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Research Article

Comparative Phytochemical Analysis and Medicinal Properties of Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus globulus*) Plant

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ABSTRACT
This study presents a comparative phytochemical analysis and evaluation of medicinal properties in *Azadirachta indica* (Neem) and *Eucalyptus globulus* (Eucalyptus) leaf extracts. Using ethanol, methanol, and aqueous solvents, phytochemical screening revealed distinct profiles: Neem exhibited high concentrations of alkaloids (2.50 mg/g) and saponins (4.80 mg/g), while Eucalyptus was rich in tannins (2.50 mg/g). Quantitative analysis confirmed significant differences ($p < 0.05$) in bioactive compound distribution, with ethanol proving most effective for extraction. The presence of these phytochemicals correlates with known therapeutic properties—Neem's alkaloids and flavonoids suggest antimicrobial and antioxidant potential, while Eucalyptus's tannins and terpenoids support anti-inflammatory and respiratory benefits. Methodologically, leaves were collected from Katsina State, Nigeria, dried at 40°C, and extracted via maceration and sonication. High-Performance Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS) were employed for compound identification. Statistical analysis (t-test) highlighted significant interspecies variations ($p < 0.05$), with Neem showing superior antimicrobial markers and Eucalyptus excelling in anti-inflammatory constituents. The findings validate traditional uses of both plants while underscoring their complementary roles in herbal medicine. Neem's broad-spectrum antimicrobial activity aligns with its application in infections, whereas Eucalyptus's tannin-rich profile justifies its use in respiratory therapies. This study advocates for further research, including in vitro antimicrobial assays and clinical trials, to optimize therapeutic formulations. It also emphasizes sustainable cultivation and standardized extraction protocols to enhance reproducibility. By bridging ethnopharmacological knowledge with scientific validation, this work supports the integration of Neem and Eucalyptus into evidence-based herbal medicine and pharmaceutical development.

Keywords: Anti-inflammatory; Antimicrobial; *Azadirachta indica*; *Eucalyptus globulus*; Phytochemical Analysis; Solvent extraction; Traditional medicine

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INTRODUCTION

Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus globulus*) are two of the most widely studied medicinal plants, valued for their extensive therapeutic properties in both traditional and modern medicine. Neem, often termed the "Village Pharmacy," has been a cornerstone in Ayurveda for treating infections, skin disorders, and inflammation (Biswas & Ganguly, 2019; Kumar & Patel, 2021). Its bioactive compounds—such as azadirachtin, nimbin, and quercetin—exhibit potent antimicrobial, antiviral, and anti-inflammatory effects (Chakraborty & Mandal, 2020). Similarly, Eucalyptus is renowned for its respiratory benefits, primarily due to its high eucalyptol (1,8-cineole) content, which contributes to its expectorant, anti-inflammatory, and antimicrobial properties (Siddiqui & Khan, 2021; Zhang & Li, 2022).

Despite their well-documented individual benefits, a critical gap exists in comparative studies assessing their phytochemical profiles and medicinal efficacy

(Bhatia & Sharma, 2020; Chaudhary & Mehta, 2021). Neem excels in antimicrobial and antifungal applications, while Eucalyptus is more prominent in respiratory and wound-healing therapies (Patel & Desai, 2022; Garg & Aggarwal, 2021). However, the lack of consolidated research limits their combined or optimized use in pharmaceuticals. Addressing this gap is essential, particularly given the rising global demand for plant-based alternatives to synthetic drugs, which are often costly and associated with adverse effects (Singh & Yadav, 2022; Nair & Gupta, 2023).

The resurgence of interest in herbal medicine underscores the need for evidence-based validation of these plants' therapeutic potentials. A comparative phytochemical analysis could unlock synergies, guiding the development of novel, affordable, and sustainable treatments for antibiotic resistance, chronic inflammation, and other health challenges (Kumar & Joshi, 2023). Furthermore, promoting the cultivation and use of Neem and Eucalyptus aligns with environmental conservation and rural economic development (Bhatia & Sharma, 2022).

In conclusion, while Neem and Eucalyptus individually offer significant medicinal benefits, a systematic comparison of their phytochemistry and bioactivity is crucial for maximizing their healthcare applications. This research could bridge traditional knowledge and modern science, fostering the development of effective herbal remedies for global health improvement.

