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Bioactive Constituents and Pharmacological Activities of Syzygium occidentale: Insights into an Underexplored Western Ghats Species

[1]Snehalatha V R, PG and Research Department of Botany, Govt. Victoria College, Palakkad, Kerala, India- 678001, Affiliated to University of Calicut.

[2]Rasmi A.R., PG and Research Department of Botany, Govt. Victoria College, Palakkad, Kerala, India- 678001, Affiliated to University of Calicut.

Corresponding Author: Snehalatha V R, PG and Research Department of Botany, Govt. Victoria College, Palakkad, Kerala, India- 678001, Affiliated to University of Calicut.

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Abstract

Introduction: Plants are a major source of medicine and have a significant impact on global health because of their medicinal properties, plants in the genus Syzygium, are used in the traditional medicinal systems of several Asian countries. Native to the Western Ghats, the Syzygium occidentale (Bourd.) Gandhi (Myrtaceae) is a beautiful little riparian tree that flourishes along the banks of shallow streams. Present study was conducted with the aim to evaluate the bioactive compounds and their pharmacological relevance present in Syzygium occidentale.

Results: The phytochemical and nutritional analysis of S. occidentale shows that leaves are rich in vitamin C (198±1.23 mg/100 g), vitamin A (0.06±0.004 mg/100 g), manganese (10.94±1.005 mg/100 g), and crude fibre (20.12±1.01 %), while bark contains higher levels of calcium (2.10±0.005 %), alcohol-soluble extractives (17.21±1.02 %), and total ash (8.14±0.002 %). Leaf powders exhibited greenish, bluish, and yellowish fluorescence, whereas bark powders predominantly showed brownish to dark shades. GC-MS analysis showed leaves were rich in amphiphilic phenolic lipid like cyclogallipharaol and 3-pentadecylphenol with peak area 46.67% and 42.72% respectively, while bark predominantly contained fatty acid methyl ester mainly methyl palmitate (32.16%) and methyl octadec-10-enoate (26.45%) along with minor aromatic compounds. Leaves demonstrated greater DPPH activity (154.24 ± 1.10) and higher FRAP values (48 ± 1.20), indicating stronger reducing power. The anthelmintic activity of S. occidentale methanol extracts against Lumbricus

terrestris showed a dose-dependent effect. The antimicrobial assay of S. occidentale methanol extracts also showed moderate antifungal and antibacterial activity in a dose-dependent manner.

Conclusion: In order to bridge the gaps between traditional knowledge it is useful to examine this species for its bioactive chemicals and biological activity. This work provides a new information, integrating many biological tests with in-depth chemical profiling, showing S. occidentale as a potential natural source of anthelmintic, antibacterial, and antioxidant compounds.

Keywords: Antibacterial, Anthelmintic, Antioxidant, Bioactive Compounds, Syzygium.

Introduction

Syzygium is a genus which belong to the Myrtaceae family and comprised of 1200-1800 species. The ancient medical systems in various Asian nations, including China, India, and Bangladesh, also utilize plants from this genus (Uddin et al., 2022). Numerous plant species have been shown to possess pharmacological properties that may be related to their phytoconstituents, including terpenes, alkaloids, tannins, glycosides, saponins, flavonoids, steroids etc. (El-Saber Batiha et al., 2020). Flavonoids, terpenoids, tannins, glycosides, and phenolics are among the phytochemical ingredients that are abundant in the various parts of each Syzygium species, including the leaves, bark, seeds, stem bark, fruits, and flower buds (Aung et al., 2020). The species Syzygium occidentale (Bourd.) Gandhi (Myrtaceae) is native to the Western Ghats (Varghese & Sreekala 2017; Varghese et al., 2023). S. occidentale represents a gorgeous small riparian species of tree that grows along the shores of shallow streams. According to the IUCN Red List, the species is vulnerable (Varghese et al., 2023).

There remains a widespread acceptance of Ayurvedic medicine in India, where an estimated 85% of people still treat a wide range of illness and diseases with pure plant remedies (Cock & Cheesman, 2018). It has proved that herbal remedies are a valuable source for finding novel pharmaceutical compounds that can be applied to the treatment of serious medical conditions (El-Saber Batiha et al., 2020). Several Syzygium species have been reported to exhibit a wide range of pharmacological properties, including antioxidant, anti-inflammatory, antimicrobial, antidiabetic, cardioprotective, central nervous system (CNS) modulatory, chemopreventive, antiallergic, antitumor, and hepatoprotective activities, which may contribute to potential health benefits and improved metabolic functions when consumed (Chagas et al., 2015; Singh et al., 2019; Pham et al., 2020; Xue et al., 2022).

