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Quantitative Evaluation of Phytochemical Profiles, Mineral Composition and In Vitro Antioxidant Activities of Selected Medicinal Plant-Based Polyherbal Formulations

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Abstract

Medicinal plants remain an important source of bioactive compounds with significant therapeutic potential due to their diverse phytochemical constituents and biological activities. Polyherbal formulations, which combine multiple medicinal plants, have gained increasing scientific interest because of their potential synergistic effects. This study investigated the quantitative phytochemical composition, mineral content and in vitro antioxidant activities of selected medicinal plants used in traditional healthcare: Vernonia amygdalina, Greenwayodendron suaveolens, Euphorbia heterophylla and Xylopia aethiopica. The phytochemical constituents, including phenolic compounds, flavonoids, tannins, saponins, alkaloids and other secondary metabolites, were evaluated using standard analytical procedures. Mineral elements comprising essential macro-elements and trace elements such as calcium, magnesium, potassium, iron, manganese, copper, chromium and nickel, as well as potentially toxic elements including lead and cadmium, were determined using flame photometry and atomic absorption spectrophotometry. The antioxidant potentials of the plant extracts were assessed through established in vitro models, including 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay, 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) assay, hydroxyl radical scavenging assay and ferric reducing antioxidant power (FRAP) assay. Results indicated the presence of important phytochemical constituents capable of contributing to biological activities. The extracts demonstrated concentration-dependent antioxidant effects, with increased radical scavenging and reducing abilities at higher extract concentrations. Variations observed among the plant species may be attributed to differences in phytochemical composition and mineral profiles. The findings suggest that the investigated medicinal plants possess considerable antioxidant potential and may provide a scientific basis for their traditional applications. However, further studies involving isolation of active compounds, toxicity evaluation and in vivo investigations are recommended before therapeutic applications.

Keywords: medicinal plants, polyherbal formulation, phytochemicals, antioxidant activity, mineral composition, free radical scavenging

1. INTRODUCTION

1.1 Background of the Study

Medicinal plants have played a central role in human healthcare for centuries and continue to serve as important sources of therapeutic agents. According to the World Health Organization, a large proportion of the global population relies on traditional medicine practices, particularly plant-based remedies, for primary healthcare needs. The biological activities of medicinal plants are largely associated with naturally occurring secondary metabolites such as phenolics, flavonoids, alkaloids, tannins and saponins.

Oxidative stress results from an imbalance between the production of reactive oxygen species and antioxidant defence mechanisms in biological systems. Excessive generation of free radicals has been associated with cellular damage and the development of several chronic diseases, including cardiovascular disorders,

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inflammation, diabetes and neurodegenerative conditions. Antioxidants derived from natural sources have, therefore, attracted considerable research attention due to their ability to neutralise reactive molecules.

Polyherbal formulations involve the combination of two or more medicinal plants to enhance therapeutic effects through complementary or synergistic interactions. Traditional medical systems frequently employ combinations of plants rather than single species because different constituents may contribute to overall pharmacological activity.

The selected plants in this study—*Vernonia amygdalina*, *Greenwayodendron suaveolens*, *Euphorbia heterophylla* and *Xylopia aethiopica*—are widely distributed tropical medicinal plants with reported ethnobotanical applications. Their leaves contain various bioactive compounds that have been linked to antimicrobial, anti-inflammatory and antioxidant properties.

Quantitative evaluation of phytochemical constituents provides valuable information about the chemical basis of medicinal plant activity. Similarly, mineral profiling helps determine the nutritional and physiological relevance of plant preparations while also assessing the presence of potentially harmful elements.

Therefore, systematic investigation of the phytochemical composition, mineral elements and antioxidant capacities of these plants is essential for validating their traditional uses and exploring their potential as sources of natural therapeutic agents.

1.2 Statement of the Problem

The increasing prevalence of oxidative stress-related diseases has created a demand for safe and effective natural antioxidants. Many medicinal plants are traditionally used for disease prevention and management, but scientific information about their chemical composition and antioxidant capabilities remains incomplete.

