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Research Article

Chemical Composition, Antimicrobial and Antioxidant Activities of *Dioscorea dumetorum* (Bitter Yam) Leaves and Stem Essential Oil

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Abstract

Background: *Dioscorea dumetorum* (bitter yam) is an underutilized West African species valued for its nutritional and ethnomedicinal importance. While its tubers have been extensively studied, the essential oils of its aerial parts remain largely unexplored. This study investigated the chemical composition, antimicrobial activity, and antioxidant potential of essential oils extracted from the leaves and stems of *Dioscorea dumetorum*, to provide scientific insight into their bioactive properties and industrial relevance. **Methods**: Leaves and stems were air-dried, pulverized, and hydro distilled using a Clevenger-type apparatus. Oil yields and physicochemical properties were determined, while chemical constituents were characterized by Gas Chromatography–Mass Spectrometry (GC-MS). Antimicrobial activity was evaluated against selected bacterial (*Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*) and fungal (*Candida albicans*, *Aspergillus niger*, *Penicillium notatum*, *Rhizopus stolonifer*) pathogens using the agar well diffusion method. Antioxidant potential was assessed by Ferric Reducing Antioxidant Power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assays. **Results**: The leaf and stem oils yielded 0.50% and 1.07%, respectively. GC-MS analysis revealed 23 and 20 compounds dominated by 2-pentadecanone (20.64%) and phytol (16.74%) in the leaf oil, and di-*n*-octyl phthalate (34.43%) and eicosanoic acid esters (15.97%) in the stem oil. Both oils exhibited broad-spectrum antimicrobial effects, with leaf oil showing larger inhibition zones (18–26 mm) than stem oil (14–24 mm). Antioxidant assays demonstrated concentration-dependent activities: leaf oil showed stronger ferric-reducing power, whereas stem oil displayed higher radical-scavenging potential. **Conclusions**: These findings demonstrated that *Dioscorea dumetorum* essential oils possess significant antimicrobial and antioxidant properties with distinct phytochemical profiles, supporting their potential applications as natural sources of bioactive compounds in nutraceutical, pharmaceutical, and cosmetic formulations.

Keywords: *Dioscorea dumetorum*; volatile oils; gas chromatography–mass spectrometry; antimicrobial agents; antioxidants; plant extracts; pharmacology

1. Introduction

Yams (*Dioscorea* spp.) are tuber crops of significant nutritional, economic, and cultural importance across tropical regions, particularly in West Africa [1]. Among these, *Dioscorea dumetorum* (bitter yam), belonging to the family Dioscoreaceae, remains underutilized despite its rich nutritional and medicinal potential [2]. In southeastern Nigeria, it is traditionally consumed for its perceived health benefits and is regarded as a dietary option for diabetic patients. However, its limited use is largely attributed to its bitter taste, postharvest hardening, and spoilage tendencies [3]. Studies have suggested that processing methods such as soaking and extended cooking can improve its nutritional and phytochemical qualities [4,5].

In recent years, interest in *Dioscorea dumetorum* has expanded beyond its nutritional composition to its phytochemical constituents and potential therapeutic applications. Plants within the *Dioscorea* genus are known to contain diverse bioactive metabolites, including alkaloids, flavonoids, saponins, and essential oils, which exhibit a wide range of pharmacological activities. Essential oils, in particular, are complex mixtures of volatile compounds synthesized by aromatic plants and have been utilized for centuries in traditional medicine, perfumery, and food preservation [6]. Their biological properties such as antimicrobial, antioxidant, anti-inflammatory, and anticancer activities make them promising candidates for natural therapeutic and industrial applications [7,8].

The extraction and characterization of essential oils depend on the plant source and the extraction technique employed, including hydrodistillation, steam distillation, and supercritical CO_2 extraction, among others [9,10]. These oils are widely applied in the pharmaceutical, cosmetic, and agro-food sectors due to their lipophilicity, low toxicity, and biological efficacy [11]. In medicine, essential oils have been investigated for their therapeutic potential against infectious and inflammatory diseases [12], while in the food industry, they serve as natural preservatives and flavoring agents with antimicrobial and antioxidant functions [13,14].

Hydro-distillation was selected for its efficiency in isolating volatile compounds without chemical degrada-

tion. Compared to solvent extraction and Soxhlet methods, hydro-distillation is environmentally friendly, requires minimal solvents, and better preserves thermolabile bioactives such as monoterpenes and sesquiterpenes. This technique also facilitates direct comparison with other medicinal plant essential oils extracted under similar conditions [12,14].

Despite the established pharmacological relevance of *Dioscorea* species, most research has focused on the tubers of *Dioscorea dumetorum*, with little attention to its aerial parts (stems and leaves) which are often discarded as waste. Yet, these parts may harbor unique volatile phytochemicals with potential biological and industrial applications [15,16]. Investigating their essential oil composition not only promotes resource optimization but also contributes to the broader understanding of the species' phytochemical diversity and pharmacological potential.

Given the growing demand for natural alternatives to synthetic additives and therapeutics, this study aims to extract, characterize, and evaluate the bioactivities of the essential oil from *Dioscorea dumetorum*. The research specifically focuses on elucidating the chemical constituents using Gas Chromatography–Mass Spectrometry (GC-MS) and assessing the oil's antioxidant and antimicrobial properties through standard *in vitro* assays. The findings will provide baseline data for future pharmacological and industrial applications of *Dioscorea dumetorum*, highlighting its potential as a source of natural bioactive compounds [12].

This is the first comprehensive study investigating both the chemical composition and the comparative antimicrobial and antioxidant potentials of *Dioscorea dumetorum* leaf and stem essential oils extracted using hydrodistillation. Unlike previous studies focused mainly on tubers, this work highlights the underexplored aerial parts of the plant as a potential source of bioactive compounds with therapeutic relevance [16].

2. Materials and Methods

2.1 Sample Collection and Preparation

Fresh leaves and stems of *Dioscorea dumetorum* (bitter yam) were collected from Fiditi, Oyo State, Nigeria, and authenticated at the Department of Botany, University of Ibadan (Voucher No.: UIH–23643). The materials were air-dried under shade at room temperature for eight days to prevent loss of volatile components, pulverized, and stored in airtight containers until extraction.

2.2 Essential Oil Extraction

Essential oils were extracted from the powdered leaves (465 g) and stems (135 g) by hydrodistillation using a Clevenger-type apparatus. Each sample was immersed in distilled water and distilled for 3 h. The condensate was collected, and the oil layer separated, dried over anhydrous sodium sulfate, and stored in amber vials at 4 °C until analysis [6,7].

2.3 Physical Examination of Essential Oil

The essential oil was visually observed for its color, consistency, and odor. The yield was calculated as a percentage using the formula:

$$\text{Oil Yield (\%)} = \frac{\text{Volume of oil (mL)}}{\text{Weight of plant material (g)}} \times 100$$

2.4 GC-MS Analysis

Chemical profiling of the oils was performed using a Shimadzu GCMS-QP2010 equipped with an AOC-20i auto-sampler. Samples were diluted (1:100, v/v) in n-hexane with n-decane as an internal standard. Separation was achieved on a capillary column using helium as the carrier gas at 0.8 mL/min. The oven temperature was programmed from 60 °C (1 min hold) to 240 °C at 13 °C/min, with a final hold of 1 min. The MS was operated in electron impact (EI) mode (70 eV), scanning m/z 35–500. Compounds were identified by comparison with NIST/Wiley libraries and confirmed via retention indices (±20 units).

