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Phytochemical and GC–MS Characterisation of *Polyscias fruticosa* Leaf Essential Oil and Its Antimicrobial Activity Against Selected Pathogens

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Abstract

The growing threat of antimicrobial resistance has reinvigorated the search for bioactive compounds of natural origin, particularly from medicinal plants. *Polyscias fruticosa* (L.) Harms (Araliaceae), a shrub long valued in ethnomedicine, was selected for investigation to establish a preliminary phytochemical, gas chromatography–mass spectrometry (GC–MS), and antimicrobial profile of its leaf essential oil. Authenticated leaves (voucher deposited) underwent qualitative phytochemical screening of the aqueous extract, while the volatile fraction was obtained by hydrodistillation and characterised by GC–MS, with tentative identifications based on mass spectral library matching. Antimicrobial activity was assessed in triplicate by agar well diffusion and minimum inhibitory concentration (MIC) assays against eight bacterial and three fungal pathogens, using ciprofloxacin and fluconazole as positive controls. The aqueous extract contained alkaloids, flavonoids, saponins, tannins, phenolics, glycosides, phytosterols, terpenoids, reducing sugars, and proteins, but no anthraquinones. GC–MS resolved twenty-three constituents, tentatively dominated by capsaicin (28.91%), zingerone (22.35%), and γ-sitosterol (13.10%), alongside oleic, linoleic, and palmitic acids and the sesquiterpene alcohol farnesol; these assignments warrant confirmation by retention index matching and authentic standards. The oil exhibited concentration-dependent inhibition zones of 10–20 mm across 5–40 mg mL^{-1}, with the strongest activity against *Escherichia coli*, *Salmonella typhi*, and *Trichophyton rubrum* (20 mm at 40 mg mL^{-1}), and MIC values of ≥40 mg mL^{-1} in nine of eleven isolates. These findings support aspects of the plant's ethnomedicinal use and

identify it as a candidate matrix warranting further pharmaceutical and nutraceutical investigation.

Keywords: *Polyscias fruticosa,* Essential Oil, GC–MS, Capsaicin, Zingerone, Antimicrobial Activity, Medicinal Plants.

Introduction

Infectious diseases and the global spread of antimicrobial resistance (AMR) remain among the most pressing public-health challenges of the twenty-first century. As the pipeline for new antibiotics has stalled, the rapid emergence of multidrug-resistant (MDR) bacterial and fungal strains has intensified the search for structurally diverse natural-product scaffolds. Plant-derived essential oils are especially attractive in this context: as chemically complex mixtures dominated by terpenoids and phenylpropanoids, their concurrent engagement of multiple microbial targets reduces the selective pressure that drives resistance in single-target synthetic drugs (Yu, 2025; Pandey & Singh, 2022).

Essential oils are volatile secondary metabolites synthesised and stored in glandular trichomes, secretory cavities, and osmophores (Selvaraj et al., 2023). Their composition, yield, and bioactivity are shaped by a web of abiotic factors (climate, soil, altitude), biotic interactions (herbivory, microbial colonisation), developmental stage, post-harvest handling, and the choice of extraction method (Cuenca-Leon et al., 2025; Śliwińska & Tomiczak, 2025). Accurate chemical profiling by gas chromatography–mass spectrometry (GC–MS) has therefore become indispensable for validating the therapeutic claims of ethnomedicinal plants and for ensuring reproducibility and safety in the standardisation of their extracts (Cagliero et al., 2022).

Polyscias fruticosa (L.) Harms (Araliaceae), commonly known as Ming aralia, is a perennial shrub native to tropical Asia and the Pacific Islands and widely cultivated as both an ornamental and a medicinal species. In traditional medicine, the leaves and roots are used to treat fever, inflammation, digestive complaints, and general debility (Rarison et al., 2023). Earlier phytochemical investigations have documented triterpenoid saponins, flavonoids, phenolic acids, and sterols in various plant parts, together with antioxidant, neuroprotective, anti-inflammatory, and hypoglycaemic activities (Rarison et al., 2023; Ly et al., 2022). More recent work has shown that ethanolic extracts protect neuronal cells from glutamate-induced cytotoxicity and delay dopaminergic neuron degeneration in *Drosophila melanogaster* models of Parkinson's disease (Ly et al., 2022; Do et al., 2021).