The use of polyherbal preparations is common in traditional medicine; however, inadequate scientific evaluation may limit understanding of their efficacy, safety and mechanisms of action. Furthermore, variations in phytochemical content and mineral composition among medicinal plants require systematic analysis.

This study therefore seeks to provide quantitative evidence on the phytochemical constituents, mineral composition and antioxidant potentials of selected medicinal plants used individually and as a polyherbal formulation.

1.3 Aim of the Study

The aim of this study is to evaluate the phytochemical constituents, mineral composition and in vitro antioxidant activities of selected medicinal plant-based polyherbal formulations.

1.4 Specific Objectives

The objectives are to:

1. Determine the quantitative phytochemical constituents of *Vernonia amygdalina*, *Greenwayodendron suaveolens*, *Euphorbia heterophylla* and *Xylopia aethiopica* leaves.
2. Evaluate the mineral element composition of the selected plant extracts.
3. Determine the free radical scavenging activities of the extracts using DPPH, ABTS, hydroxyl radical and FRAP assays.
4. Compare the antioxidant potentials of the different plant extracts.
5. Establish possible relationships between phytochemical composition and antioxidant activity.

1.5 Research Questions

1. What phytochemical constituents are present in the selected medicinal plants?
2. What minerals are contained in the plant extracts?
3. Do the extracts demonstrate significant antioxidant activities?
4. Is there a relationship between phytochemical concentration and antioxidant performance?

1.6 Significance of the Study

This study contributes scientific information regarding the chemical and biological properties of selected medicinal plants. The findings may support future development of plant-based antioxidant formulations and provide baseline information for further pharmacological investigations.

The research may also assist in validating traditional medicinal practices and promoting evidence-based use of indigenous plant resources.

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1.7 Scope of the Study

The study focuses on the quantitative determination of phytochemicals, mineral elements and in vitro antioxidant properties of selected medicinal plants. The work does not include animal studies, clinical trials or isolation of individual bioactive compounds.

2. LITERATURE REVIEW

2.1 Medicinal Plants and Their Role in Healthcare

Medicinal plants have served as important sources of therapeutic substances throughout human history. The use of plants in traditional medicine is based on accumulated knowledge of their healing properties, which has been transmitted across generations. Modern pharmacological research has increasingly focused on medicinal plants because they contain diverse chemical compounds capable of producing biological effects.

Plants synthesise a wide range of primary and secondary metabolites. While primary metabolites such as carbohydrates, proteins and lipids are directly involved in plant growth and development, secondary metabolites including phenolics, flavonoids, alkaloids and terpenoids contribute to plant defence and often possess pharmacological properties.

The increasing interest in natural products has been associated with the search for safer alternatives to synthetic compounds. Many synthetic antioxidants have raised concerns regarding possible adverse effects, encouraging investigations into plant-derived antioxidant compounds.

2.2 Polyherbal Formulations

Polyherbal formulations involve the combination of multiple medicinal plants or plant extracts to achieve enhanced biological activity. Traditional medicine systems frequently utilise mixtures of plants because different components may act through complementary mechanisms.

The concept of combining plants is based on the possibility of synergism, where the biological activity of the mixture exceeds the activity of individual components. Such interactions may result from combined antioxidant, antimicrobial, anti-inflammatory or metabolic effects.

However, scientific evaluation is necessary because plant combinations may also produce unpredictable interactions. Quantitative phytochemical and biological assessments provide useful information for establishing the quality and efficacy of polyherbal products.

2.3 Phytochemical Constituents of Medicinal Plants

Phytochemicals are naturally occurring chemical compounds produced by plants. Many phytochemicals contribute to plant survival and also possess biological activities important in human health.

The major phytochemicals investigated in medicinal plants include phenolic compounds, flavonoids, tannins, alkaloids and saponins.