2.5 Antimicrobial Activity

The antimicrobial activity of the essential oils was tested against *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and fungal strains (*Candida albicans*, *Aspergillus niger*, *Penicillium notatum*, and *Rhizopus stolonifer*). The agar well diffusion method was used on Nutrient Agar (bacteria) and Sabouraud Dextrose Agar (fungi). Gentamicin and tioconazole served as positive controls, while dimethyl sulfoxide (DMSO) served as the negative control. Zones of inhibition were measured after incubation (37 °C for 24 h for bacteria; 26–28 °C for 48 h for fungi). Minimum inhibitory concentration (MIC) values were determined by broth microdilution in 96-well plates [7,8].

All antimicrobial assays were carried out in triplicate (n = 3). Essential oil concentrations of 250, 500, 1000, 2000, and 4000 µg/mL were tested using the agar well diffusion method. Gentamicin (for bacteria) and tioconazole (for fungi) served as positive controls, while dimethyl sulfoxide (DMSO) was used as the negative control to exclude solvent effects.

2.6 Antioxidant Activity

Antioxidant capacity was evaluated using 2, 2, diphenylpicrylhydrazyl (DPPH) radical scavenging and Ferric Reducing Antioxidant Power (FRAP) assays. All antioxidant assays were performed in triplicate (n = 3), and results were expressed as mean ± standard deviation. Statistical analysis was conducted to compare leaf and stem extracts.

DPPH Assay: Essential oil samples (25–400 µg/mL) were reacted with 0.4 mM DPPH in methanol, incubated in

Table 1. Physical characteristics and percentage yield of essential oils from *Dioscorea dumetorum*.

Plant part	Weight of dried sample (g)	Volume of oil (mL)	Oil yield (%)	Color	Odor
Leaves	465	2.34	0.50	Pale yellow	Aromatic
Stems	135	1.45	1.07	Pale yellow	Aromatic

the dark for 30 min, and absorbance read at 517 nm. The radical scavenging activity was expressed as percentage inhibition of the DPPH radical, calculated relative to the control (DPPH solution without extract) using the equation:

$$\% \text{ Inhibition } = \frac{AC - AS}{AC} \times 100$$

Where AC represents the absorbance of the control, AS represents the absorbance of the test sample. A higher percentage inhibition indicated a stronger radical scavenging capacity.

FRAP Assay: Samples were mixed with phosphate buffer, potassium ferricyanide, and trichloroacetic acid, followed by ferric chloride addition. Absorbance was measured at 700 nm, with increased absorbance indicating higher reducing power. For the assay, different concentrations of the extract were mixed with 2.5 mL of phosphate buffer (200 mM, pH 6.6) and 2.5 mL of 1% potassium ferricyanide. The mixtures were incubated at 50 °C for 20 minutes, after which 2.5 mL of 10% trichloroacetic acid was added to terminate the reaction. The mixtures were then centrifuged at 650 ×g for 10 minutes, and 5 mL of the resulting supernatant was collected. To this, 5 mL of distilled water and 1 mL of 0.1% ferric chloride were added. The absorbance of the resulting solution was measured at 700 nm using a UV-Vis spectrophotometer [7].

Table 2. Volatile compounds identified in the essential oil of *Dioscorea dumetorum* leaves by GC-MS.

S/N	Retention time	%Composition	Name
1	9.745	1.07	1-Octen-3-ol
2	9.889	2.30	5-Hepten-2-one
3	11.543	4.12	Acetophenone
4	13.673	1.05	1-Cyclohexene
5	14.127	0.83	Cyclohexanone
6	14.600	0.61	1,5-Heptadiene
7	15.538	1.44	2-Undecanone
8	16.163	10.18	5,9-Undecadien-2-one
9	16.860	4.72	trans-.beta.-Ionone
10	19.063	2.22	Octadecanal
11	19.147	1.07	1-Dodecanol
12	19.241	1.81	Spiro [4.5] dec-8-en-7-ol
13	19.650	1.56	Pentadecane
14	19.735	12.77	Spiro [4.5] dec-6-en-8-one
15	20.083	0.96	Tetracontane
16	20.321	20.64	2-Pentadecanone
17	20.689	1.15	2-methyltetracosane
18	21.095	1.23	Docosane
19	21.232	8.91	5,9,13-Pentadecatrien-2-one
20	22.902	1.09	Heptadecane
21	23.005	1.34	2-methyltetracosane
22	23.358	16.74	Phytol
23	25.565	1.19	Octacosane
		99.00	

3. Results

3.1 Yield and Physical Properties

The essential oils obtained from the leaves and stems were pale yellow with aromatic odor (Table 1).

The physical characteristics and modest yields of *Dioscorea dumetorum* essential oils suggest potential applications in food, medicinal, and industrial sectors. The pale-yellow coloration, often linked to carotenoids and flavonoids, reflects antioxidant potential, while the aromatic odor implies the presence of volatile terpenoids with known antimicrobial and therapeutic properties [17]. Similar to other *Dioscorea* species, these bioactive constituents may enhance the functional value of the oils as natural preservatives or flavoring agents in food systems [18].

3.2 GC-MS Analysis

GC-MS profiling revealed 24 and 20 compounds in the leaf and stem oils, respectively. The leaf oil was dominated by phytol (16.74%), 2-pentadecanone (20.64%), and spiro ketone derivatives (12.77%), compounds known for antioxidant, antimicrobial, and aromatic properties. The stem oil contained di-*n*-octyl phthalate (34.43%), eicosanoic acid esters (11.87% and 4.10%), and 13-octadecenal (9.32%) as major constituents, reflecting a fatty acid-rich composition. Both oils shared acetophenone and phytol, indicating overlapping pharmacological potential. The chemical variation suggests the leaf oil may possess stronger antioxidant activity due to its higher proportion of oxygenated terpenes, while the stem oil's composition favors antimicrobial and emollient applications.

3.2.1 GC-MS Analysis of *Dioscorea dumetorum* Leaves Essential Oil

The GC-MS analysis of the essential oil revealed 24 distinct compounds, representing 100% of the total oil composition. The identified compounds, their retention times (RT), percentages composition are presented in Table 2. Fig. 1 shows the GC-MS Analysis of Leaves.

