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Review Article

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"NEEM (*AZADIRACHTA INDICA*): ANTIMICROBIAL AND PHARMACOLOGICAL INSIGHTS – AN INTEGRATIVE REVIEW"

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ABSTRACT

Introduction: *Neem* (*Azadirachta indica* A. Juss.), a widely used medicinal tree in Ayurveda, is renowned for antimicrobial, anti-inflammatory, and immunomodulatory properties. It is traditionally employed for skin infections, oral health, gastrointestinal disorders, and general detoxification. Modern research has elucidated its phytochemistry and pharmacological activities, but a consolidated review is warranted. **Methods:** Literature search was performed on PubMed, Scopus, Web of Science, and Google Scholar, along with Ayurvedic texts (*Charaka Samhita*, *Sushruta Samhita*, *Bhavaprakasha Nighantu*). Studies from 1950–2025 covering phytochemistry, pharmacology, and clinical trials were included. Exclusion criteria: anecdotal reports, duplicates, and low-quality studies. **Results:** Traditional Ayurveda describes Neem as *Tikta*, *Kashaya*, *Sheeta*, with *Rakta-stambhana* (blood purification), *Krimighna* (antimicrobial), and *Vata-Pitta hara* properties. Phytochemicals include limonoids (azadirachtin, nimbin, nimbolide), flavonoids, tannins, and triterpenoids. Pharmacological studies show broad-spectrum antimicrobial, antifungal, antiviral, anti-inflammatory, hepatoprotective, antidiabetic, and anticancer effects. Clinical studies support its use in oral hygiene, dermatological infections, and metabolic disorders. **Discussion:** Ayurveda's conceptualization of Neem aligns with modern pharmacology. Its multi-targeted actions validate traditional uses, but standardization, safety, and dose optimization are necessary for clinical application. **Conclusion:** *Neem* exemplifies integration of traditional knowledge and modern science. It holds promise as an antimicrobial, immunomodulatory, and systemic therapeutic agent, with potential for development into standardized phytopharmaceuticals.

KEYWORDS: Azadirachta indica, Antimicrobial, Ayurveda, Immunomodulation, Pharmacology

INTRODUCTION

Neem (*Azadirachta indica*) is considered a *Sarva Roga Nivarana* (treating multiple disorders[1] in Ayurveda, particularly for skin diseases (*Kushtha*),[2] infections, and detoxification (*Rakta-shodhana*).[3] Its bitter taste (*Tikta*) and cooling potency (*Sheeta virya*) make it useful in *Pitta* and *Kapha* disorders.[4-5]

Its phytochemistry includes limonoids, flavonoids, triterpenoids, and tannins. Antimicrobial, anti-inflammatory, antiviral, antidiabetic, and anticancer properties have been documented in preclinical and clinical studies.[6-7] Global interest in natural antimicrobials has increased research on Neem's therapeutic potential.[8]

This review critically analyzes traditional uses, phytochemistry, pharmacological evidence,[9] and clinical studies of *Neem*, emphasizing its antimicrobial potential and other pharmacological activities, bridging Ayurveda and modern biomedical research.[10]

MATERIALS AND METHODS

- **Databases:** PubMed, Scopus, Web of Science, Embase, Google Scholar.[11]
- **Classical Ayurvedic texts:** *Charaka Samhita, Sushruta Samhita, Ashtanga Hridaya, Bhavaprakasha Nighantu.*[12]
- **Inclusion criteria:** Studies from 1950–2025 on phytochemistry, pharmacology, preclinical, and clinical trials.[13]
- **Exclusion criteria:** Anecdotal reports, duplicates, non-English studies without translation, poor methodology.[14]
- **Review strategy:** Data categorized under Ayurveda, phytochemistry, antimicrobial/pharmacological studies, clinical evidence, and safety.[15]

OBSERVATION AND RESULTS

1. Ayurvedic Perspective

- Neem is *Tikta (bitter), Kashaya (astringent), Sheeta (cooling)*.
- Traditional indications: skin disorders (*Kushtha*), fever, diarrhea, jaundice, dental disorders, and parasitic infections.
- Classified as *Rakta-stambhana* (blood purifier), *Krimighna* (antimicrobial), *Pitta-Kapha hara*.

2. Phytochemistry

Major constituents:

- **Limonoids:** Azadirachtin, Nimbin, Nimbidin, Nimbolide – responsible for antimicrobial and anticancer activity.
- **Flavonoids & Polyphenols:** Antioxidant and anti-inflammatory effects.
- **Triterpenoids:** Anti-inflammatory, hepatoprotective.
- **Tannins:** Astringent and antimicrobial actions.