Several investigations have been carried out to identify the therapeutic significance and bioactive compounds of Syzygium species, particularly S. cumini and S. aromaticum. The phytochemical constitution and biological potential of S. occidentale are still poorly understood, and it receives little scientific attention. Considering the increasing need for new phytotherapeutics worldwide, particularly from unexplored species, examining S. occidentale may offer important insights into the creation of innovative medicines. Thus, the objective for this study is to critically evaluate the physicochemical properties, phytochemical profile, and bioactivities of S. occidentale using conventional antioxidant, antimicrobial, and anthelmintic studies.

Materials and Methods

Sample collection and physicochemical evaluation

The fresh leaves and bark of S. occidentale were obtained from Athirapilly- Vazhachal region, Thrissur, Kerala, India. This species was also verified by a taxonomist and test samples was kept in the department's herbarium, by which the species could be revisited in future (Imran et al., 2025).

Leaves and bark of S. occidentale were analyzed for the physicochemical characteristics, including the mineral content (vitamins, sodium, potassium, calcium, copper, manganese, zinc, and trace heavy metals), crude fiber, various ash fractions, with extractives that were soluble in water, alcohol, petroleum ether, and ethyl acetate. Six replicates were used for all measures, and the mean ± SEM was used to express the results (AOAC, 2000).

Fluorescence Analysis

Dried powders of leaves and bark were treated with different reagents and subjected to visible light, 254 nm UV, and 366 nm UV light. Fluorescence and color changes were noted to identify the phytochemical components (Kokate et al., 2009).

GC-MS Profiling

To find bioactive chemicals, gas chromatography-mass spectrometry was used to examine methanol extracts of leaves and bark. To ascertain the chemical composition and possible biological activity, peaks were compared to established standards and data in the literature (Sarkar & Chattopadhyay, 2021; Martins et al., 2022; Nakaziba et al., 2022).

Antioxidant Assays

DPPH radical scavenging, superoxide radical scavenging (riboflavin photoreduction technique), hydroxyl radical scavenging, and ferric reducing antioxidant power (FRAP) tests were used to assess antioxidant activity. Readings in triplicate were used to derive the IC_{50} values (Brand-Williams et al., 1995; Halliwell & Gutteridge, 1989).

Anthelmintic Activity

Different concentrations of methanolic extracts have been tested on Lumbricus terrestris. The duration of paralysis and mortality was noted and examined with a positive control, albendazole. The percentage of inhibition was computed to evaluate effectiveness.

Antimicrobial Activity

Zones of inhibition were measured at various doses to test extracts against bacteria (Staphylococcus aureus, Escherichia coli, etc.) and fungus (Aspergillus niger, Candida albicans). Streptomycin and clotrimazole were used as traditional antibacterial and antifungal drugs, respectively (Clinical and Laboratory Standards Institute, 2012).

Results

Physicochemical Parameters

Physicochemical tests of S. occidentale leaves and bark gave necessary baseline parameters. The phytochemical and nutritional analysis of S. occidentale shows that leaves are rich in vitamin C, vitamin A, manganese, and crude fibre, while bark contains higher levels of calcium, alcohol-soluble extractives, and total ash. Heavy metals (Lead, Arsenic, Cadmium, and Mercury) are present in negligible amounts, indicating overall safety for potential medicinal and nutritional use (Table 1).

Table 1: Physicochemical and Nutritional Parameters (Mean ± SE) of S. occidentale

Parameters	Leaves	Bark
Water soluble extractive (%)	9.92±0.23	12.78±0.580
Alcohol-soluble extractive (%)	11.03±1.01	17.21±1.02
Petroleum ether extractive (%)	5.54±0.10	1.13±0.06
Ethyl acetate soluble extractive (%)	6.19±0.09	1.06±0.76
Crude Fibre (%)	20.12±1.01	18.71±1.05
Vitamin A (mg/100 g)	0.06±0.004	Not detected
Vitamin C (mg/100 g)	198±1.23	Not detected
Sodium (mg/100 g)	6.58±0.124	8.32±0.04
Potassium (%)	0.88±0.011	0.31±0.001
Calcium (%)	0.43±0.020	2.10±0.005
Copper (mg/100 g)	0.37±0.001	0.42±0.004
Manganese (mg/100 g)	10.94±1.005	9.52±1.010
Zinc (mg/100 g)	1.04±0.010	0.70±0.001
Total ash (%)	4.84±0.002	8.14±0.002
Acid insoluble ash (%)	0.26±0.001	0.18±0.001
Water-soluble ash (%)	1.80±0.001	1.53±0.001
Sulphated ash (%)	6.45±0.022	12.56±0.122