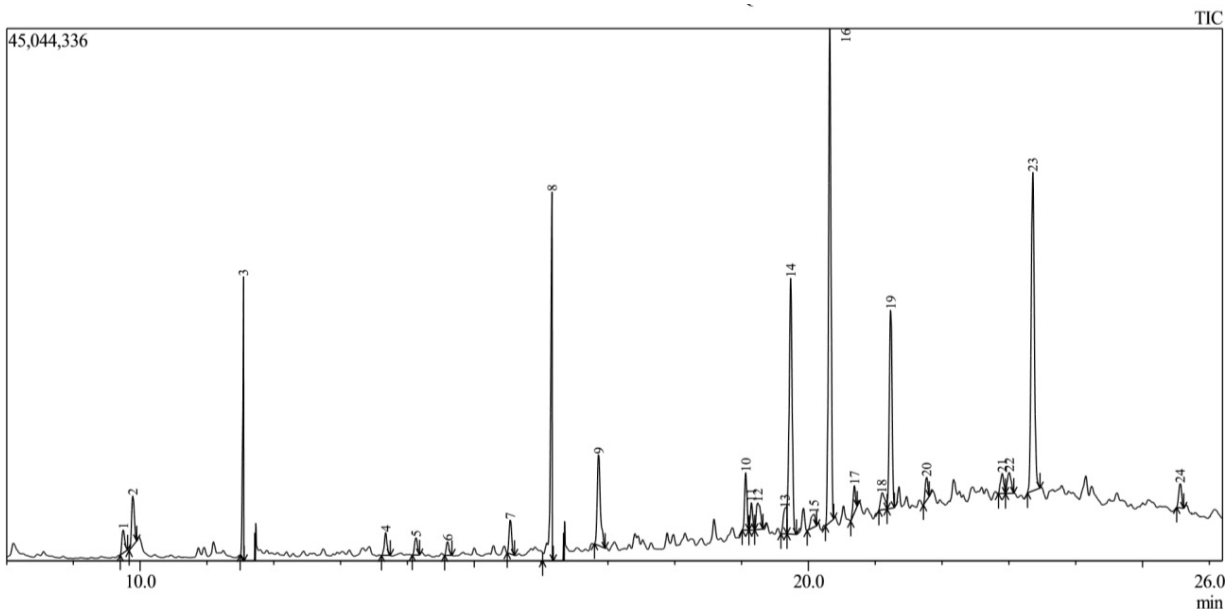

Fig. 1. Chromatographic profile of *Dioscorea dumetorum* leaf extract. The chromatogram shows distinct peaks corresponding to the various phytochemical compounds present in the leaf extract, each peak representing a specific retention time and relative concentration.

Table 3. Volatile compounds identified in the stem oil of *Dioscorea dumetorum* by GC-MS.

S/N	Retention time	%Composition	Name
1	11.635	6.60	Acetophenone
2	14.275	7.83	3-hydroxypropyl ester
3	16.192	0.54	cis-Z-.alpha.-Bisabolene epoxide
4	16.770	9.32	13-Octadecenal
5	17.982	0.66	Tridecanal
6	18.815	1.17	Heptasiloxane
7	18.960	34.43	Di-*n*-octyl phthalate
8	19.054	3.84	Pentadecanal
9	19.660	1.85	1-Decanol, 2-octyl-
10	20.125	1.97	Octadecanoic acid
11	20.305	3.55	2-Pentadecanone
12	21.043	1.73	9,17-Octadecadienal, (Z)-
13	21.489	11.87	2,3-bis(acetyloxy)propyl ester
14	21.969	0.48	5-methylhex-2-yl butyl ester
15	22.170	0.50	trans-2-undecenoic acid
16	22.408	2.18	3-n-Butylthiophene-1,1-dioxide
17	22.791	4.10	Eicosanoic acid
18	23.050	3.79	Hexadecanoic acid
19	23.339	2.79	Phytol
20	26.070	0.82	1-(2-aminoethoxy)hydro
		100.00	

3.2.2 GC-MS Analysis of *Dioscorea dumetorum* Stem Essential Oil

The GC-MS analysis of the essential oil revealed 20 distinct compounds, representing 100% of the total oil composition. The identified compounds, their retention times (RT), peak areas relative percentages are presented in Table 3. Fig. 2 shows the GC-MS Analysis of Stem.

3.3 Antimicrobial Activity

The leaf and stem essential oils exhibited broad-spectrum antimicrobial activity against six bacterial and four fungal strains. The leaf oil produced larger inhibition zones (18–26 mm) than the stem oil (14–24 mm). Statistical analysis showed that the antimicrobial activity of the leaf oil was significantly higher than that of the stem oil at the highest concentration ($p < 0.05$). Although less active than standard antibiotics (gentamycin) and antifungal agents (tioconazole), both extracts demonstrated dose-dependent inhibition, confirming the presence of bioactive secondary metabolites. The stronger efficacy of the leaf oil may result from higher levels of phenolics, flavonoids, and terpenoids concentrated in photosynthetic tissues. These findings suggest potential for *Dioscorea dumetorum* oils as natural antimicrobial agents, particularly in formulations requiring moderate, broad-spectrum activity. The antimicrobial inhibition zones are presented in Table 4 (leaf oil) and Table 5 (stem oil). A comparison of both extracts is shown in Table 6.

Table 6 shows a comparison of activity between the leaf and stem inhibition zones at the highest concentration across all ten microorganisms. These provide a straightforward comparison, emphasizing the greater activity of the leaf extracts relative to the stems. Fig. 3 also shows the comparison using the bar chart.

The values represent mean inhibition zones (mm) from three independent experiments (n = 3), and differences between leaf and stem oils were statistically significant at $p < 0.05$.

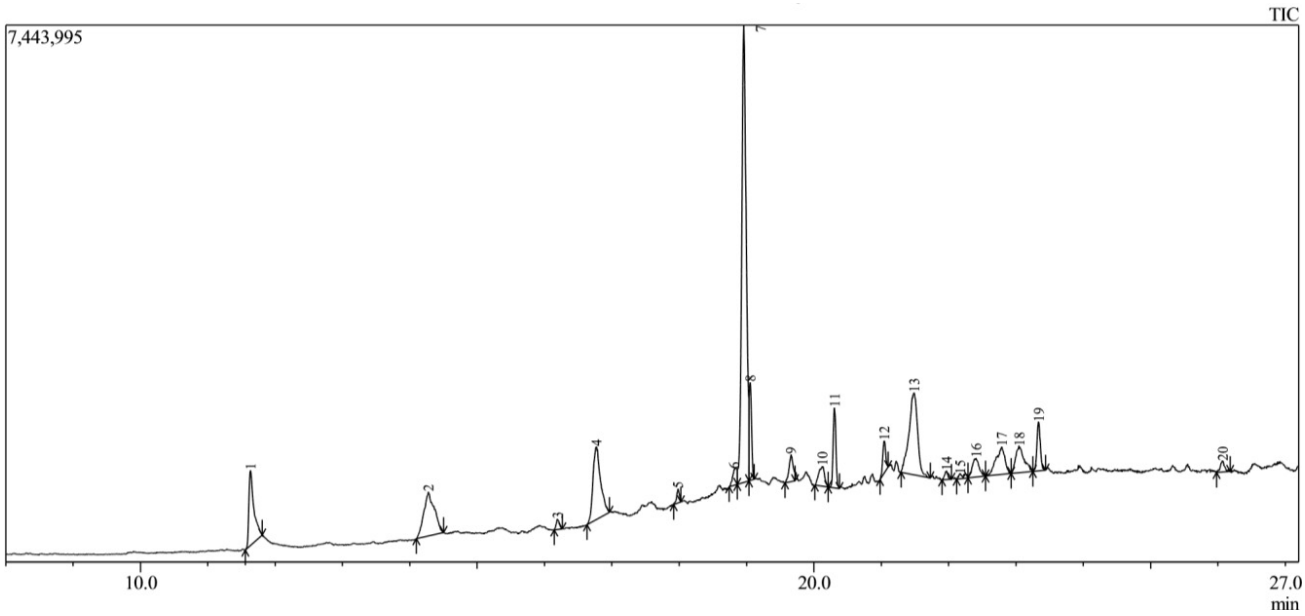

Fig. 2. Chromatographic profile of *Dioscorea dumetorum* stem extract. The chromatogram displays distinct peaks corresponding to individual phytochemical compounds detected in the stem extract, each peak representing a specific retention time and relative abundance.