Table 2.1: Major Phytochemicals and Their Biological Activities

Phytochemical	General Properties	Reported Biological Activities
Phenolics	Hydroxyl-containing aromatic compounds	Antioxidant, anti-inflammatory
Flavonoids	Polyphenolic compounds	Free radical scavenging, cardiovascular protection
Tannins	Polymeric phenolic substances	Antimicrobial, antioxidant
Alkaloids	Nitrogen-containing compounds	Analgesic, antimicrobial effects
Saponins	Glycoside compounds	Immunomodulatory, cholesterol-lowering activities

Phenolic compounds are among the most widely studied plant antioxidants because they can donate hydrogen atoms or electrons to stabilise reactive oxygen species. Flavonoids, a major subgroup of phenolics, have been shown to contribute significantly to the antioxidant properties of many medicinal plants.

2.4 Oxidative Stress and Antioxidant Mechanisms

Oxidative stress occurs when reactive oxygen species exceed the capacity of biological antioxidant systems. Reactive oxygen species include molecules

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such as superoxide radicals, hydroxyl radicals and hydrogen peroxide.

Although reactive oxygen species have physiological roles in cellular signalling and defence, excessive production may damage proteins, lipids and nucleic acids.

Antioxidants protect biological systems through several mechanisms:

1. Donation of hydrogen atoms to free radicals.
2. Electron transfer reactions.
3. Metal ion chelation.
4. Prevention of oxidative chain reactions.

Plant-derived antioxidants, particularly phenolics and flavonoids, are important because their chemical structures allow effective interaction with reactive molecules.

2.5 Antioxidant Evaluation Methods

Several laboratory methods are used to evaluate antioxidant capacity. Since antioxidants may function through different mechanisms, multiple assays are often applied.

2.5.1 DPPH Radical Scavenging Assay

The DPPH assay is based on the ability of antioxidants to reduce the stable purple-coloured DPPH radical into a yellow-coloured compound. The reduction reflects the hydrogen-donating ability of the tested extract.

The method is widely used because it is simple, rapid and suitable for comparing antioxidant activity among plant samples.

2.5.2 ABTS Radical Scavenging Assay

The ABTS assay measures the ability of antioxidants to neutralise the ABTS radical cation. It is applicable to both water-soluble and lipid-soluble antioxidant compounds.

Compared with some other antioxidant methods, ABTS provides a broad measurement of antioxidant capacity.

2.5.3 Ferric Reducing Antioxidant Power (FRAP)

The FRAP assay estimates antioxidant capacity based on the reduction of ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}). A higher reducing capacity indicates stronger electron-donating ability.

2.5.4 Hydroxyl Radical Scavenging Assay

Hydroxyl radicals are among the most reactive oxygen species. The hydroxyl radical assay evaluates the ability of plant extracts to prevent hydroxyl radical-mediated reactions.

2.6 Review of Selected Medicinal Plants

2.6.1 *Vernonia amygdalina*

Vernonia amygdalina (bitter leaf) is a widely utilised medicinal plant in Africa. It belongs to the family Asteraceae and is traditionally used for various health conditions.

Studies have reported the presence of bioactive constituents including flavonoids, phenolic compounds, saponins and sesquiterpene lactones. These compounds have been associated with antioxidant and antimicrobial activities.

The antioxidant activity of *Vernonia amygdalina* has been linked mainly to its phenolic composition, which contributes to the neutralisation of free radicals.

2.6.2 *Xylopia aethiopica*

Xylopia aethiopica is a tropical plant commonly used as both a spice and medicinal resource. Different parts of the plant have been traditionally used for digestive, inflammatory and infectious conditions.

The plant contains several secondary metabolites, including alkaloids, flavonoids and volatile compounds. These constituents may contribute to its biological effects.

2.6.3 *Euphorbia heterophylla*

Euphorbia heterophylla belongs to the family Euphorbiaceae. Species within this family are known to contain diverse phytochemical compounds.

Research on Euphorbia species has identified phenolics, terpenoids and other metabolites with antioxidant and antimicrobial potential. However, careful evaluation is required due to the presence of bioactive compounds that may have toxic effects at high concentrations.

2.6.4 *Greenwayodendron suaveolens*

Greenwayodendron suaveolens is a tropical plant

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reported in ethnomedicine. Traditional applications have been associated with treatment of infections and inflammatory conditions.

The plant is believed to contain secondary metabolites responsible for its biological activities. Scientific studies evaluating its phytochemical and antioxidant characteristics help clarify its medicinal value.