Despite this growing pharmacological interest, detailed GC–MS profiles of the leaf essential oil of *P. fruticosa* remain scarce, and systematic antimicrobial evaluation against a broad panel of Gram-positive, Gram-negative, yeast, and dermatophyte pathogens has not been reported for the

Nigerian chemotype. Closely related species and neighbouring West African medicinal plants are known to yield essential oils rich in sesquiterpenes such as β-caryophyllene and germacrene D, with appreciable antibacterial and antioxidant effects (Gonçalves & Romano, 2024; Ogwuche et al., 2025). This precedent suggests that *P. fruticosa* leaves may represent a similarly valuable, yet under-exploited, source of bioactive volatiles.

The Effurun area of Delta State lies within the humid tropical rainforest zone of southern Nigeria, characterised by high annual rainfall (≈2,500–3,000 mm), year-round elevated relative humidity (commonly 75–95%), mean ambient temperatures of 24–32 °C, and predominantly hydromorphic, alluvial soils of high organic-matter content typical of the Niger Delta. Such warm, humid conditions, combined with the elevated microbial and herbivore pressure and the localised hydrocarbon and heavy-metal load reported for soils in this petroleum-producing region, are known to elicit oxidative and biotic stress responses in plants and to remodel secondary-metabolite biosynthesis, particularly the methoxyphenol and phytosterol pathways (Śliwińska & Tomiczak, 2025). These edaphic and climatic factors plausibly contribute to the distinctive chemotype of *P. fruticosa* documented in the present study.

The present study was therefore designed to (i) qualitatively screen the aqueous leaf extract of *P. fruticosa* for the principal classes of secondary metabolites, (ii) characterise the chemical profile of its hydrodistilled leaf essential oil by GC–MS, and (iii) evaluate its antimicrobial activity and minimum inhibitory concentration (MIC) against a panel of clinically relevant bacteria and fungi. Together, these objectives provide a chemical and microbiological rationale for the ethnomedicinal use of the species and identify candidate constituents for future mechanistic and *in vivo* investigations.

Materials and Methods

Plant Material and Authentication

Fresh, healthy leaves of *Polyscias fruticosa* (L.) Harms were collected from mature plants in Effurun, Delta State, Nigeria. The plant was authenticated by a qualified botanist at the Department of Botany, Faculty of Life Sciences, Ahmadu Bello University (ABU), Zaria, Nigeria, and a voucher specimen was deposited in the departmental herbarium (Voucher No. ABUH0931). Leaves were rinsed thoroughly with distilled water, blotted dry, cut into small pieces, and processed immediately to preserve the integrity of the volatile fraction.

Chemicals and Reagents

All solvents and reagents, methanol, n-hexane, anhydrous sodium sulphate, concentrated sulphuric acid, hydrochloric acid, ferric chloride, Mayer's reagent, Biuret reagent, and sodium nitroprusside, were of analytical grade. Mueller–Hinton agar, Sabouraud dextrose agar, ciprofloxacin (5 μg mL^{-1}), and fluconazole (10 μg mL^{-1}) were used in the antimicrobial assays.

Preparation of Aqueous Extract and Phytochemical Screening

Air-dried and pulverised leaves (100 g) were refluxed in distilled water for approximately 4h in a round-bottom flask fitted with a condenser. The filtrate was concentrated at 70 °C to yield the crude aqueous extract. Standard qualitative procedures were then applied to screen for alkaloids (Mayer's test), flavonoids (alkaline/lead acetate test), saponins (frothing test), tannins (Gold Beater's skin test), phenolics (ferric chloride test), glycosides (Keller–Kiliani test), phytosterols (Liebermann–Burchard-type reaction), terpenoids (Salkowski's test), anthraquinones (nitric acid test), reducing sugars (Tollens'/Benedict's reagent), and proteins (Biuret test), following well-established procedures (Ndukwe et al., 2020; Clark et al., 2023; Ogwuche & Pere, 2024; Clark et al., 2026).

Essential Oil Extraction

The essential oil was recovered from fresh *P. fruticosa* leaves by hydrodistillation. Approximately 250 g of comminuted plant material and 500 mL of distilled water were transferred to a round-bottom flask mounted on a heating mantle, and the condenser, filter, and separation tube were pre-rinsed with *n*-hexane. Distillation was carried out for 4 h, after which the distillate was partitioned between aqueous and *n*-hexane phases. The oil layer was collected, dried over anhydrous Na_2SO_4, and stored in amber vials at 4 °C until analysis.