Table 4. The antimicrobial inhibition zones for the leaves essential oil.

S/N	*S.aur*	*E.col*	*B.sub*	*P.aer*	*S.typ*	*K.pne*	*C.alb*	*A.nig*	*P.not*	*R.sto*
1.	26	24	26	25	24	24	20	20	18	20
2.	24	21	22	22	20	21	18	18	16	18
3.	21	18	20	19	18	18	16	16	14	16
4.	18	10	17	17	16	16	12	14	12	12
5.	14	12	13	14	12	13	10	10	10	10
–ve	-	-	-	-	-	-	-	-	-	-
+ve	40	40	38	38	40	38	30	28	28	28

S.aur, *Staphylococcus aureus*; *E.col*, *Escherichia coli*; *B.sub*, *Bacillus subtilis*; *P.aer*, *Pseudomonas aeruginosa*; *S.typ*, *Salmonella typhi*; *K.pne*, *Klebsiella pneumoniae*; and fungal strains *C.alb*, *Candida albicans*; *A.nig*, *Aspergillus niger*; *P.not*, *Penicillium notatum*; and *R.sto*, *Rhizopus stolonifer*; –ve, negative control; +v, positive control (Gentamicin and tioconazole served as positive controls, while DMSO served as the negative control); DMSO, dimethyl sulfoxide.

Table 5. The antimicrobial inhibition zones for the stem essential oil.

S/N	*B.cer*	*E.col*	*B.sub*	*P.aer*	*S.typ*	*K.pne*	*C.alb*	*A.nig*	*P.not*	*R.sto*
1.	22	24	23	24	24	23	20	18	14	16
2.	18	21	20	21	21	20	18	16	12	14
3.	16	18	17	18	18	16	16	12	10	10
4.	14	10	14	15	16	14	12	10	-	-
5.	10	12	11	12	13	12	10	10	-	-
–ve	-	-	-	-	-	-	-	-	-	-
+ve	40	40	38	38	40	38	30	28	28	28

S.aur, *Staphylococcus aureus*; *E.col*, *Escherichia coli*; *B.sub*, *Bacillus subtilis*; *P.aer*, *Pseudomonas aeruginosa*; *S.typ*, *Salmonella Typhi*; *K.pne*, *Klebsiella pneumoniae*; and fungal strains *C.alb*, *Candida albicans*; *A.nig*, *Aspergillus niger*; *P.not*, *Penicillium notatum*; and *R.sto*, *Rhizopus stolonifer*; –ve, negative control; +v, positive control (Gentamicin and tioconazole served as positive controls, while DMSO served as the negative control).

Table 6. The leaf and stem inhibition zones at the highest concentration across all ten microorganisms.

Organisms	*S.aur*	*E.col*	*B.sub*	*P.aer*	*S.typ*	*K.pne*	*C.alb*	*A.nig*	*P.not*	*R.sto*
Leaf (mm)	26	24	26	25	24	24	20	20	18	20
Stem (mm)	22	24	23	24	24	23	20	18	14	16

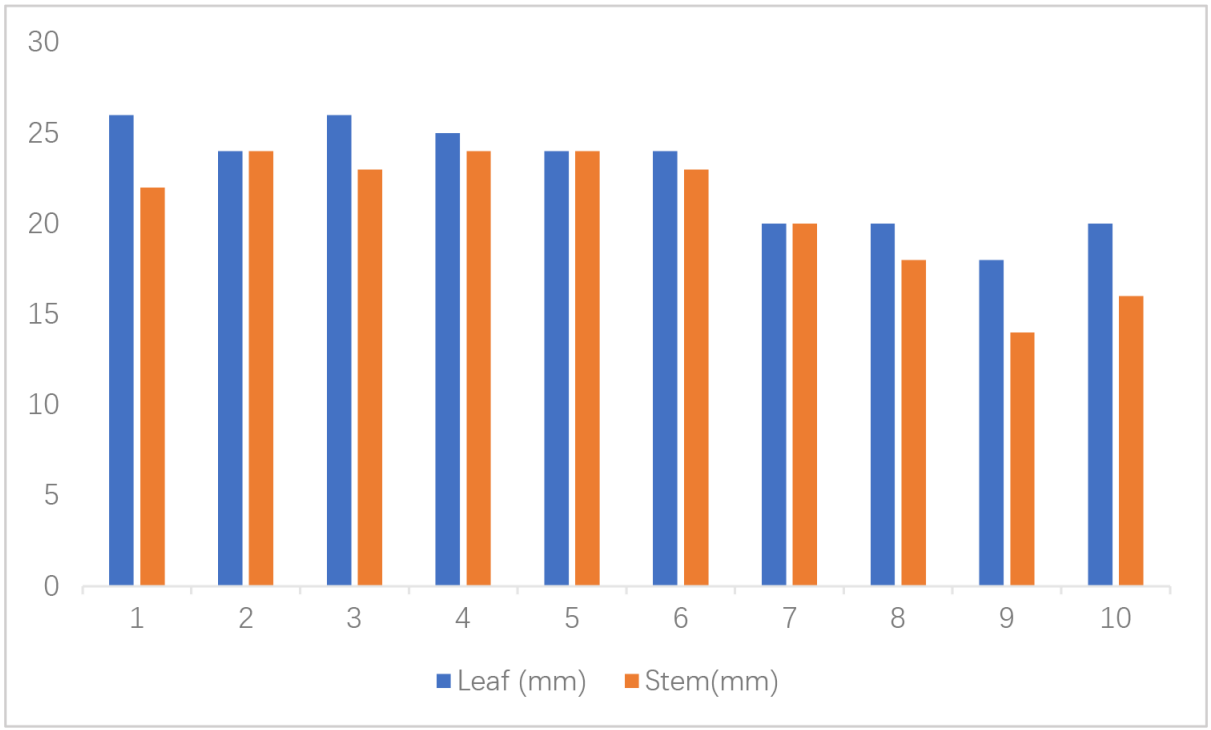

Fig. 3. Comparison of leaf and stem essential oils against ten microorganisms. Data represent mean ± SD (n = 3).

3.4 Ferric Reducing Antioxidant Power (FRAP)

Both extracts demonstrated concentration-dependent ferric reducing power, confirming their electron-donating and radical-quenching abilities. The leaf extract showed higher FRAP values than the stem extract across all concentrations tested. Statistical analysis confirmed that the FRAP values of the leaf extract were significantly higher than those of the stem extract ($p < 0.05$) (18.02 ± 0.02 mg AAE/g at 4000 µg/mL) than the stem extract (14.12 ± 0.04 mg AAE/g), indicating greater reducing potential. This suggests that antioxidant compounds such as flavonoids and phenolic are more abundant in leaves. The FRAP results for leaf and stem oils are presented in Table 7 and Table 8, respectively. Fig. 4 shows the ferric reducing antioxidant power (FRAP) activity of leaf and stem extracts.