Fluorescence Analysis

The fluorescence analysis of S. occidentale leaf and bark powders under visible light, 254 nm, and 366 nm UV light revealed notable differences in color responses when treated with various chemical reagents. Leaf powders generally exhibited greenish, bluish, and yellowish fluorescence, whereas bark powders predominantly showed brownish to dark shades. Reagents like ethanol, acetone, picric acid, and iodine produced distinct color variations, indicating the presence of different classes of phytochemicals. These variations suggest that the chemical constituents differ significantly between leaves and bark, reflecting their diverse phytochemical profiles.

GC-MS Analysis

The GC-MS analysis of S. occidentale extracts identified various bioactive compounds. Leaves were rich in amphiphilic phenolic lipid like cyclogallipharaol and 3-pentadecylphenol with peak area 46.67% and 42.72% respectively, while bark predominantly contained fatty acid methyl ester such as methyl palmitate (32.16%), methyl octadec-10-enoate (26.45%), linoleic acid, methyl ester (16.81%) and methyl stearate (8.16%) along with minor aromatic compounds (Table 2).

Table 2: GC-MS profile of methanol extract of leaves and bark of S. occidentale

Compound name	Extract	Type	Molecular formula	Peak area (%)
Cyclogallipharaol	Leaf	Amphiphilic phenolic lipid	$C_{21}H_{36}O$	46.67
3-Pentadecylphenol	Leaf and Bark	Amphiphilic phenolic lipid	$C_{21}H_{36}O$	42.72 (Leaf) and 3.71 (Bark)
1-Tert-butoxy-3-methylbenzene	Leaf	Aromatic ether	$C_{11}H_{16}O$	5.48
Neophytadiene	Leaf	Diterpene	$C_{20}H_{38}$	2.59
Phytol, acetate	Leaf	Diterpene	$C_{22}H_{42}O_2$	2.54
Methyl palmitate	Bark	Fatty acid methyl ester	$C_{17}H_{34}O_2$	32.16
Methyl octadec-10-enoate	Bark	Fatty acid methyl ester	$C_{19}H_{36}O_2$	26.45
Linoleic acid, methyl ester	Bark	Fatty acid methyl ester	$C_{19}H_{34}O_2$	16.81
Methyl stearate	Bark	Fatty acid methyl ester	$C_{19}H_{38}O_2$	8.16
Benzene, 1-chloro-4-methoxy-	Bark	Aromatic organic compound	C_7H_7ClO	4.24
2-(4'-Methoxyphenyl)-2-(2'-methoxyphenyl) propane	Bark	Aromatic ethers	$C_{17}H_{20}O_2$	3.38
Methyl behenate	Bark	Fatty acid methyl ester	$C_{23}H_{46}O_2$	2.06
Methyl myristate	Bark	Saturated fatty acid methyl ester	$C_{15}H_{30}O_2$	1.60
Methyl arachate	Bark	Fatty acid methyl ester	$C_{21}H_{42}O_2$	1.44

Antioxidant Activity

The antioxidant assay of S. occidentale showed that leaf extracts exhibited higher free radical scavenging activity compared to bark extracts. Leaves demonstrated greater DPPH activity (154.24 ± 1.10) and higher FRAP values (48 ± 1.20), indicating stronger reducing power. Superoxide and hydroxyl radical scavenging activities were also slightly higher in leaves than in bark, suggesting leaves possess better overall antioxidant potential (Table 3).

Table 3: IC_{50} Values of Antioxidant Assays (µg/mL)

Assay	Leaves	Bark
DPPH	154.24 ± 1.10	114.58 ± 1.03
Superoxide	84 ± 0.37	81± 1.41
Hydroxyl	62 ± 1.82	60± 1.21
FRAP	48 ± 1.20	44 ± 1.21

Anthelmintic Activity

The anthelmintic activity of S. occidentale methanol extracts against Lumbricus terrestris showed a dose-dependent effect. Leaf extracts demonstrated stronger activity than bark, with the highest concentration (100 mg/mL) causing paralysis and death faster than lower doses, achieving 73.5% inhibition, comparable to the standard drug albendazole (72.1%). This indicates significant anthelmintic potential, especially in leaf extracts.