GC–MS Analysis

Chemical profiling was performed on an Agilent 7890 gas chromatograph coupled to a 5977B mass-selective detector and fitted with an HP-5MS capillary column (30 m × 0.25 mm i.d., 0.25 µm film thickness). Helium (≥99.999% purity) served as the carrier gas at a constant flow of 1.0 mL min^{-1}, with the injector maintained at 250 °C. The oven programme began at 60 °C (held 2 min), ramped to 150 °C at 5 °C min^{-1}, then to 280 °C at 10 °C min^{-1}, and was held at 280 °C for 10 min. Mass spectra were acquired in electron-ionisation (EI) mode at 70 eV over an m/z range of 40–550. Compounds were tentatively identified by matching their mass spectra against the NIST reference library, and relative abundances were calculated from peak areas in the total ion chromatogram (Ogwuche & Edema, 2020). Because authentic reference standards and Kováts retention-index confirmation were not available, all assignments should be considered tentative and interpreted with caution.

Antimicrobial Assay

The antimicrobial activity of the essential oil was evaluated by the agar well diffusion method against eight bacterial strains, *Bacillus cereus*, *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Staphylococcus saprophyticus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella typhi*, and *Pseudomonas aeruginosa*, and three fungal strains, *Candida albicans*, *Chrysosporium merdarium*, and *Trichophyton rubrum*. Mueller–Hinton agar (bacteria) and Sabouraud dextrose agar (fungi) plates were inoculated with 0.1 mL of standardised microbial suspension (≈1.0×10^6 CFU mL^{-1}). Wells of 6 mm diameter were cut with a sterile cork-borer

and filled with 100 µL of the oil at 40, 20, 10, and 5 mg mL^{-1}. Ciprofloxacin (5 µg mL^{-1}) and fluconazole (10 µg mL^{-1}) served as positive controls for bacteria and fungi, respectively. Plates were incubated at 37 °C for 24 h (bacteria) or 28 °C for 48 h (fungi), and zones of inhibition were measured in millimetres. All assays were performed in triplicate, and values are reported as means.

Minimum Inhibitory Concentration (MIC)

MIC values were determined by the broth dilution method. Two-fold serial dilutions of the oil were prepared, inoculated with the standardised microbial suspensions, and incubated under the conditions described above. The MIC was defined as the lowest concentration at which no visible microbial growth was observed.

Statistical Analysis

All antimicrobial measurements were carried out in triplicate and are presented as mean values. Concentration–response trends were evaluated by inspection of inhibition-zone increases with dose.

Results

Phytochemical Composition of the Aqueous Leaf Extract

The aqueous extract of *P. fruticosa* leaves was a dark-green liquid. Qualitative screening (Table 1) revealed the presence of alkaloids, flavonoids, saponins, tannins, phenolics, glycosides, phytosterols, terpenoids, reducing sugars, and proteins; anthraquinones alone were not detected.

Table 1: Qualitative phytochemical screening of the aqueous leaf extract of *Polyscias fruticosa*.

Phytochemical class	Result
Alkaloids	+
Flavonoids	+
Saponins	+
Tannins	+
Phenolics (total)	+
Glycosides	+
Sterols / Phytosterols	+
Terpenoids	+
Anthraquinones	−
Reducing sugars	+
Proteins	+

Key: (+) detected; (−) not detected.

GC–MS Profile of the Essential Oil

GC–MS analysis resolved twenty-three constituents that together accounted for 100% of the total ion chromatogram (Table 2 and Figure 1). The profile was dominated by capsaicin (28.91%), zingerone (22.35%), and γ-sitosterol (13.10%), followed by oleic acid (7.26%) and palmitic acid (5.19%). All assignments are tentative and were based on NIST library matching of EI mass spectra alone; they were not corroborated by authentic standards or retention-index matching. Accordingly, the reported composition should be interpreted cautiously, particularly for higher-molecular-weight and low-volatility constituents.

Table 2: GC–MS peak report of the essential oil of *Polyscias fruticosa* leaves

Peak	Rt (min)	Compound	Area (%)
1	3.601	Cumene	0.33
2	15.159	Octacosane	0.37
3	15.630	Farnesane	0.59
4	16.292	Myristic acid	0.99
5	16.509	Ledol	0.63
6	16.677	1-Nonadecene	3.43
7	17.047	Isopropyl myristate	1.00
8	18.565	Palmitic acid, methyl ester	1.71
9	19.106	Palmitic acid	5.19
10	19.981	Farnesol	3.55
11	20.827	Linoleic acid, methyl ester	2.06
12	20.905	Linoleoyl chloride	1.55
13	21.307	Linoleic acid	1.57
14	21.379	Oleic acid	7.26
15	23.191	Carvomenthol	0.53
16	23.856	Stearic acid, hexyl ester	0.52
17	24.185	Eucalyptol	0.49
18	24.758	Resorcinol, 2-acetyl-	1.56
19	25.060	Carvomenthol (isomer)	0.44
20	25.355	Stigmasterol	1.86
21	25.468	Capsaicin	28.91
22	25.677	Zingerone	22.35
23	26.754	γ-Sitosterol	13.10
		Total identified	100.00