3.5 DPPH Radical Scavenging Activity

The DPPH assay confirmed that both extracts possess free radical scavenging activity in a concentration-dependent manner. Fig. 5 shows the leaf extract activity. Fig. 6 shows the stem extract activity. The stem extract exhibited a lower IC_{50} value (224.11 µg/mL) than the leaf extract (1288.52 µg/mL), suggesting stronger scavenging efficiency, though both were less potent than ascorbic acid (IC_{50} = 156.15 µg/mL). Fig. 7 shows the standard antioxidant activity. The antioxidant properties can be attributed to secondary metabolites such as terpenoids and phenolic compounds identified in the GC-MS analysis. These findings reinforce the potential of *Dioscorea dumetorum* essential oils particularly from the stem as moderate natural antioxidants suitable for applications in oxidative stress management and product stabilization. The DPPH radical scavenging activities are presented in Table 9 (leaf oil) and Table 10 (stem oil), while the standard is shown in Table 11. A comparison of IC_{50} values is provided in Table 12. Fig. 8 shows the experimental workflow schematic.

4. Discussion

4.1 Discussion of GC-MS Results

The GC-MS analysis of *Dioscorea dumetorum* essential oils showed distinct compositional differences between the leaf and stem oils, reflecting organ-specific biosynthetic activity and environmental influence on metabolite accumulation [19,20].

The leaf oil contained 23 identified compounds, mainly oxygenated terpenoids and ketones, while the stem

Table 7. Ferric reducing antioxidant power (FRAP) of *Dioscorea dumetorum* leaf essential oil.

Concentration (µg/mL)	1	2	3	Mean	SD	Mean ± SD
4000	18.009	18.040	18.009	18.019	0.018	18.019 ± 0.018
2000	15.852	15.884	15.884	15.873	0.018	15.873 ± 0.018
1000	14.478	14.478	14.478	14.478	0.000	14.478 ± 0.000
500	11.978	12.040	12.035	12.018	0.034	12.018 ± 0.034
250	10.415	10.665	10.665	10.582	0.144	10.582 ± 0.144

Table 8. Ferric reducing antioxidant power (FRAP) of *Dioscorea dumetorum* stem essential oil.

Concentration (µg/mL)	1	2	3	Mean	SD	Mean ± SD
4000	14.103	14.103	14.165	14.124	0.036	14.124 ± 0.036
2000	12.072	12.197	12.290	12.186	0.109	12.186 ± 0.109
1000	10.822	10.822	10.790	10.811	0.018	10.811 ± 0.018
500	10.103	9.478	9.478	9.686	0.361	9.686 ± 0.361
250	8.290	8.290	8.290	8.290	0.000	8.290 ± 0.000

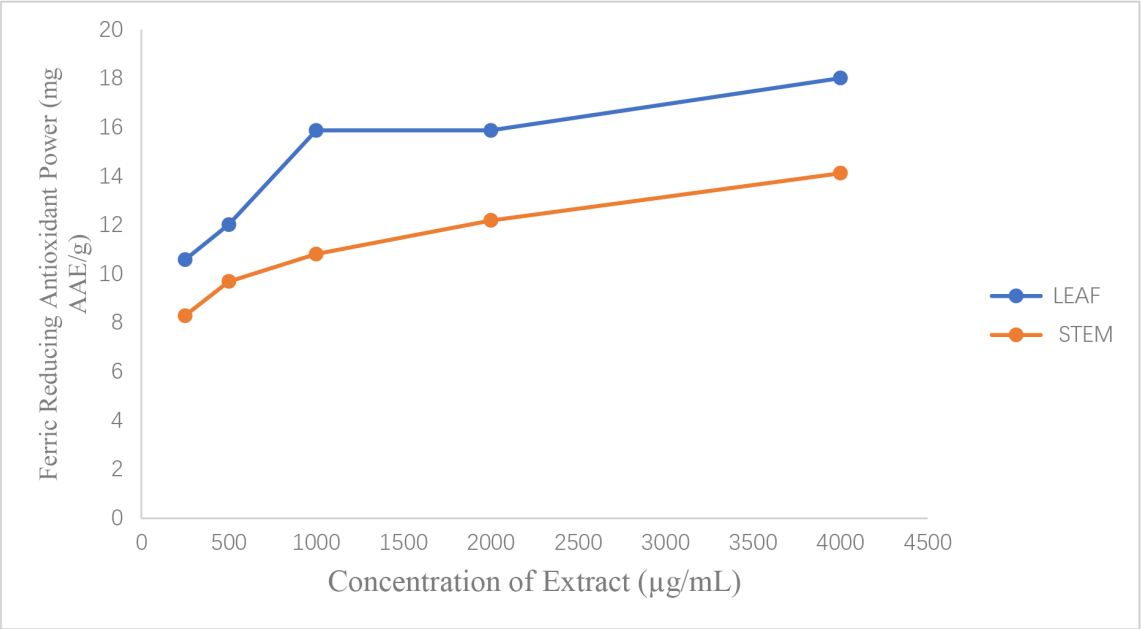

Fig. 4. Comparative bar charts showing ferric reducing antioxidant power (FRAP) activity of leaf and stem extracts. X-axis: Concentration of Extract µg/mL. Y-axis: Ferric Reducing Antioxidant Power (mg AAE/g).

Table 9. DPPH radical scavenging activity of *Dioscorea dumetorum* leaf essential oil.

Conc (µg/mL)	1	2	3	Mean	SD	Mean ± SD
4000	41.39	41.23	41.15	41.26	0.12	41.26 ± 0.12
2000	38.43	38.43	38.11	38.32	0.18	38.32 ± 0.18
1000	32.27	32.50	32.35	32.37	0.12	32.37 ± 0.12
500	29.31	29.15	28.92	29.13	0.20	29.13 ± 0.20
250	26.81	27.00	27.00	26.94	0.11	26.94 ± 0.11

DPPH, 2,2-diphenyl-1-picrylhydrazyl.

oil had 20 compounds dominated by fatty acid esters and aldehydes. 2-pentadecanone (20.64%) and phytol (16.74%) were the predominant constituents, in the leaf oil, followed by spiro [4.5] dec-6-en-8-one (12.77%) and 5,9-undecadien-2-one (10.18%). These oxygenated molecules are known for their antimicrobial, antioxidant, and aromatic properties [21,22].

Phytol, a chlorophyll-derived diterpene, has been reported to exhibit strong antioxidant, anti-inflammatory, and antimicrobial effects [23,24], while methyl ketones such as 2-pentadecanone enhance the oxidative stability and antimicrobial performance of essential oils [25,26]. The presence of spiro ketones and ionone-type compounds further supports the high antioxidant potential of the leaf oil [26,27].

