ISSN: 3029-0716

Review Article

Journal of Infectious Diseases & Treatments

Explorative Study of the Phytochemistry and Bioactivity of Caesalpinia benthamiana: A Review

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Received: February 20, 2026; **Accepted:** February 26, 2026; **Published:** March 05, 2026

ABSTRACT

Caesalpinia benthamiana (C. benthamiana), a member of the family Fabaceae, and genus Caesalpinia is a Tropical African Plant whose roots, stem barks and leaves and/or their extracts have has gained significant attention in traditional uses due to their diverse and promising bioactive properties. This review seeks to explore current literature on phytochemistry and biological activities of C. benthamiana. Previous Studies have revealed significant presence of bioactive phytochemicals such as flavonoids, phenolics, alkaloids, tannins, steroids and saponins. Flavonoids possess strong antioxidant activity such as free radicals scavenging activities and thus helps reduce oxidative stress, and prevent diseases such as cancer and related cardiovascular disorders. Phenolics, are primarily involved in antioxidant and antimicrobial actions, protecting cells from oxidative damage. Alkaloids are known anti-inflammatory, antimicrobial, and anticancer agents. Tannins, steroids and saponins are also significant for antimicrobial and related biological activities. Although analysis of plant extracts with known advanced methods has revealed presence of bioactive compounds such as phytols, gallic acid and quercetin derivatives; notable gaps still exist in the isolation of specific compounds present and the elucidation of their mechanisms of action. This review explores the potential of C. benthamiana as a source of bioactive molecules for relevant nutraceutical and pharmaceutical development.

Keywords: Caesalpinia Benthamiana, Phytochemistry, Bioactivity, Antimicrobial, Antioxidant, Fabaceae

Introduction

Medicinal plants have been used for treatments and maintenance of the human health and well-being from time immemorial, providing remedies for various health disorders; as well as serving as sources for novel therapeutic agents [1]. The World Health Organization (WHO) estimates that about 80% of the global population relies on traditional medicine for primary healthcare [2]. Plants belonging to the Fabaceae family have overtime demonstrated significant pharmacological potential due to their vastly rich phytochemical constitution [3].

Caesalpinia benthamiana (C. benthamiana) is native the tropics in West Africa in countries such as Guinea and Nigeria. It is widely used in traditional medicine for treating infections, inflammatory conditions, gastrointestinal disorders, and fever [3,4]. Systematic studies on the biological activities and phytochemical composition Caesalpinia benthamiana has been limited so far, despite its popular usage in alternative medicinal systems and exploration [5].

The aim of this review is to provide a comprehensive summary of the existing knowledge on the phytochemistry and bioactivity of C. benthamiana. This will facilitate further studies on the isolation of its active constituents and the validation of its therapeutic properties.

Medicinal Uses

Caesalpinia benthamiana is known for its primary use in the treatment of malaria. It has been known to possess potent antimalaria activities. Significant antiprotozoal activities have been observed in leaf extracts of C. benthamiana against the parasite Plasmodium falciparum, responsible for very severe forms of malaria. For example, In-vitro studies of the methanolic extracts of the plant's leaves have been shown to exhibit strong antimalaria activity with IC50 value of 4 µg/ml against the severe malaria parasite Plasmodium falciparum [6].

Caesalpinia benthamiana is not just an alternaive remedy against several levels of the malaria parasite infection, but also used in traditional folk medicine for treatment of a range of ailments including body infections, fever and in some cases, sexual dysfunction [7]. The root extracts of C. benthamiana

Citation: Joshua Inanabor Isibor, Vincent Oghenerobo Imieje, Favour Ufoma Akpokiro. Explorative Study of the Phytochemistry and Bioactivity of Caesalpinia benthamiana: A Review. J Infect Dise Treat. 2026. 4(1): 1-5. DOI: doi.org/10.61440/JIDT.2026.v4.65

are also known to be locally used in treatment of male erection impairments [8]. African traditional healers utilize parts of the Caesalpinia benthamiana plant to treat ailments such as dysentery, diarrhea as well as digestive disorders [9]. The root and leaf preparations of the C. benthamiana plant are locally used to treat different cases of cough and other respiratory ailments or disorders [10]. Also, applications such as Poultices made from this plant's leaves have been used on inflamed areas on patients to reduce pain and swellings, as well as treat related inflammatory disorders.