2.7 Mineral Elements in Medicinal Plants

Plants accumulate mineral elements from their environment. Some minerals are essential for physiological functions, while others may be harmful when present above acceptable limits.

Table 2.2: Selected Mineral Elements and Biological Importance

Element	Biological Importance
Calcium	Bone formation and cellular signalling
Magnesium	Enzyme activation and metabolism
Potassium	Fluid balance and nerve function
Iron	Haemoglobin formation
Zinc/Copper	Enzymatic antioxidant systems
Manganese	Enzyme cofactor
Chromium	Glucose metabolism

The determination of mineral content in medicinal plants is important because minerals may contribute to their therapeutic effects. However, potentially toxic metals such as lead and cadmium require monitoring.

3. MATERIALS AND METHODS

3.1 Study Design

This study was designed as an experimental laboratory investigation aimed at evaluating the phytochemical constituents, mineral composition and in vitro antioxidant activities of selected medicinal plants used in polyherbal preparations. The study involved collection and preparation of plant materials, extraction of bioactive compounds, quantitative phytochemical analysis, mineral determination and antioxidant assessment.

3.2 Plant Materials

Fresh leaves of the selected medicinal plants:

- *Vernonia amygdalina*
- *Greenwayodendron suaveolens*
- *Euphorbia heterophylla*
- *Xylopia aethiopica*

were used for the investigation.

The plants were selected based on their documented ethnomedicinal applications and reported presence of biologically active constituents.

Table 3.1: Selected Plants Used for the Study

Plant species	**Common name**	**Plant part investigated**	**Family**
Vernonia amygdalina	Bitter leaf	Leaves	Asteraceae
Greenwayodendron suaveolens	—	Leaves	Annonaceae
Euphorbia heterophylla	Mexican fire plant	Leaves	Euphorbiaceae
Xylopia aethiopica	Ethiopian pepper	Leaves	Annonaceae

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3.3 Collection and Preparation of Samples

Fresh plant leaves were collected and carefully examined to remove unwanted materials such as soil particles, insects and damaged portions. The samples were washed with clean water and allowed to air dry under shade at room temperature to prevent degradation of heat-sensitive phytochemicals.

The dried samples were pulverised into fine powder using a laboratory grinding device and stored in clean airtight containers until analysis.

3.4 Preparation of Plant Extracts

A measured quantity of powdered plant material was extracted using an appropriate solvent system. The extraction process was carried out to obtain soluble phytochemical constituents.

The extract was filtered to remove plant residues, concentrated and stored under suitable conditions until further analysis.

The extraction procedure was designed to preserve important bioactive compounds, including phenolics, flavonoids and other antioxidant-related constituents.

3.5 Quantitative Phytochemical Analysis

3.5.1 Determination of Total Phenolic Content

The total phenolic content of the extracts was determined using a colorimetric method based on the reaction between phenolic compounds and the Folin-Ciocalteu reagent.

The intensity of colour development was measured spectrophotometrically. Results were expressed as milligrams of gallic acid equivalent per gram of extract.

Phenolic compounds are important indicators of antioxidant capacity because they can donate electrons or hydrogen atoms to neutralise reactive oxygen species.

3.5.2 Determination of Total Flavonoid Content

Total flavonoid content was determined using an aluminium chloride-based method.

The formation of a flavonoid–aluminium complex produced a measurable colour intensity proportional to the flavonoid concentration.

Results were calculated using a standard calibration curve and expressed as equivalent concentrations of the reference compound.

3.5.3 Determination of Tannins

Tannin content was determined using established spectrophotometric procedures.

Tannins are polyphenolic compounds capable of binding proteins and demonstrating antioxidant properties through radical scavenging mechanisms.

3.5.4 Determination of Saponins

Saponin content was determined using an extraction and quantification method based on the ability of saponins to form stable complexes.

Saponins have been reported to possess biological activities, including antimicrobial and antioxidant effects.

3.6 Mineral Element Analysis

The mineral composition of the plant extracts was determined after sample digestion.

3.6.1 Sample Digestion

A known quantity of powdered plant sample was treated with concentrated acids to release mineral elements into a solution.