Conversely, the stem oil was dominated by di-n-octyl phthalate (34.43%), 13-octadecenal (9.32%), and

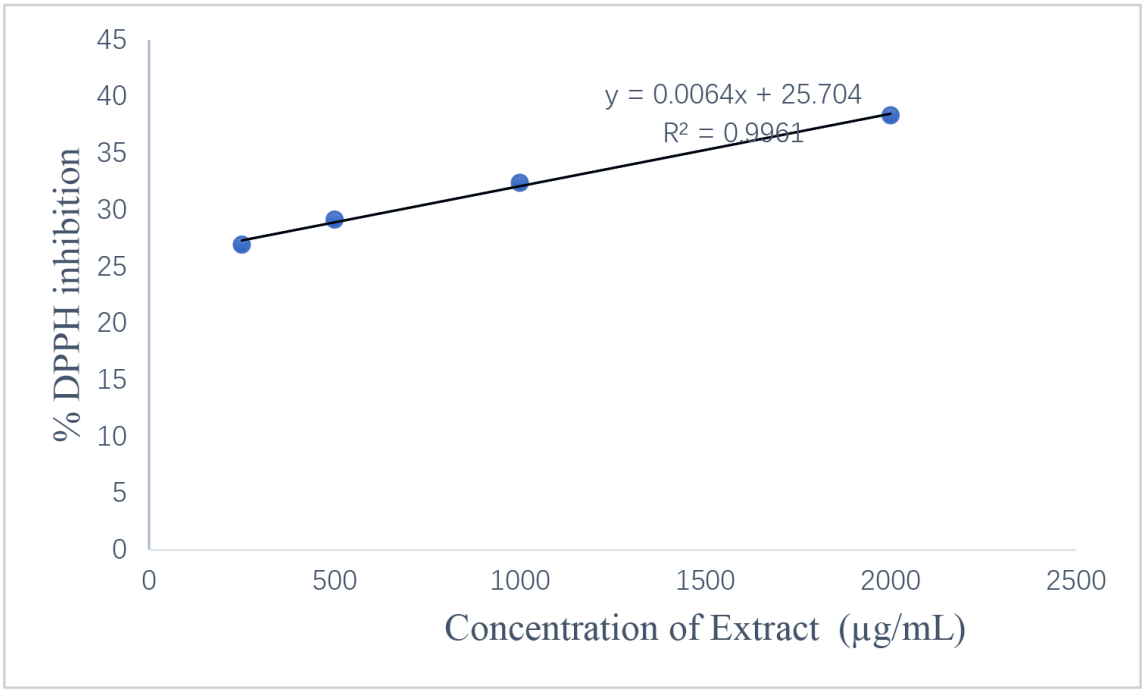

Fig. 5. DPPH radical scavenging activity of *Dioscorea dumetorum* leaf extract. Showing % DPPH inhibition (Y-axis) against Concentration of Extract (µg/mL) (X-axis). Data represent mean ± SD (n = 3). The graph shows the percentage of DPPH radical inhibition at varying extract concentrations, used to determine the antioxidant potential of the extract. The calculated half-maximal inhibitory concentration (IC_{50}) was approximately 1288.52 µg/mL, indicating moderate free-radical scavenging capacity.

Table 10. DPPH radical scavenging activity of *Dioscorea dumetorum* stem essential oil.

Conc (µg/mL)	1	2	3	Mean	SD	Mean ± SD
4000	30.32	30.48	30.71	30.50	0.20	30.50 ± 0.20
2000	28.84	28.84	29.00	28.89	0.09	28.89 ± 0.09
1000	26.35	26.58	26.35	26.43	0.13	26.43 ± 0.13
500	23.77	23.77	23.70	23.75	0.04	23.75 ± 0.04
250	20.58	20.34	20.58	20.50	0.14	20.50 ± 0.14

eicosanoic acid derivatives (11.87% and 4.10%), suggesting a fatty acid–rich fraction with emollient and preservative properties [21,28]. Although phthalates are sometimes associated with laboratory contamination, precautions were taken during sample preparation, including the use of clean glassware and analytical-grade solvents. Therefore, its presence is reported with caution, and further studies are recommended to confirm its biological origin.

Both oils contained acetophenone and phytol, indicating shared pharmacological potential [23]. However, the higher oxygenated terpene content in the leaf oil likely accounts for its stronger ferric-reducing antioxidant power, whereas the fatty acid–based composition of the stem oil supports its superior radical-scavenging and antimicrobial activities [26]. Overall, the GC-MS results confirm that *Dioscorea dumetorum* essential oils are rich in bioactive compounds with promising antioxidant and antimicrobial potential, supporting their value for nutraceutical and pharmaceutical applications.

The extraction process significantly impacted both the yield and chemical profile of the essential oils. Hydrodistillation tends to recover lighter volatile molecules, such as α-pinene and limonene, which may contribute to enhanced antimicrobial and antioxidant activities. The observed compositional differences between leaf and stem oils could be linked to tissue-specific distribution of biosynthetic enzymes and the mild thermal conditions during distillation [28].

4.2 Discussion of the Antimicrobial Results

The antimicrobial evaluation of *Dioscorea dumetorum* revealed that both the leaf and stem essential oils exhibited inhibitory activity against a wide range of microorganisms, including both bacteria and fungi. All tests were done in triplicate (n = 3). Gentamicin and tioconazole were used as positive controls; DMSO as negative control. Extract concentrations ranged from 250–4000 µg/mL. However, the results consistently showed that the leaf extracts were

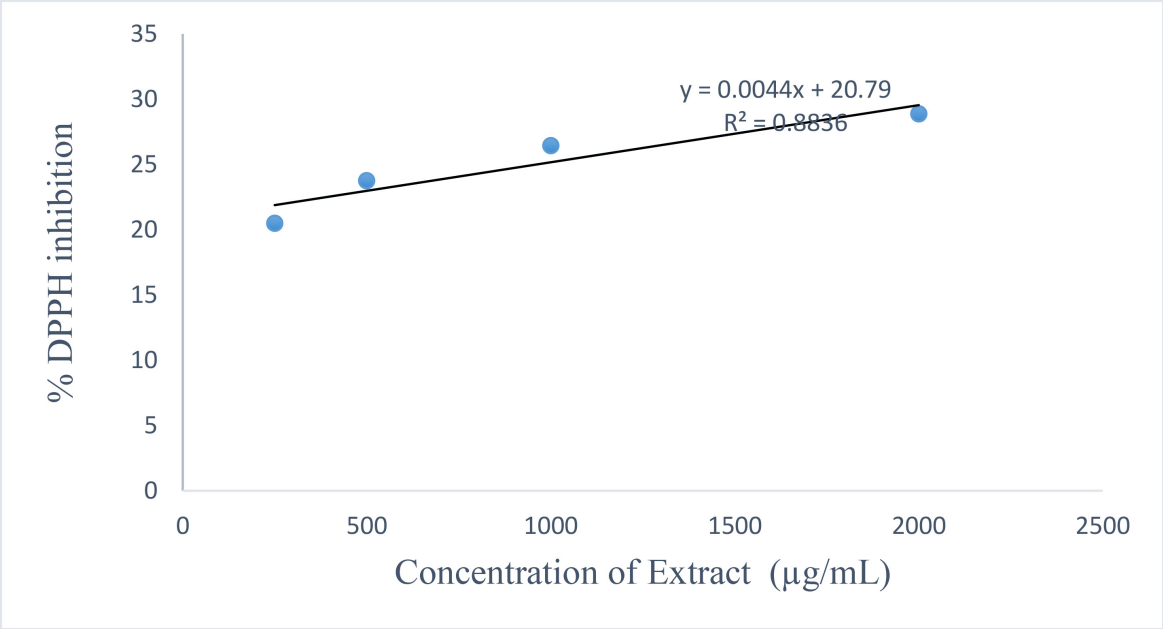

Fig. 6. DPPH radical scavenging activity of *Dioscorea dumetorum* stem essential oil. Showing % DPPH inhibition (Y-axis) against Concentration of Extract (µg/mL) (X-axis). Data represent mean ± SD (n = 3). The figure illustrates the percentage inhibition of DPPH radicals at different concentrations of the stem essential oil, indicating its antioxidant potential. The calculated half-maximal inhibitory concentration (IC_{50}) was approximately 224.11 µg/mL, demonstrating a strong free-radical scavenging capacity.