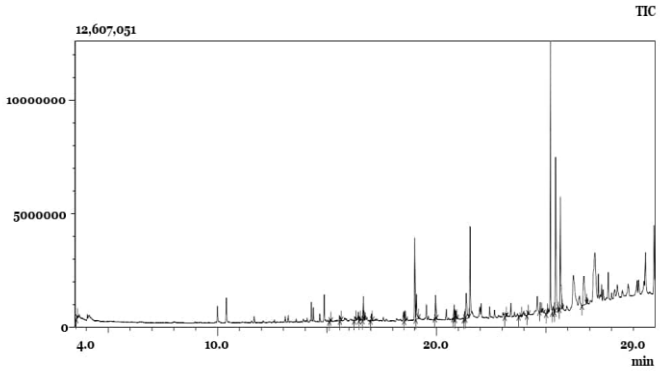


Figure 1: GC–MS chromatogram of the essential oil extracted from *Polyscias fruticosa* leaves

Antimicrobial Activity

Zones of inhibition (Table 3) confirmed that the essential oil was active against all eleven test organisms in a concentration-dependent manner. Inhibition zones ranged from 10 to 20 mm across the 5–40 mg mL^{-1} range, compared with 24–32 mm produced by the reference antibiotics. The strongest activity (20 mm at 40 mg mL^{-1}) was recorded against *E. coli*, *S. typhi*, and *T. rubrum*. Gram-positive bacteria (*B. cereus*, *S. aureus*, *S. pneumoniae*, *S. saprophyticus*) were inhibited with zones of 17–19 mm at 40 mg mL^{-1}, and the Gram-negative isolates (*E. coli*, *K. pneumoniae*, *S. typhi*, *P. aeruginosa*) produced 17–20 mm zones at the same concentration.

Table 3: Zones of inhibition (mm) produced by the essential oil of *Polyscias fruticosa* against test pathogens

Test pathogen	40	20	10	5	Control (Cipro/Fluc)
B. cereus	18	15	13	11	26
S. aureus	17	15	13	10	32
S. pneumoniae	18	15	13	11	25
S. saprophyticus	19	18	14	11	29
E. coli	20	17	14	10	26
K. pneumoniae	19	15	14	12	29
S. typhi	20	18	14	11	30
P. aeruginosa	17	14	13	10	28
C. albicans	19	17	15	13	26
C. merdarium	19	16	13	10	24
T. rubrum	20	18	15	12	27

Key: Ciprofloxacin (5 µg mL^{-1}) served as the positive control for bacteria and fluconazole (10 µg mL^{-1}) for fungi

Minimum Inhibitory Concentration

MIC values are summarised in Table 4. The essential oil inhibited all eight bacterial isolates and *C. albicans* at 40 mg mL^{-1}, whereas *C. merdarium* and *T. rubrum* yielded no detectable MIC within the range tested (ND).

Table 4: Minimum inhibitory concentration (MIC) of the essential oil of *Polyscias fruticosa* against the test organisms.

Test pathogen	MIC (mg mL^{-1})
B. cereus	40
S. aureus	40
S. pneumoniae	40
S. saprophyticus	40
E. coli	40
K. pneumoniae	40
S. typhi	40
P. aeruginosa	40
C. albicans	40
C. merdarium	ND
T. rubrum	ND

Key: ND = not detected at the concentrations tested.

Discussion

Phytochemical Diversity and Therapeutic Implications

The breadth of secondary-metabolite classes detected in the aqueous leaf extract of *P. fruticosa* is consistent with its long-standing ethnomedicinal use and parallels earlier reports for this species and other members of the Araliaceae (Rarison et al., 2023; Ogwuche & Edema, 2020). The alkaloids observed here plausibly underpin the plant's traditional deployment against pain and infection, given the well-documented analgesic, antimalarial, antimicrobial, and neuroprotective activities of plant alkaloids (Aryal et al., 2022). The co-occurrence of flavonoids and phenolics is itself a reliable predictor of antioxidant and anti-inflammatory capacity in leafy medicinal plants, reflecting their capacity to scavenge free radicals and modulate redox-sensitive signalling pathways (Zhang et al., 2011).

