral analysis of herbal tea

Elements	Concentration (mg/100g)
Pb	71.85
Cd	BDL
Zn	19.80
Fe	212.49
Cu	26.42
Co	BDL
K	6290.19
Mg	773.38
Ca	2640.54
Ni	8.85

BDL = Below detectable limit

Discussion

The presence of various phytochemicals suggests that the herbal tea may have several therapeutic properties including antioxidant, anti-inflammatory, and antimicrobial properties. Flavonoids, tannins and phenolic compounds are recognized for scavenging free radicals, which can contribute to reducing oxidative stress and lowering the effect of inflammation, anticancer, and cardioprotective effects (Gallia et al., 2024), these may have also contributed to the antioxidant activity of the tea. Saponins, triterpenoids and steroidal compounds are known for their potential to exhibit antimicrobial, antioxidant, anti-inflammatory effects which can contribute to immune modulation, antiviral, and anticancer activities (Kumar et al., 2023). Glycosides can enhance the antioxidant capacity of other molecules and has cardiovascular benefits which provide various health benefits. Alkaloids exhibit varied biological activities, including antimicrobial effects, analgesic, antimalarial, and anticancer properties and the ability to modulate inflammation. Terpenoids are known for their antioxidant, anti-inflammatory, antimicrobial properties, and antiviral activities contributing to various health benefits (Riaz et al., 2023). The presence of resins supports antimicrobial and anti-inflammatory properties and indicates the thickening effect of the herbs when prepared.

Meanwhile, the absence of carbohydrates suggests that the tea could be low in calories which could be beneficial for individuals managing blood sugar levels, making it suitable for monitoring their dietary intake.

At a concentration of 2 mg/L, the herbal tea shows an absorbance of 43.42% compared to 91.41% for vitamin C. This suggests that while the herbal tea exhibits antioxidant properties, they are

significantly lower than the well-known antioxidant effects of vitamin C. The herbal tea exhibits dose-dependent antioxidant activity, with higher concentrations showing greater absorbance (antioxidant potential). Nonetheless, therapeutic herbal teas can offer a complementary source of antioxidants as the presence of phenols, flavonoids, and tannins in the herbal tea likely contributes to its antioxidant properties (Gallia et al., 2024).

These essential minerals; Potassium (K), Magnesium (Mg), and Calcium (Ca) are present in high concentrations, which is beneficial for maintaining electrolyte balance, bone health, and muscle function (Shokunbi et al., 2023).The high iron content suggests that the herbal tea could be a good dietary supplement for individuals with iron deficiency (Charlebois & Pantopoulos, 2023).The presence of zinc and copper indicates potential support for immune function and antioxidant activity, with zinc frequently associated with various biochemical processes in the body. (Djoko et al., 2015). The presence of lead in high concentrations is concerning, as lead is a toxic heavy metal. Prolonged exposure to lead can cause neurological and developmental issues (WHO, 2010). The source of lead contamination should be investigated, and steps should be taken to reduce its levels in the herbal tea preparation.

The negative values for Cadmium (Cd) and Cobalt (Co) is great for the herbal tea consumption.

Vitamin A is essential for vision, immune function, and skin health. The presence of vitamin A in the herbal tea adds to its nutritional value (Sommer & Vyas, 2012). The vitamin C concentration is very low, which is consistent with the antioxidant assay results showing lower activity compared to pure vitamin C.

Conclusion

The combination of spices in this locally made herbal tea blend not only contributes to its therapeutic properties but also its sensory profile. As research continues to bear out the potential health benefits of these individual ingredients, further explorations into their synergistic effects could provide valuable insights into herbal tea formulations.

The herbal tea exhibits a promising phytochemical and mineral profile, suggesting potential benefits for antioxidant activity, anti-inflammatory effects, and mineral supplementation (e.g., potassium, magnesium, and calcium). However, the low vitamin C content highlights an opportunity for fortification to enhance its antioxidant capacity. While the phytochemicals demonstrate therapeutic potential, the presence of lead raises safety concerns and warrants further investigation. Additional research should explore the specific health impacts of these bioactive compounds and minerals, as well as strategies to mitigate contamination risks while optimizing nutritional value.

Declarations

Conflict of interest

The authors declare no conflict of interest.

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Consent for publications

All authors have read and approved the manuscript for publication.

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Authors' contributions

VON and BS initiated the research concept and developed the overall framework. VON, BS, and MA conducted all experiments and prepared the initial draft of the manuscript, while VON and MA performed the literature survey. BS and MA carried out the formal analysis, data curation, and visualization. AM was responsible for funding acquisition, project administration, resources provision, and overall supervision of the research. BS also contributed to software implementation. Validation of the results was performed by VON and MA. Finally, AM and VON reviewed and edited the manuscript. The final version of the manuscript was read and approved for publication by VON, BS, and MA.

Ethical considerations

Ethical issues (including plagiarism, misconduct, data fabrication, falsification, double publication or submission, redundancy) have been completely observed by the authors.

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