The resulting solutions were filtered and prepared for instrumental analysis.

3.6.2 Atomic Absorption Spectrophotometry (AAS)

Mineral elements including iron, manganese, copper, chromium, nickel, lead and cadmium were determined using atomic absorption spectrophotometry.

The principle of AAS is based on the absorption of specific wavelengths of light by free atoms of elements in the sample.

3.6.3 Flame Photometry

Elements such as sodium and potassium were

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determined using flame photometric analysis.

The intensity of emitted radiation was measured and compared with standard solutions to determine mineral concentrations.

Table 3.2: Mineral Elements Evaluated

Element group	Elements analysed
Macro-elements	Calcium, magnesium, potassium
Trace elements	Iron, manganese, copper, chromium, nickel
Heavy metals	Lead, cadmium

3.7 Determination of Antioxidant Activity

3.7.1 DPPH Radical Scavenging Assay

The antioxidant capacity of extracts was evaluated using the DPPH radical scavenging method.
Different concentrations of extracts were prepared and mixed with DPPH solution. After incubation, absorbance reduction was measured.
The percentage inhibition was calculated using:

Percentage inhibition = [(Acontrol − Asample) / Acontrol] × 100

where:

- Acontrol = absorbance of control solution
- Asample = absorbance of extract sample

Higher percentage inhibition indicated stronger antioxidant activity.

3.7.2 ABTS Radical Scavenging Assay

ABTS radical scavenging activity was determined by mixing plant extracts with ABTS radical solution.

A reduction in absorbance indicated neutralisation of ABTS radicals by antioxidant compounds present in the extracts.

3.7.3 Ferric Reducing Antioxidant Power (FRAP) Assay

The reducing power of extracts was measured based on their ability to convert ferric ions (Fe^{3+}) into ferrous ions (Fe^{2+}).
Increased absorbance indicated greater reducing capacity.

3.7.4 Hydroxyl Radical Scavenging Assay

Hydroxyl radical scavenging ability was evaluated by determining the ability of extracts to prevent hydroxyl radical-mediated oxidation reactions.

3.8 Experimental Controls

Appropriate controls were used during antioxidant assays

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Table 3.3: Experimental Controls

Control type	Purpose
Blank	Corrects background absorbance
Negative control	Determines radical stability
Standard antioxidant	Comparison of antioxidant effectiveness

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3.9 Statistical Analysis

All experiments were performed in replicates, and results were expressed as mean ± standard deviation.
Statistical differences between groups were determined using one-way analysis of variance (ANOVA).
A probability value of $p < 0.05$ was considered statistically significant.
Data analysis was performed using appropriate statistical software.

3.10 Ethical Considerations

This study involved plant materials only and did not include human or animal subjects. All laboratory procedures were performed according to accepted scientific standards.

3.11 Limitations of the Methodology

The study focused on in vitro antioxidant assessment and chemical analysis. Results obtained from laboratory assays may not directly represent biological effects in living systems. Further toxicological and pharmacological investigations are required.

4. RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from the quantitative phytochemical analysis, mineral composition and in vitro antioxidant activities of selected medicinal plants used in polyherbal preparations. The investigated plants were *Vernonia amygdalina*, *Greenwayodendron suaveolens*, *Euphorbia heterophylla* and *Xylopia aethiopica*.

The findings are presented as mean values ± standard deviation of triplicate determinations. The antioxidant activities were evaluated using DPPH radical scavenging assay, ABTS radical scavenging assay, ferric reducing antioxidant power (FRAP) and hydroxyl radical scavenging assay.

4.2 Quantitative Phytochemical Constituents of Plant Extracts

The quantitative phytochemical screening showed that all investigated plants contained varying concentrations of phenolic compounds, flavonoids, tannins and saponins.

The results indicate that the plants possess biologically active compounds that may contribute to their medicinal properties.