Saponins contribute amphiphilic, membrane-perturbing activity alongside cholesterol-lowering and immunomodulatory effects (Timilsena et al., 2023), while tannins confer astringent, wound-healing, and antimicrobial properties through protein precipitation (Murugesu et al., 2021). The Keller–Kiliani-positive response indicates the presence of cardiac glycosides, which, together with the detected phytosterols, carry potential cardiovascular relevance; phytosterols, in particular, compete with dietary cholesterol for micellar incorporation and can thereby lower serum LDL (Shen et al., 2024). Terpenoids, identified qualitatively here and confirmed by GC–MS (Section 3.2), are central to the antimicrobial action of many plant oils (Masyita et al., 2022). The absence of anthraquinones suggests that

stimulant-laxative mechanisms are unlikely to feature prominently in this extract's pharmacology. Taken together, the metabolite profile aligns with antimicrobial, antioxidant, anti-inflammatory, and cardioprotective applications.

GC–MS Profile: Dominance of Capsaicin, Zingerone, and γ-Sitosterol

A striking feature of the GC–MS chromatogram is the predominance of capsaicin (28.91%), zingerone (22.35%), and γ-sitosterol (13.10%). Although capsaicin and zingerone are most commonly associated with *Capsicum* and *Zingiber*, respectively, their occurrence in other plant matrices has been reported and may reflect chemotype-specific methoxyphenol biosynthesis shaped by local environmental factors. Both constituents are established antibacterial agents: capsaicin disrupts bacterial membrane integrity, modulates virulence determinants such as toxin release and biofilm formation, and can potentiate several conventional antibiotics, which together account for its broad antibacterial spectrum (Füchtbauer et al., 2021). Zingerone, in turn, exhibits antibiofilm activity, suppresses bacterial motility, and has been shown to enhance antibiotic efficacy against methicillin-resistant *Staphylococcus aureus* (Kharga et al., 2023). γ-Sitosterol, together with the related stigmasterol (1.86%), contributes membrane-perturbing and anti-inflammatory effects and has been reported to act additively with co-occurring phenolic antimicrobials in plant matrices (Barber et al., 2020).

Long-chain fatty acids further enrich the antimicrobial potential of the oil. Oleic acid (7.26%) and linoleic acid, together with its methyl ester (~3.6% combined), are well-established inhibitors of bacterial fatty-acid biosynthesis, targeting enzymes such as FabI, as well as of membrane-associated virulence (Borreby et al., 2023; Desbois & Smith, 2010). Palmitic acid (5.19%), though less potent in isolation, is thought to act synergistically with unsaturated fatty acids and phenolics to amplify membrane permeabilisation. Farnesol (3.55%), a quorum-sensing molecule in *Candida albicans*, is a recognised antifungal and antibiofilm agent (Polke et al., 2018), consistent with the marked activity observed here against *C. albicans* and the dermatophyte isolates. Minor constituents such as eucalyptol and ledol, although each present at <1%, have documented antimicrobial activity and may contribute through additive or penetration-enhancing effects (Ibrahim et al., 2020).

Concentration-Dependent Antimicrobial Activity

The inhibition data (Table 3) reveal a clear dose–response relationship, with zones increasing monotonically from 5 to 40 mg mL^{-1}. Gram-positive and Gram-negative bacteria displayed broadly comparable susceptibility across the concentration range tested, although the most pronounced inhibition at 40 mg mL^{-1} (20 mm) was observed against the Gram-negative isolates *E. coli* and *S. typhi*. This is notable, as the outer-membrane permeability barrier and lipopolysaccharide layer of Gram-negative bacteria typically attenuate the activity of lipophilic antimicrobials (Fisher & Mobashery, 2018). Against the fungal panel, activity was strongest towards *T. rubrum* (20 mm at 40 mg mL^{-1}), followed by *C. albicans* and *C.*

merdarium. The pronounced antidermatophytic action is consistent with the known effects of farnesol, γ-sitosterol, and the fatty-acid pool on fungal membrane sterol metabolism (Barber et al., 2020; Polke et al., 2018).