Table 11. Ascorbic acid (standard).

Conc (µg/mL)	1	2	3	Mean	SD	Mean ± SD
4000	96.40	96.41	96.38	96.40	0.02	96.40 ± 0.02
2000	79.86	80.02	79.96	79.95	0.08	79.86 ± 0.08
1000	55.26	55.30	55.34	55.30	0.04	55.26 ± 0.04
500	36.10	36.14	36.11	36.12	0.02	36.10 ± 0.02
250	24.38	24.44	24.43	24.42	0.03	24.38 ± 0.03

more potent than the stem extracts, producing larger zones of inhibition across almost all test organisms. This suggests that the leaves contain higher concentrations of active phytochemicals responsible for antimicrobial effects [24]. Both extracts demonstrated a clear dose-dependent pattern, where antimicrobial activity decreased progressively with dilution, confirming that higher concentrations of the bioactive compounds enhance effectiveness [25]. Importantly, the extracts displayed broad-spectrum activity by inhibiting both Gram-positive and Gram-negative bacteria (e.g., *Bacillus cereus*, *Escherichia coli*, *Salmonella typhi*, and *Pseudomonas aeruginosa*) as well as pathogenic fungi such as *Candida albicans* and *Aspergillus niger* [21,25]. Despite this broad antimicrobial profile, the potency of the crude extracts was lower than that of the standard drugs used as positive controls (gentamycin for bacteria and tioconazole for fungi). For instance, while the extracts produced inhibition zones in the range of 18–26 mm at the highest concentration, the standard antibiotics yielded much larger zones (38–40 mm for bacteria and 28–30 mm for fungi). Nevertheless, the significant activity of the oils, especially from the leaves, highlights their potential as sources of natural antimicrobial agents. These findings align with previous reports linking antimicrobial efficacy in *Dioscorea* species and other medicinal plants to terpenoids, phenolic compounds, and ketones identified in their essential oils [21,23,26,29].

The antibacterial efficacy of the essential oils can be attributed to the disruption of microbial membranes and increased permeability, leading to leakage of cellular components and inhibition of enzymatic activity. This activity is primarily linked to oxygenated monoterpenes such as 1,8-cineole and α-terpineol. Similarly, antioxidant potential may arise from the ability of phenolic and terpenoid constituents to scavenge free radicals and stabilize reactive oxygen species (ROS) by donating hydrogen atoms [30].

4.3 Discussion of FRAP Result for the Leaf and Stem Extracts of Dioscorea dumetorum

Both the leaf and stem extracts of *Dioscorea dumetorum* demonstrated ferric reducing antioxidant power, confirming the presence of bioactive compounds capable of

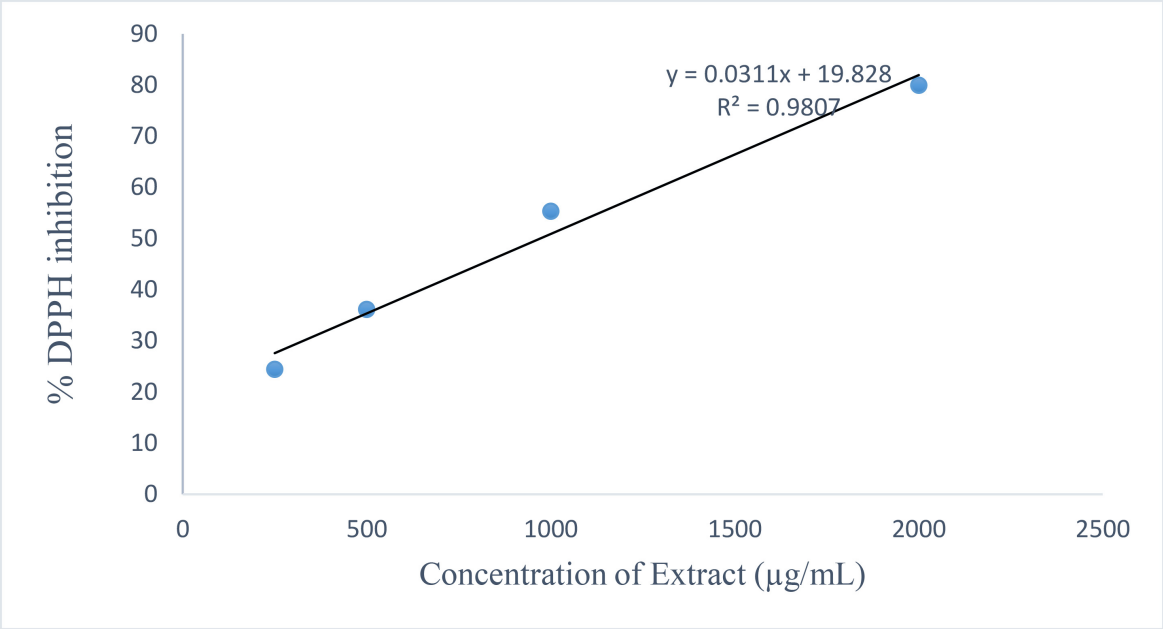

Fig. 7. DPPH radical scavenging activity of the ascorbic acid standard. Showing % DPPH inhibition (Y-axis) against Concentration of Extract (µg/mL) (X-axis). Data represent mean ± SD (n = 3). The graph presents the percentage inhibition of DPPH radicals at different concentrations of ascorbic acid, used as the reference antioxidant standard. The calculated half-maximal inhibitory concentration (IC_{50}) was approximately 156.15 µg/mL, confirming the high free-radical scavenging efficiency of ascorbic acid.

Table 12. Comparison of IC_{50} values.