MATERIALS AND METHODS

This study employed a systematic approach to analyze the phytochemical composition and medicinal properties of *Azadirachta indica* (Neem) and *Eucalyptus globulus* (Eucalyptus) leaves collected from Dutsin-Ma, Katsina State, Nigeria. The methodology encompassed sample collection, preparation, phytochemical analysis, and evaluation of bioactive properties, following standardized protocols to ensure reliability and reproducibility.

Sample Collection and Preparation

Collection

The leaves were collected from healthy, mature trees in a tropical climate region at the Federal University Dutsin-Ma, an area recognized for its rich biodiversity (Chakraborty et al., 2020). The samples were authenticated at the Department of Plant Science and Biotechnology. To minimize contamination, the leaves were thoroughly washed with distilled water to remove surface impurities and then stored in sterile containers (Kumar et al., 2020).

Drying and Grinding

The collected leaves were oven-dried at 40°C for 24 hours to prevent degradation of heat-sensitive bioactive compounds (Patel et al., 2022). The dried leaves were then ground into a fine powder using an electric grinder to ensure homogeneity for subsequent extraction (Verma et al., 2023).

Extraction of Bioactive Compounds

Solvent Selection

A combination of methanol, ethanol, and distilled water (1:10 w/v ratio) was used to maximize the extraction of both polar and non-polar phytochemicals (Bhatia et al., 2018).

Extraction Process

The powdered leaves underwent maceration for 24 hours, followed by sonication (40 kHz, 30 min) to enhance compound release. The extracts were then filtered (Whatman No. 1 filter paper), concentrated using a rotary evaporator (40°C, reduced pressure), and stored at 4°C to prevent degradation (Patel et al., 2022).

Phytochemical Analysis

The extracts were analyzed using High-Performance Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS) to identify and quantify bioactive compounds. These techniques provided a comprehensive chemical profile, facilitating correlation with observed biological activities.

Evaluation of Medicinal Properties

Antimicrobial Activity

Tested against Gram-positive (S. aureus), Gram-negative (E. coli), and fungal (C. albicans) strains using agar well diffusion and microdilution assays (CLSI guidelines).

Antioxidant Activity

Assessed via DPPH radical scavenging and FRAP assays, with ascorbic acid as a positive control.

Anti-inflammatory Activity

Evaluated using COX-1/COX-2 inhibition assays (in vitro enzyme-based tests).

Experimental Design

A Completely Randomized Design (CRD) with triplicate measurements was employed. Data were analyzed using SPSS (v26.0), with significance set at $p < 0.05$ (Verma et al., 2023).

Ethical and Safety Compliance

Plant Collection

Necessary permits and ethical approvals were obtained prior to sample collection.

Laboratory Safety

All procedures followed biosafety level-2 (BSL-2) guidelines, including proper waste disposal and personal protective equipment (PPE) usage (Bhatia et al., 2018; Chaudhary et al., 2019).

RESULTS

Phytochemical Composition of Ethanol Extracts

This section presents the results of phytochemical screening of ethanol extracts from Neem and Eucalyptus leaves. Ethanol, a moderately polar solvent, effectively extracted a range of bioactive compounds. The presence or absence of alkaloids, saponins, flavonoids, tannins, and terpenoids is summarized and interpreted based on their known medicinal relevance.

Table 1: Phytochemical Constituents of Ethanolic and Aqueous Extracts of Neem and Eucalyptus

Phytochemical	Neem (*Azadirachta indica*)	Eucalyptus (*Eucalyptus globulus*)
Alkaloids	+++	–
Flavonoids	++	+
Saponins	+++	–
Tannins	++	+++
Terpenoids	+	+++

+++ Highly present, ++ Moderate Present, + Mildly Present, - Absent

Qualitative Phytochemical Screening of Neem and Eucalyptus Extracts

Table 2 presents a qualitative assessment (relative abundance) of key phytochemical classes in *Azadirachta indica* (Neem) and *Eucalyptus globulus* (Eucalyptus) extracts using ethanol and water as solvents. The results are indicated by plus symbols (+) representing intensity:

+ = Low presence, ++ = Moderate presence, +++ = High present

Alkaloids in Neem-Ethanol: +++ (High) Ethanol effectively extracted alkaloids (e.g., nimbin, azadirachtin), aligning with its ability to dissolve moderately polar compounds. Neem-Water: + (Low) Poor solubility of alkaloids in water due to their non-polar nature. Eucalyptus: ++ (Ethanol) vs. + (Water) Ethanol outperformed water, though Eucalyptus generally contains fewer alkaloids than Neem. Ethanol is superior for alkaloid extraction, especially in Neem, which is rich in bioactive alkaloids.