Pharmacognostic and Geographical Description

Caesalpinia benthamiana possess characteristic leafed twigs which are usually used for medicinal purposes. The leaves are compound, typically pinnate, with possess numerous leaflets that exhibit a green coloration. The plant can grow as a shrub or small tree [11]. Phytochemical screening of the leaf extracts of the plant has revealed the presence of several bioactive compounds including terpenoids, flavonoids, saponins, tannins, as well as iridoids. These compounds essentially contribute to the plant's antimalarial and cytotoxic properties [12].

Research indicates that methanolic extracts of C. benthamiana exhibit significant antiprotozoal activity against Plasmodium falciparum (IC50 4 µg/ml), Trypanosoma brucei (IC50 13 µg/ml), and Trypanosoma cruzi (IC50 31 µg/ml [13]. Research study on cytotoxicity on Caesalpinia benthamiana extracts on human cell lines (MRC-5 cells) has shown an IC50 value of 32 µg/ml, which suggests that the plant's safety profile should be given important considerations, while its medicinal therapeutic potentials have been established to considerable measures [14]. Further studies have isolated several new cytotoxic compounds from C. benthamiana including benthamiacone, which has shown promising activity against various cancer cell lines [15]. In-vivo studies of C. benthamiana involving clinical trials of its syrup on children with common malaria symptoms have been carried out in comparism with conventional treatments like with chloroquine. The results reveal the plant's medicinal effectiveness and tolerability and thus relevance in contemporary ethnomedicine.

Geographically, C. benthamiana is primarily found in Guinea where it thrives in regions with record high rates of the malaria parasites transmission among especially the locals. The plant has been extensively studied within context of the Guinea trado-medicinal system, due to its widespread use among local populations for treating malaria and other ailments [16]. However, the geographical distribution of Caesalpinia benthamiana extends beyond the Guinea regions into other areas in West Africa with similar climatic conditions, allowing this species to essentially flourish in the tropics.

Phytochemistry of Caesalpinia Benthamiana

Phytochemical Screening

Phytochemicals such as the alkaloids, phenolics and flavonids screening which have been researched to be present in extracts of C. benthamioana [17,18], are basically the compounds responsible for this plant's various pharmacological activities such as the antimicrobial, antioxidant and anti-inflammatory characteristics [19,20].

For example, research studies carried out by Edeoga et al. [21], revealed abundant presence of flavonoids and phenolic compounds from qualitative analysis, while the quantitative assays carried out indicated significant levels of total phenolics (123.45 ± 2.34 mg GAE/g) and flavonoids (4l5.67 ± 1.12 mg QE/g). Comparable results were likewise reported by Dickson et al. [22], who noted the presence of additional alkaloid derivatives.

Table of Medicinal Use of Various Parts of Caesalpinia Benthamiana

Plant Part	Medicinal Use	Reference
Leaves	Antimalarial treatment	(23)
Leaves	Antiprotozoal activity against Trypanosoma spp. and Plasmodium falciparum	(24)
Bark	Treatment for various infectious diseases	(25)
Roots	Used in traditional medicine for fever relief	(26)
Whole plant	General tonic and health booster	(27)

Table 1: Major Phytochemicals Identified in Caesalpinia benthamiana

Phytochemical Class	Examples	Analytical Method	References
Phenolics	Gallic acid, caffeic acid	HPLC, GC-MS	[21,28]
Flavonoids	Quercetin derivatives	HPLC, UV-Vis Spectroscopy	[22,29]
Saponins	Progenin	TLC, FTIR	[17,30]
Alkaloids	Isoquinoline derivatives	GC-MS	[22,31]
Tannins	Condensed tannins	Folin-Ciocalteu assay	[18,21]

Advanced Analytical Techniques

Advanced analytical techniques have been largely employed to identify bioactive constituents in C. benthamiana extracts such as;

High-Performance Liquid Chromatography (HPLC): Analysis with which has led to identification of major phenolic acids such as caffeic acid, gallic acid, and few derivatives of quercetin in the extracts of Caesalpinia benthamiana [21,28].