The MIC values (Table 4) of 40 mg mL^{-1} for nine of the eleven isolates indicate a uniform inhibitory threshold for the crude oil, in line with previously reported essential oil preparations of comparable chemistry (Chouhan et al., 2017). The failure to detect an MIC against *C. merdarium* and *T. rubrum* within the tested range, despite unambiguous diffusion-zone inhibition, most likely reflects the limited aqueous dispersion of the lipophilic constituents in broth medium.

The relatively elevated MIC of 40 mg mL^{-1} warrants scrutiny, as values in this range are weak for a crude essential oil and do not, by themselves, support a strong therapeutic claim. This threshold is unlikely to reflect only the intrinsic chemistry of the oil, since several constituents identified here, including capsaicin, zingerone, farnesol, oleic and linoleic acids, and eucalyptol, have been reported to inhibit the same organisms at lower concentrations when tested individually (Füchtbauer et al., 2021; Borreby et al., 2023; Ibrahim et al., 2020). A more plausible explanation is methodological: broth dilution is poorly suited to highly lipophilic, water-immiscible matrices, which may coalesce at the air–liquid interface and lose volatile constituents during incubation. The clearer dose-dependent inhibition seen in agar diffusion is consistent with this limitation. Future work should therefore use emulsifiers or nanoemulsion-based delivery systems, together with sealed broth microdilution plates, to better estimate intrinsic potency (Hasheminejad et al., 2019).

Mechanistic Interpretation and Synergy

The observed antimicrobial profile is unlikely to arise from any single constituent; it is better understood as the net outcome of several parallel mechanisms operating in concert: (i) membrane destabilisation and permeabilisation driven by capsaicin, zingerone, γ-sitosterol, stigmasterol, and the fatty-acid pool; (ii) inhibition of key bacterial biosynthetic enzymes, notably FabI and FabH by unsaturated fatty acids; (iii) interference with quorum sensing and biofilm formation by farnesol and zingerone; and (iv) adjunct contributions from minor monoterpenes such as eucalyptol, which can enhance membrane penetration of co-occurring phenolics (Masyita et al., 2022; Füchtbauer et al., 2021; Polke et al., 2018; Ibrahim et al., 2020). This multi-target architecture is therapeutically attractive because it lowers the probability of rapid resistance acquisition, the principal limitation of single-target synthetic antibiotics.

Comparison with the Literature and Novelty

Earlier reports on *P. fruticosa* have tended to emphasise its triterpenoid saponin content and the neuroprotective activity of ethanolic extracts (Do et al., 2021; Ly et al., 2022), while studies of its essential oil from other geographical chemotypes have described largely sesquiterpene-dominated profiles (Gonçalves & Romano, 2024). By contrast, the present data

reveal a chemotype dominated by phenolic methoxy-compounds (capsaicin, zingerone) together with phytosterols and fatty acids, a profile not previously highlighted for this species and one plausibly driven by local soil, climatic, and developmental factors (Śliwińska & Tomiczak, 2025). Comparable ecological variability has been documented within related aromatic species, where thymol/carvacrol ratios shift with environmental conditions (Etri & Pluhár, 2024; Rowshan et al., 2013), underscoring the need for regional chemical fingerprinting of medicinal plants prior to any attempt at standardisation.

These findings are consistent with, and extend, recent work demonstrating the antimicrobial and antioxidant value of essential oils from related West African medicinal species (Ogwuche et al., 2025). To the authors' knowledge, this is the first integrated phytochemical, GC–MS, and broad-panel antimicrobial dataset reported for the Nigerian leaf chemotype of *P. fruticosa*.

Conclusions

The aqueous leaf extract of *P. fruticosa* contains a broad spectrum of pharmacologically relevant secondary metabolites, and the hydrodistilled essential oil is tentatively dominated by capsaicin, zingerone, and γ-sitosterol, together with biologically important fatty acids and a sesquiterpene alcohol, pending confirmation by retention-index matching and authentic reference standards. The oil exerts concentration-dependent antimicrobial activity against Gram-positive, Gram-negative, yeast, and dermatophyte pathogens, with MIC values of 40 mg mL^{-1} for most isolates; these MIC values are modest and likely reflect, in part, the poor aqueous dispersion of the lipophilic oil, an issue that future work should address through emulsified or nanoformulated delivery. These results furnish the first integrated phytochemical and antimicrobial fingerprint for the Nigerian chemotype of the species, corroborate its ethnomedicinal use, and identify it as a promising lead matrix for development as a natural antimicrobial in pharmaceutical, cosmetic, and food-preservation applications. Further bioactivity-guided fractionation, mechanistic work, and *in vivo* evaluation are warranted.

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