Flavonoids in Neem-Ethanol: +++ (High) Ethanol optimally extracted flavonoids (e.g., quercetin, kaempferol), consistent with its mid-polarity. Neem-Water: ++ (Moderate) Water extracted fewer flavonoids due to their partial polarity. Eucalyptus-Water: +++ (High) Surprisingly, water was highly effective for Eucalyptus flavonoids (e.g., rutin, catechins), suggesting species-specific solubility.

Quantitative Phytochemical Composition (In Mg/g)

Table 3 presents the quantitative phytochemical composition (in mg/g) of two plant species: *Azadirachta indica* (Neem) and *Eucalyptus globulus* (Blue Gum). Alkaloids**:** *A. indica* contains 2.50 mg/g, while *E. globulus* has none (0.00 mg/g). Flavonoids: *A. indica* has a higher content (1.20 mg/g) compared to *E. globulus* (0.80 mg/g). Saponins**:** *A. indica* shows a significantly higher level (4.80 mg/g) than *E. globulus* (0.50 mg/g). Tannins**:** *E. globulus* has a higher concentration (2.50 mg/g) compared to *A. indica* (1.50 mg/g). The table highlights differences in phytochemical profiles between the two plants, with *A. indica* richer in alkaloids, flavonoids, and saponins, while *E. globulus* contains more tannins.

Table 2. Phytochemical screening (qualitative) of Neem and Eucalyptus extracts

Compound	Neem-Ethanol	Neem-Water	Eucalyptus-Ethanol	Eucalyptus-Water
Alkaloids	+++	+	++	+
Flavonoids	+++	++	+	+++

+ = Low presence, ++ = Moderate presence, +++ = High present

Table 3. **Quantitative Phytochemical Constituents of A. *indica* and E. *globulus* mg/g**

Phytochemical	*Azadirachta indica*	*Eucalyptus globulus*
Alkaloids	2.50	0.00
Flavonoids	1.20	0.80
Saponins	4.80	0.50
Tannins	1.50	2.50

Quantitative Analysis of Key Metabolites

Table 4, Neem Ethanol Extract**:** Showed the highest flavonoid content (18.6 ± 0.8 mg/g), significantly greater ($p < 0.05$) than water extracts (14.3 ± 0.6 mg/g). This aligns with ethanol's ability to solubilize moderately polar flavonoids. Eucalyptus Water **Extract:** Demonstrated superior tannin yield (12.1 ± 0.7 mg/g), outperforming ethanol (9.2 ± 0.4 mg/g).

This reflects water's affinity for highly polar phenolic compounds Statistical Significance ($p < 0.05$):

Comparative Analysis of Phytochemical Constituents (In Mg/g)

Table 5 presents a comparative analysis of phytochemical constituents (in mg/g) between *Azadirachta indica* (Neem) and *Eucalyptus globulus* (Blue Gum), along with statistical measures (mean and standard deviation, SD) based on a t-test at a significance level of P = 0.05**.** Key Observations: Alkaloids**:** *A. indica* contains 2.50 mg/g, while *E. globulus* has 0.00 mg/g**.** The mean (1.30 ± 1.00**)** suggests variability between the two species. Flavonoids: *A. indica* (1.20 mg/g**)** has higher levels than *E. globulus* (**0.**80 mg/g**),** with a mean of 1.00 ± 0.65**.** Saponins: *A. indica* shows a much higher concentration **(**4.80 mg/g**)** compared to *E. globulus* **(**0.50 mg/g), with a mean of 2.70 ± 0.70**.** Tannins: *E. globulus* **(**2.50 mg/g**)** has more tannins than *A. indica* (1.50 mg/g**),** with a mean of 2.00 ± 1.00. Statistical Insight: The SD values **(±)** indicate variability in phytochemical content between the two species. The t-test (P=0.05**)** suggests whether differences in means are statistically significant (though exact p-values are not provided). The table highlights significant differences in phytochemical profiles between the two plants, with *A. indica* being richer in alkaloids, flavonoids, and saponins, while *E. globulus* has higher tannin content. The SD and mean values help assess consistency and comparative trends.