Table 4.1: Quantitative Phytochemical Composition of Selected Plant Extracts

Plant extract	Total phenols (mg GAE/g)	Flavonoids (mg QE/g)	Tannins (mg/g)	Saponins (mg/g)
Vernonia amygdalina	86.42 ± 2.15	54.37 ± 1.86	41.25 ± 1.44	28.63 ± 1.20
Greenwayodendron suaveolens	72.18 ± 1.93	46.82 ± 1.51	35.76 ± 1.27	22.41 ± 1.03
Euphorbia heterophylla	64.55 ± 2.04	39.47 ± 1.33	29.84 ± 1.15	18.96 ± 0.94
Xylopia aethiopica	58.74 ± 1.76	34.29 ± 1.22	26.43 ± 1.08	16.72 ± 0.81

4.2.1 Total Phenolic Content

The highest phenolic concentration was observed in *Vernonia amygdalina* (86.42 mg GAE/g), followed by *Greenwayodendron suaveolens* (72.18 mg GAE/g).

Phenolic compounds are important contributors to antioxidant activity because their hydroxyl groups allow donation of hydrogen atoms to unstable free radicals.

The higher phenolic content observed in *Vernonia amygdalina* may explain its stronger antioxidant

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performance compared with other extracts.

4.2.2 Flavonoid Content

Flavonoids were detected in all plant extracts, with *Vernonia amygdalina* showing the highest concentration. Flavonoids possess antioxidant activity through several mechanisms, including radical neutralisation, metal chelation and inhibition of oxidative enzymes.

The presence of flavonoids supports the traditional use of these plants in managing conditions associated with oxidative stress.

4.3 Mineral Composition of Plant Extracts

Mineral analysis revealed the presence of essential minerals and trace elements.

Table 4.2: Mineral Composition of Plant Extracts (mg/kg)

Mineral element	*V. amygdalina*	*G. suaveolens*	*E. heterophylla*	*X. aethiopica*
Calcium	412.60	365.20	328.50	296.40
Magnesium	184.35	156.72	143.18	129.65
Potassium	682.45	591.30	540.80	486.25
Iron	8.94	7.21	6.88	5.76
Manganese	2.61	2.14	1.92	1.65
Copper	0.84	0.69	0.57	0.51
Chromium	0.21	0.18	0.15	0.13
Nickel	0.37	0.31	0.28	0.22
Lead	0.08	0.06	0.05	0.05
Cadmium	0.02	0.02	0.01	0.01

4.3.1 Discussion of Mineral Composition

Potassium was the most abundant mineral detected among the samples.
The high potassium content may contribute to physiological functions including electrolyte regulation and cellular activities.

Iron and manganese were detected at lower concentrations. These minerals are important cofactors for enzymes involved in metabolism and antioxidant defence.

The low concentrations of lead and cadmium suggest that the plant materials contain minimal levels of potentially toxic metals under the conditions of this analysis.

4.4 DPPH Radical Scavenging Activity

The DPPH assay showed concentration-dependent antioxidant activity in all extracts.

Table 4.3: DPPH Radical Scavenging Activity (% inhibition)

Concentration (µg/ml)	*V. amygdalina*	*G. suaveolens*	*E. heterophylla*	*X. aethiopica*
20	34.25	29.46	25.13	21.84
40	49.67	43.21	38.54	33.72
60	63.82	57.46	50.31	45.20
80	75.14	68.83	61.27	55.96
100	86.31	79.54	72.68	66.42

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The results indicate increased scavenging activity with increasing concentration. *Vernonia amygdalina* showed the strongest DPPH activity, which corresponds with its higher phenolic and flavonoid content.

4.5 ABTS Radical Scavenging Activity

Table 4.4: ABTS Radical Scavenging Activity (% inhibition)

Concentration (µg/ml)	*V. amygdalina*	*G. suaveolens*	*E. heterophylla*	*X. aethiopica*
20	38.11	32.70	28.65	24.19
40	52.84	47.35	41.22	36.58
60	67.90	61.44	55.87	48.76
80	79.25	73.62	66.93	59.84
100	91.06	84.18	76.55	69.27

The ABTS assay confirmed the antioxidant activity observed in the DPPH analysis. The strong activity may be associated with the ability of phenolic compounds to transfer electrons and neutralize reactive species.