Table 4: Anthelmintic activity of S. occidentale methanol extracts against Lumbricus terrestris

Treatment	Concentration (mg/mL)	Paralysis Time (minutes)	Death Time (minutes)	Inhibition %
Control (Distilled water)	0	50.00 ± 0.00	73.00 ± 0.00	0.0 ± 0.0
Standard (Albendazole)	20	15.36 ± 0.82	20.36 ± 1.05	72.1 ± 1.44
Leaf methanol extract	25	29.40 ± 1.34	39.15 ± 1.58	46.3 ± 2.16
	50	22.65 ± 1.18	32.25 ± 1.44	55.8 ± 1.97
	75	17.25 ± 0.98	26.45 ± 1.28	63.8 ± 1.75
	100	12.05 ± 0.80	19.35 ± 1.10	73.5 ± 1.51
Bark methanol extract	25	33.20 ± 1.42	42.85 ± 1.66	41.3 ± 2.27
	50	25.95 ± 1.25	36.10 ± 1.52	50.5 ± 2.08
	75	20.80 ± 1.10	30.45 ± 1.38	58.3 ± 1.89
	100	15.45 ± 0.92	24.85 ± 1.22	65.9 ± 1.67

Antimicrobial Activity

The antimicrobial assay of S. occidentale methanol extracts showed moderate antifungal and antibacterial activity in a dose-dependent manner. Leaf extracts exhibited stronger inhibition against Aspergillus niger (31 mm at 1000 µg/mL) compared to bark, while Candida albicans showed minimal sensitivity. Among bacteria, leaf extracts displayed higher activity against Staphylococcus aureus Streptococcus mutans at higher concentrations, whereas bark extracts showed comparatively weaker effects. No affect against Enterococcus fecalis recorded. Bark extract displayed higher activity against Escherichia coli and Pseudomonas aeruginosa compared to leaves extract.

Table 5: Antimicrobial activity of methanol extracts of the leaves and bark of S. occidentale against the pathogenic microorganisms

Fungus	Concentrations (Zone of inhibition in mm)							
	Clotrimazole (100 µg/ml)		250 (µg/ml)		500 (µg/ml)		1000 (µg/ml)	
	Leaves	Bark	Leaves	Bark	Leaves	Bark	Leaves	Bark
Aspergillus niger	36 ± 0.28	34 ± 0.26	23 ± 0.20	11 ± 0.11	26 ± 0.18	13 ± 0.18	31 ± 0.30	17 ± 0.19
Candida albicans	31 ± 0.29	30 ± 0.27	11 ± 0.13	11 ± 0.12	12 ± 0.17	12 ± 0.16	13 ± 0.17	13 ± 0.12
Bacteria	Streptomycin (100 µg/ml)		250 (µg/ml)		500 (µg/ml)		1000 (µg/ml)	

	Leaves	Bark	Leaves	Bark	Leaves	Bark	Leaves	Bark
Staphylococcus aureus	26 ± 0.14	26 ± 0.14	Nil	Nil	11 ± 0.10	Nil	12 ± 0.11	11 ± 0.09
Streptococcus mutans	25 ± 0.21	25 ± 0.23	Nil	Nil	11 ± 0.08	Nil	12 ± 0.07	11 ± 0.05
Enterococcus fecalis	21 ± 0.14	21 ± 0.17	Nil	Nil	Nil	Nil	Nil	Nil
Escherichia coli	25 ± 0.12	25 ± 0.18	Nil	11 ± 0.05	11 ± 0.08	12 ± 0.14	12 ± 0.07	13 ± 0.11
Pseudomonas aeruginosa	32 ± 0.20	32 ± 0.19	Nil	Nil	11 ± 0.07	11 ± 0.10	12 ± 0.10	12 ± 0.09

Discussion

The Syzygium plant has a variety of phytochemical elements, including flavonoids, glycosides, terpenoids, tannins, and phenolics, in its leaves, seeds, fruits, bark, stem bark, and flower buds (Aung et al., 2020). Inorganic elements as well as mineral salts that occur in wood constitute ash. Biochemical processes, mineral intake from the soil, and element movement within the trees are the reasons for ash-forming elements are present in plants (Werkelin et al., 2005). A change in total ash indicates different mineral constituents (Chiteva et al., 2023). Physicochemical analysis of leaves and bark of S. occidentale shows that bark contains higher levels of calcium, alcohol-soluble extractives, and total ash.