Gas Chromatography-Mass Spectrometry (GC-MS): analysis of the plant with GC-MS has revealed presence of volatile bioactive compounds such as hexadecanoic acid, phytol and squalene, which are known for their antioxidant and antimicrobial activities [29,32].

Fourier Transform Infrared Spectroscopy (FTIR): whose analysis of C. benthamiana has confirmed chemical functional groups characteristic of phenols, flavonoids and saponins [30].

Biological Activities of Caesalpinia benthamiana

Antimicrobial Activity

Novel scientific research studies have explored antimicrobial activities of extracts of Caesalpinia benthamiana pathogenic elements such as fungi and bacteria micro-organisms. Adegboye et al. have for example reported significant inhibitory activity of the plant's extracts against Staphylococcus aureus and Escherichia coli, with inhibition zones ranging from 15 to 20 mm [33].

Similarly, MIC values of range between 25-100 µg/mL indicating potent activity was reported by Okeke et al [34]. The presence of phenols and flavonoids in extracts of C. benthamiana act by disrupting microbial cell walls and inhibit key enzymes and thus responsible for the plant's antimicrobial effect [35].

Table 2: Antimicrobial Activity of C. Benthamiana Extracts

Pathogen	Extract Type	Inhibition Zone (mm)	MIC (µg/mL)	References
Staphylococcus aureus	Methanolic	18.5	50	[33,34]
Escherichia coli	Ethanolic	15.2	100	[33,35]
Candida albicans	Aqueous	12.0	75	[34,36]

Antioxidant Activity

Antioxidant activity of C. benthamiana has been largely examined using in vitro assays such as ferric reducing antioxidant power (FRAP) and DPPH radical scavenging. Experiments show plant's methanolic extract exhibiting average IC50 values of 45.23 µg/mL, indicating strong antioxidant [37,38]. Free radical scavenging ability of the plant is largely due to its constituent phenolic and flavonoid compounds, which leads to reduction of oxidative stress and prevention of cellular damage [39,40].

Anti-inflammatory Effects

The anti-inflammatory activity of C. benthamiana can be studied using protein denaturation inhibition and membrane stabilization assays [41]. Recent study using these assays shows using plant extracts showed significant inhibition of protein denaturation (72.5%) and reduced membrane lysis, showing potentials of activity against inflammation [42,43].

Trado-Medicinal Uses and Ethnopharmacology

Ethnopharmacological surveys reveals that Caesalpinia benthamiana is locally used in the West Africa region for the treatment of malaria, infections, fever, inflammation, as well as gastrointestinal issues [44]. Preparations from the leaves and stems of the plant are usually administered orally or topically in the African tropics, for the treatment of wounds, as well as skin infection [45,46].

Challenges / Limitations

- Research on the herbal plant Caesalpinia benthamiana faces several notable set-backs:
- **Mechanism of Action:** There is faint knowledge of the fundamental mechanisms of action of its pharmacological activities.
- **Toxicological Studies:** Available data on the toxicity and safety profiles of this plant is not very robust.
- **Isolation of Specific Compounds:** There is limited data on research studies on isolated compounds from the plant.
- **Lack of Standardization:** there is still lack of available standardized extracts due to differences of phytochemical constituents of different plant extracts, as a result of varying environmental and genetic factors of the plant at different locations.
- **Bioavailability and Formulation:** There is no sufficient optimization bioavailability and formulation of the plant extracts, which is essential for nutraceutical efficacies.

Future Perspectives

Scientists with interest in further research on C. benthamiana in future should endeavour to focus their works on bioactivity-guided fractionation, isolation, advanced phytochemical characterization, as well as related clinical studies and relevant trials to validate alternative medicinal claims, while exploring new grounds in novel therapeutic applications.

Conclusion

Bioactivity of Caesalpinia benthamiana characteristics such as antimalaria, anti-inflammatory, antimicrobial, antioxidant, and anti-inflammatory activities are strong pharmacological attributes of the plant significant for its use as a therapeutic agent. It is a reservoir of bioactive compounds and phytochemicals such as the flavonoids, phenolics, and alkaloids, which provide scientific basis for its traditional use. However, further studies should include elucidation of mechanism of action and isolation of specific bioactive compound, while toxicity levels evaluated for clinical use purposes.

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