Sample	IC_{50} (µg/mL)	Antioxidant potency (Lower = Stronger)
Standard Ascorbic Acid	156.15	Very strong
Dioscorea dumetorum Stem Essential Oil	224.11	Moderate
Dioscorea dumetorum Leaf Essential Oil	1288.52	Weak

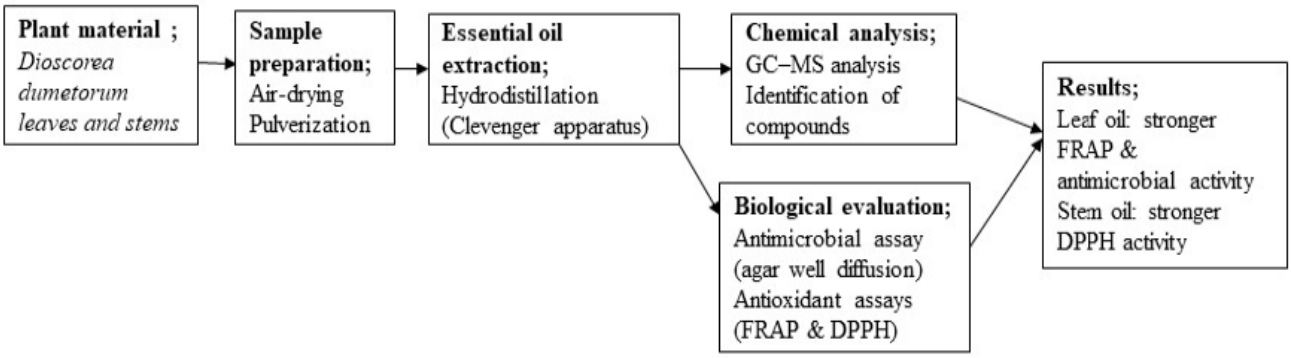

Fig. 8. Schematic representation of the experimental workflow for the extraction, chemical characterization, and biological evaluation of *Dioscorea dumetorum* leaf and stem essential oils. The diagram summarizes sample preparation, hydrodistillation extraction, GC-MS analysis, antimicrobial screening, and antioxidant assays (FRAP and DPPH).

donating electrons to reduce Fe^{3+} to Fe^{2+} and thereby neutralize free radicals [27]. The antioxidant activity increased proportionally with concentration across all tested concentrations, reflecting a clear concentration–response relationship. However, the leaf extract consistently exhibited higher FRAP values than the stem extract at every concentration tested. This suggests that the leaves contain a greater abundance of antioxidant phytochemicals, likely including phenolics and flavonoids, which are well-established contributors to redox activity [24,27]. In contrast, the stem exhibited moderate but lower reducing capacity, which may be attributed to its primarily structural role and reduced metabolic activity. These findings are consistent with previous studies on other medicinal plants,

where leaves typically display stronger antioxidant activity due to higher levels of photosynthetically derived secondary metabolites [26,27]. The results therefore highlight *Dioscorea dumetorum* leaves as a richer source of natural antioxidants with potential applications in functional foods, nutraceuticals, and pharmaceutical formulations targeted at managing oxidative stress [24].

4.4 Discussion of DPPH Result for the Leaf and Stem Extracts of Dioscorea dumetorum

The results clearly show that both the leaf and stem essential oils of *Dioscorea dumetorum* possess free radical–scavenging capacity as measured by the DPPH assay [26]. The activity was concentration dependent, with higher concentrations producing stronger radical-scavenging effects. Between the two plant parts, the stem extract exhibited greater potency (IC_{50} = 224.11 µg/mL) than the leaf extract (IC_{50} = 1288.52 µg/mL), despite the leaf showing slightly higher percentage inhibition at individual concentrations (e.g., 41.26% at 4000 µg/mL for leaf vs. 30.50% for stem). This indicates that the stem oil requires much lower concentrations to reach 50% inhibition, making it more effective overall. When compared to the ascorbic acid standard (IC_{50} = 156.15 µg/mL), both extracts demonstrated significantly lower antioxidant activity, confirming that while *Dioscorea dumetorum* has notable free radical–scavenging potential, it is less potent than pure ascorbic acid [31]. These findings are consistent with reports on other medicinal plants, where crude extracts typically show moderate antioxidant capacity compared to pure standards but still contribute significantly to overall antioxidant potential [27,31]. The observed activity likely reflects the presence of secondary metabolites such as phenolic compounds and flavonoids, which are known for their radical-scavenging properties [24,26,27]. Thus, *Dioscorea dumetorum* extracts, particularly the stem, may serve as a source of natural antioxidants with potential applications in nutraceuticals, functional foods, and phytomedicine aimed at combating oxidative stress [24,27].

The observed differences between FRAP and DPPH results highlight the assay-dependent nature of antioxidant evaluation. While FRAP measures electron-donating ability, DPPH assesses free radical scavenging efficiency. Therefore, the higher FRAP activity of the leaf oil and the stronger DPPH activity of the stem oil reflect differences in their phytochemical composition and antioxidant mechanisms rather than contradiction [32].

5. Limitations

This study has several limitations. First, the antimicrobial and antioxidant activities were evaluated using in vitro assays only, which may not fully reflect in vivo biological effects. Second, the identification of compounds by GC-MS was based on spectral library matching, and further confirmation using advanced analytical techniques such as NMR is recommended. Third, the potential contamination of certain compounds such as di-n-octyl phthalate cannot be completely ruled out. Additionally, the study did not investigate the toxicity or safety profile of the essential oils. Future studies should include in vivo evaluations, toxicity assessments, and isolation of individual bioactive compounds.

6. Conclusion

This study successfully investigated the essential oils of *Dioscorea dumetorum* leaves and stems with respect to their yield, chemical composition, antimicrobial properties, and antioxidant potential. The oils were pale yellow with characteristic aromatic odor, and their yields, though relatively low (0.50% for leaves and 1.07% for stems), and are consistent with reports that *Dioscorea* species generally accumulate more starch than volatile oils.

Gas Chromatography–Mass Spectrometry (GC-MS) revealed a diverse array of bioactive constituents: 23 compounds in the leaf oil and 20 compounds in the stem oil. Leaf oil was rich in phytol (16.74%) and oxygenated ketones such as 2-pentadecanone (20.64%), both linked with strong antioxidant properties. Stem oil was dominated by di-*n*-octyl phthalate (34.43%) and long chain fatty acid esters, compounds associated with antimicrobial and emollient activities.

Biological assays confirmed that both oils possess broad-spectrum antimicrobial activity, inhibiting Gram-positive and Gram-negative bacteria as well as pathogenic fungi. However, the leaf extracts consistently produced larger inhibition zones than the stem extracts, though both were less potent compared to standard antibiotics and antifungal agents. In antioxidant assays, both oils demonstrated concentration-dependent activity. The leaf oil exhibited stronger ferric reducing power, while the stem oil showed higher radical scavenging potency (IC_{50} = 224.11 µg/mL) than the leaf oil (IC_{50} = 1288.52 µg/mL), but both were weaker than ascorbic acid (IC_{50} = 156.15 µg/mL).

Leaf oil has higher FRAP, indicating stronger reducing power, but stem oil has lower IC_{50} in DPPH, meaning stronger radical scavenging. These differences are due to the specific mechanisms of each assay.

Overall, the results provided scientific evidence that *Dioscorea dumetorum* contains bioactive compounds with both antimicrobial and antioxidant activities. The leaves appear more promising as a source of antioxidant agents, while the stems show better antimicrobial and radical scavenging potential. These findings support the ethnomedicinal use of *Dioscorea dumetorum* and highlight its relevance for further development in nutraceutical, pharmaceutical, and cosmetic applications.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

GO: Conceptualization, Methodology, Supervision, Investigation, Data analysis, Writing-original draft, Supervision. AB: Laboratory investigation, Practical, Result analysis, Conceptualization, Methodology. Both authors contributed to editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The plant *Dioscorea dumetorum* used in this study was collected from Fiditi, Oyo State, Nigeria, with the consent of the landowner. The collection was carried out in accordance with local regulations and recognized ethical guidelines for the collection of plant materials.

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Conflicts of Interest

Given her role as the Editorial Board member, Ganiyat K. Oloyede had no involvement in the peer-review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to Mehmet Ozaslan.

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