Fluorescence occurs when a molecule stimulated by electromagnetic radiation absorption release some of its energy as photons (Lakowicz, 2006; Agati et al., 2020). Fluorescence spectroscopy emerged as a practical analytical method for molecular characterization (Agati et al., 2020). Present study found green, blue, and brown fluorescence in leaf and bark powder of S. occidentale in different lights and with different chemicals. When S. palghatense leaf and bark powder was treated with acetone, the fluorescence analysis revealed a dark (254 nm UV light) and bluish-black (366 nm UV light) coloration (Snehalatha & Rasmi 2021). Fluorescence analysis and phytochemical screening assists in determining if phytoconstituents are present or absent (Prasad et al., 2021).

Leaves were found rich in amphiphilic phenolic lipid like cyclogallipharaol and 3-pentadecylphenol with peak area 46.67% and 42.72% respectively, while bark predominantly contained fatty acid methyl ester such as methyl palmitate (32.16%), methyl octadec-10-enoate (26.45%), linoleic acid, methyl ester (16.81%) and methyl stearate (8.16%) along with minor aromatic compounds. n-hexane (HSP), ethyl acetate (EASP), and methanol (MSP) of S. polyanthum leaf extracts have been identified by Rahim et al. (2018) to contain several recognized bioactive chemicals with potential therapeutic uses. 3-pentadecylphenol has anti-inflammatory, antibacterial, and antipyretic activity (Devakumar et al., 2017). Neophytadiene was also observe in leaf extract which exhibit analgesic, antimicrobial, anti-inflammatory, antioxidant (Willie et al., 2021). Methyl palmitate observed in bark extract which have anti-apoptotic, antioxidant, anti-fibrotic, anti-inflammatory, and vasodilatation importance (Hamed et al., 2020).

There have been reports of cytotoxic, antibacterial, anti-inflammatory, anticancer, antidiabetic, antioxidant, and anthelmintic properties in a variety of extracts (methanol, ethanol, and aqueous) from distinct Syzygium sp (Aung et al., 2020). People who live in tropical areas are at serious risk for helminthic

infections, which can have serious negative consequences such as diarrhea, anemia, malabsorption, and poor health (Rashmi & Negi, 2022). Kavitha et al. (2011) reported the bark of S. cumini has moderate anthelmentic activity in an aqueous extract and potential anthelmentic activity in a methanolic extract. Whereas the findings from the present study indicates significant anthelmintic potential, especially in leaf extracts.

In their studies, Ali et al. (2024) discovered that, in contrast to the leaves and flowers, the bark of S. cumini exhibited the least amount of antibacterial activity against the harmful bacteria. These findings are in line with present study that bark exhibit lower antifungal and antibacterial activity then leaves extract. Yahaya et al. (2024) reported the ethanol extract of S. samarangense leaves provided a maximum inhibition zone of 22.03±0.096 mm and 17±0.182 mm against Klebsiella pneumoniae and E. coli, respectively. In the present study 13 ± 0.11 mm inhibition was recorded against E. coli by at 1000 µg/ml concentration of bark extract.

Conclusion

This study represents the first detailed phytochemical, pharmacological, and pharmacognostic investigation of S. occidentale, an endemic and largely neglected species of the genus due to insufficient research. Physicochemical profiling established baseline parameters, including ash values, extractive yields, and mineral content, which could serve as quality control standards for future inclusion in pharmacopoeia. GC-MS analysis revealed a diverse array of bioactive compounds, such as neophytadiene, cyclogallipharaol, and fatty acid methyl esters, with cyclogallipharaol being reported for the first time in this species. These findings significantly contribute to the ongoing chemotaxonomic research on Syzygium. The medicinal potential of the plant was validated through biological assays. Bark extracts exhibited stronger antioxidant activity in all assays, whereas leaf extracts demonstrated superior antimicrobial and anthelmintic activity, in some cases comparable to conventional drugs. This complementary distribution of activities suggests that different plant parts can be utilized for distinct pharmacological purposes. The novelty of this work lies in its comprehensive approach, combining detailed chemical profiling with multiple biological assays, positioning S. occidentale as a promising natural source of antioxidant, antimicrobial, and anthelmintic agents.

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