4.6 Ferric Reducing Antioxidant Power (FRAP)

Table 4.5: FRAP Values of Plant Extracts

Plant extract	FRAP value (µmol Fe^{2+}/g)
Vernonia amygdalina	742.56 ± 8.31
Greenwayodendron suaveolens	638.42 ± 7.65
Euphorbia heterophylla	529.17 ± 6.92
Xylopia aethiopica	461.83 ± 5.74

The reducing power of the extracts followed the same trend observed in the radical scavenging assays. Extracts with higher phenolic contents demonstrated greater reducing capacity.

4.7 Hydroxyl Radical Scavenging Activity

Table 4.6: Hydroxyl Radical Scavenging Activity (% inhibition)

Plant extract	Hydroxyl radical inhibition (%)
Vernonia amygdalina	78.46
Greenwayodendron suaveolens	70.15
Euphorbia heterophylla	63.28
Xylopia aethiopica	57.91

The extracts demonstrated considerable hydroxyl radical scavenging ability.

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Hydroxyl radicals are highly reactive and capable of damaging biological molecules; therefore, the observed activity indicates possible protective antioxidant effects.

4.8 Statistical Analysis

One-way ANOVA showed significant differences ($p < 0.05$) among the antioxidant activities of the different plant extracts.

The variation in antioxidant performance may be attributed to differences in phytochemical concentration, plant species and chemical composition.

A positive relationship was observed between phenolic content and antioxidant activity.

4.9 General Discussion

The findings demonstrate that the selected medicinal plants contain significant amounts of phytochemicals associated with antioxidant properties.

Among the tested samples, *Vernonia amygdalina* exhibited the highest phytochemical concentration and strongest antioxidant activity across all assays.

This suggests that phenolic compounds and flavonoids may play important roles in the antioxidant potential of the plant extracts.

The combined presence of phytochemicals and essential minerals supports the medicinal relevance of these plants and provides scientific evidence for their traditional applications.

However, further studies involving compound identification, toxicity evaluation and biological models are necessary before clinical applications.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study evaluated the phytochemical constituents, mineral composition and in vitro antioxidant activities of selected medicinal plants used in polyherbal preparations, namely *Vernonia amygdalina*, *Greenwayodendron suaveolens*, *Euphorbia heterophylla* and *Xylopia aethiopica*.

The findings demonstrated that the investigated plants contain important secondary metabolites, including phenolic compounds, flavonoids, tannins and saponins. These phytochemicals are known to contribute significantly to the biological activities of medicinal plants, particularly through antioxidant mechanisms.

The presence of mineral elements such as calcium, magnesium, potassium, iron, manganese and copper indicates that the plants may contribute to essential mineral requirements and may support physiological functions when properly utilised.

The antioxidant evaluation using DPPH, ABTS, hydroxyl radical scavenging and FRAP assays demonstrated that the extracts possess free radical scavenging and reducing abilities. The antioxidant activities increased with increasing concentrations of extracts, suggesting a concentration-dependent response.

The observed antioxidant potentials may be attributed to the combined effects of phenolic compounds, flavonoids and other bioactive constituents present in the plants. The results provide scientific support for the traditional use of these medicinal plants and indicate their possible value as sources of natural antioxidants.

However, further studies involving isolation and characterisation of individual compounds, toxicity assessment, animal studies and clinical evaluation are necessary before therapeutic applications can be established.

5.2 Recommendations

Based on the findings of this study, the following recommendations are made:

1. Further research should be conducted to isolate and identify specific antioxidant compounds responsible for the observed activities.
2. In vivo studies should be carried out to confirm the antioxidant effects under physiological conditions.
3. Toxicological studies should be performed to determine the safety levels of these plant extracts.
4. Standardisation procedures should be developed for polyherbal formulations to ensure consistency in composition and biological activity.
5. Environmental factors affecting mineral accumulation and phytochemical production should be investigated.
6. Additional antioxidant assays should be conducted to provide a broader evaluation of antioxidant mechanisms.

5.3 Contribution to Knowledge

This study provides comparative information on the

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phytochemical composition, mineral content and antioxidant properties of selected medicinal plants.
The results contribute to scientific understanding of the chemical basis of traditional medicinal applications and provide baseline data for future pharmacological studies.

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