3. Pharmacological Activities

3.1 Antimicrobial Activity

- Broad-spectrum antibacterial: effective against *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa.*
- Antifungal: effective against *Candida albicans, Aspergillus spp.*
- Antiviral: inhibits herpes simplex, dengue virus, and others in vitro.

3.2 Anti-inflammatory and Immunomodulatory Activity

- Limonoids and triterpenoids modulate pro-inflammatory cytokines (TNF-α, IL-6), reducing systemic inflammation.
- Enhances macrophage function and antibody response.

3.3 Antidiabetic & Metabolic Effects

- Neem extracts reduce blood glucose, improve insulin sensitivity, and protect pancreatic β-cells in animal models.

3.4 Hepatoprotective Effects

- Nimbolide and nimbidin reduce oxidative stress and liver enzyme elevation in toxin-induced hepatotoxicity.

3.5 Anticancer & Antioxidant Properties

- Limonoids induce apoptosis in cancer cell lines; potent free radical scavenging reduces oxidative stress.

4. Clinical Studies

Population	Study Design	Intervention & Dose	Duration	Outcomes / Key Findings	Reference
Patients with oral precancerous	Randomized, controlled	Neem leaf extract 100	8 weeks	Reduced lesion size and microbial	5

lesions (n=40)		mg/day		load	
Healthy volunteers (n=60)	Double-blind, placebo-controlled	Neem mouthwash 2%	4 weeks	Reduced dental plaque, gingivitis, and oral microbial counts	6
Patients with acne (n=50)	Clinical trial	Neem gel 5% topical	12 weeks	Significant reduction in lesion count and inflammation	7
Type 2 diabetes patients (n=45)	Open-label	Neem leaf powder 1 g/day	12 weeks	Reduced fasting and postprandial glucose	8
Skin infection patients (n=35)	Randomized	Neem oil topical	6 weeks	Complete recovery in bacterial and fungal infections	9

5. Safety and Toxicity

- Neem is generally safe at therapeutic doses.
- Mild GI upset reported in some individuals.
- Toxicity reported at high doses (>5 g/day of leaf extract or concentrated seed oil).
- Standardization needed due to variability in phytochemical content.

DISCUSSION

Ayurvedic principles describe Neem as *Krimighna* and *Rakta-shodhana*, reflecting its antimicrobial and blood-purifying actions. Modern pharmacology confirms these properties through identification of limonoids, flavonoids, and triterpenoids, which exhibit antibacterial, antifungal, antiviral, anti-inflammatory, and immunomodulatory activities.[16]

Neem's antimicrobial efficacy against Gram-positive and Gram-negative bacteria, fungi, and viruses supports its traditional indications for skin, oral, and systemic infections. Anti-inflammatory and immunomodulatory effects explain its role in chronic inflammatory and autoimmune disorders. Its antidiabetic, hepatoprotective, and anticancer properties demonstrate multi-targeted actions.[17]

Challenges and gaps: [18]

- Clinical studies are limited in number, sample size, and duration.
- Variability in extract preparation (leaves, seeds, oil, standardized fractions) affects reproducibility.
- Long-term safety data, particularly in pediatric and pregnant populations, are lacking.

Future directions: [19]

- Standardized formulations with defined limonoid content.
- Large-scale randomized controlled trials for skin, oral, and metabolic disorders.
- Exploration in combination therapies (polyherbal formulations).
- Investigations into molecular mechanisms, gut microbiome interactions, and antiviral applications.

Neem represents a successful convergence of Ayurveda and modern pharmacology, validating traditional knowledge while offering avenues for new drug development.[20]

CONCLUSION

Neem (*Azadirachta indica*) is a cornerstone of Ayurvedic medicine with documented antimicrobial, anti-inflammatory, immunomodulatory, hepatoprotective, antidiabetic, and anticancer activities. Phytochemicals such as limonoids, flavonoids, and triterpenoids mediate these diverse pharmacological effects.

Clinical evidence supports its role in oral hygiene, skin infections, acne, and glycemic control, though most studies are small-scale and short-term. Its safety profile is generally favorable at therapeutic doses, with toxicity primarily associated with high-dose seed oil.

Integrative analysis confirms that Ayurveda's conceptualization of Neem as *Krimighna* and *Rakta-shodhana* is aligned with modern pharmacological findings. To translate these benefits into broader clinical practice, standardized formulations, rigorous large-scale trials, and mechanistic studies are

required.

In conclusion, Neem exemplifies the bridge between traditional knowledge and evidence-based medicine, offering a multi-targeted, safe, and efficacious phytotherapeutic resource with potential for systemic health applications, particularly antimicrobial and immunomodulatory therapy.

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