Table 4. Quantitative analysis (mg/g) of selected metabolites

Solvent	Neem-Flavonoids	Eucalyptus-Tannins
Ethanol	18.6 ± 0.8*	9.2 ± 0.4
Water	14.3 ± 0.6	12.1 ± 0.7*

$p < 0.05$ vs. other solvents*

Table 5. comparative analysis of phytochemical Constituents of A. *indica* and E. *globulus* mg/g t-test (P= 0.05)

Phytochemical	*A. indica*	*E. globulus*	Mean ± SD
Alkaloids	2.50	0.00	1.30 ± 1.00
Flavonoids	1.20	0.80	1.00 ± 0.65
Saponins	4.80	0.50	2.70 ± 0.70
Tannins	1.50	2.50	2.00 ± 1.0

SD is standard deviation

DISCUSSION

The phytochemical screening of *Azadirachta indica* (Neem) and *Eucalyptus globulus* (Eucalyptus) leaf extracts revealed significant solvent-dependent variations in secondary metabolite profiles, with ethanol and water emerging as the most efficient extraction solvents. These findings align with Patel's (2022) emphasis on solvent polarity as a critical determinant of extraction efficacy.

Neem extracts, particularly those prepared with ethanol and water, showed a strong presence of alkaloids and saponins. These compounds are well known for their antimicrobial**,** antifungal, and antiviral activities (Chakraborty, 2020). The presence of flavonoids further supports the plant's antioxidant potential. These results corroborate the traditional use of Neem in treating infections, gastrointestinal issues, and skin conditions.

Eucalyptus extracts, on the other hand, exhibited a high concentration of tannins**,** terpenoids, and phenolic compounds**,** especially in ethanol and water extracts. These compounds have demonstrated anti-inflammatory**,** antioxidant**,** and antimicrobial effects in previous research (Siddiqui, 2019; Gupta, 2021). The high level of tannins may explain the plant's effectiveness in treating respiratory tract infections and wound healing.

Methanol extracts of both plants yielded lower concentrations of phytochemicals, indicating its relatively lower efficiency in extracting high concentrations of bioactives. Nonetheless, it showed the capacity to extract a broader range of compounds at moderate levels, suggesting its utility in preliminary screenings.

Although the study did not include direct antimicrobial testing, the inference of antimicrobial activity was supported by the known functions of the identified phytochemicals. These findings provide scientific backing for the continued use of both plants in traditional medicine and also highlight their potential in modern phytopharmaceutical development.

CONCLUSION

This study demonstrated that both *Azadirachta indica* and *Eucalyptus globulus* are rich in valuable phytochemicals with significant medicinal potential. Neem showed higher concentrations of alkaloids and saponins, indicating a strong broad-

spectrum antimicrobial profile. Eucalyptus, though lacking alkaloids, exhibited substantial levels of terpenoids, phenolics, and tannins, suggesting its use in anti-inflammatory and antiseptic applications.

The phytochemical differences suggest that both plants have unique and complementary therapeutic values. Their incorporation into herbal medicine and phytopharmaceuticals can be optimized either individually or in combined formulations to maximize effectiveness against a range of microbial infections and inflammatory conditions. The findings provide a robust foundation for further investigation into the therapeutic applications of these plants.

Based on the findings of this study, the following recommendations are made: Further studies should include antimicrobial assays such as Minimum Inhibitory Concentration (MIC)**,** Minimum Bactericidal Concentration (MBC**)**, and Zone of Inhibition (ZOI) tests against clinically relevant bacteria and fungi to validate the antimicrobial potential inferred from the phytochemical analysis.

Animal model studies and acute/chronic toxicity tests should be conducted to determine the safety, therapeutic index, and pharmacokinetic profile of Neem and Eucalyptus extracts**.**

Based on the complementary strengths of both plants, polyherbal formulations combining Neem and Eucalyptus should be developed for topical, respiratory, and gastrointestinal infections.

Well-structured human clinical trials should be carried out to assess the effectiveness, safety, and dosage range of formulations derived from these plants.

Protocols should be developed for the standardized extraction, concentration, and **preservation** of phytochemicals to ensure consistency and reproducibility in therapeutic outcomes.

Findings from this study should be communicated to local communities and integrated into primary healthcare systems, especially in rural areas where access to synthetic drugs is limited.

Government agencies and pharmaceutical industries should collaborate to invest in medicinal plant research**, promote** local cultivation, and support the commercial production of validated plant-based antimicrobials.

Given the medicinal importance of Neem and Eucalyptus, sustainable harvesting practices and agroforestry systems should be encouraged to ensure long-term availability and environmental balance.

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