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A Review on Medicinal Uses and Pharmaceutical Application of Neem (Azadirachta Indica A. Juss.)

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Abstract : ***Background:*** *Neem (Azadirachta indica A. Juss.) is an evergreen tree of the Indian subcontinent that has been used in Ayurveda, Unani and Siddha medicine for more than two thousand years, and almost every part of the tree is used traditionally for skin disorders, fever, infections, diabetes, dental care and parasitic disease.* ***Objective:*** *This review summarizes the botany, traditional uses, phytochemistry, pharmacology, pharmaceutical applications and safety of neem, and identifies gaps in the existing evidence.* ***Methods:*** *Published literature on neem was compiled and critically analysed, and the information was organized under botanical, traditional, phytochemical, pharmacological, pharmaceutical and toxicological headings.* ***Results:*** *More than 300 compounds have been isolated from neem, mainly limonoids such as azadirachtin, nimbin, nimbidin, salannin, gedunin and nimbolide, together with flavonoids, polyphenols, polysaccharides and fatty acids. Laboratory and animal studies report antimicrobial, anti-inflammatory, antidiabetic, antimalarial, anticancer, hepatoprotective, wound-healing and immunomodulatory effects, whereas well-designed human trials remain limited. Pharmaceutically, neem is used as a crude drug, standardized extract, topical and oral-care ingredient, source of lead molecules, nanoformulation material and natural excipient. Oral neem oil is toxic to children, and internal use should be avoided during pregnancy.* ***Conclusion:*** *The evidence best supports topical, oral-care and wound-healing uses; standardized preparations, clinical trials, pharmacokinetic studies and strong quality control are needed to develop safe and effective neem-based medicines.*

Keywords: Neem; *Azadirachta indica*; Limonoids; Nimbolide; Azadirachtin; Phytochemistry; Pharmacological Activity; Herbal Drug Delivery; Standardization.

I. INTRODUCTION

Plants have been the base of medicine for most of human history, and they are still an important source of new drug leads. A large share of approved small-molecule drugs is either a natural product or derived from one, and in many countries traditional herbal medicine still provides primary health care. Among the medicinal plants of South Asia, very few have been used as widely as neem. Its Sanskrit name, *nimba*, is linked to the idea of a tree that gives good health, and in Indian homes neem twigs, leaves and oil have long been used for oral hygiene, skin care, household protection and common everyday ailments.[1]

Neem is often called the "village pharmacy" because one tree can provide raw material for so many different preparations. Its bitter taste comes mainly from a group of oxidised triterpenoids called limonoids, and these are also responsible for much of its biological activity.[2] Since the 1960s, interest in neem has gone well beyond traditional

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medicine. Azadirachtin from the seed kernel became one of the best-known botanical insecticides,[3] neem oil found its way into cosmetics and soaps, and neem extracts have been tried in toothpastes, creams and herbal tablets.

The scientific literature on neem is huge, but it is uneven.[4–6] Many studies use crude extracts of unknown composition, the doses differ a lot from study to study, and clinical evidence is far behind laboratory evidence. The aim of this review is to bring together the main findings on the medicinal uses and pharmaceutical applications of neem, to point out where the evidence is strong and where it is weak, and to discuss the technological and regulatory steps needed to turn a traditional remedy into a reliable, standardised medicine.



Figure 1. Neem (*Azadirachta indica* A. Juss.) leaves and twigs.

II. MATERIALS AND METHODS

This review was prepared by compiling and critically analysing published literature on neem (*Azadirachta indica* A. Juss.). Information on its botany, distribution, traditional uses, phytochemical constituents, pharmacological activities, pharmaceutical applications, regulation and safety was collected from the selected articles and organized under separate headings. The evidence was assessed with attention to whether it came from *in vitro* studies, animal studies or human trials.

III. RESULTS

3.1 Botany, Distribution and Cultivation

Azadirachta indica belongs to the mahogany family, Meliaceae. It is a fast-growing evergreen or semi-deciduous tree that usually reaches 15 to 20 m in height, with a rounded crown and a short, straight trunk covered in rough, fissured, greyish-brown bark. The leaves are imparipinnate, 20 to 40 cm long, with 9 to 17 serrate, asymmetrical leaflets. The small white flowers are honey-scented and grow in axillary panicles. The fruit is a smooth, olive-like drupe that turns from green to yellow and usually contains a single seed. The seed kernel is rich in oil, commonly reported at roughly 30 to 45% of kernel weight. The taxonomic and botanical profile is given in Table 1.

Table 1. Taxonomic and botanical profile of neem.

Category	Details
Kingdom/Order/Family	Plantae / Sapindales / Meliaceae
Genus and species	*Azadirachta indica* A. Juss. (syn. *Melia azadirachta* L.)
Common names	Neem, Nimba (Sanskrit), Margosa tree, Indian lilac, Veppam (Tamil), Vepa (Telugu), Limdo (Gujarati), Kadunimb (Marathi)

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Category	Details
Native range	Indian subcontinent and Myanmar; now naturalised in Africa, the Middle East, Southeast Asia, Australia and the Americas
Climate	Hot, semi-arid to sub-humid tropics; tolerates poor soil and drought; sensitive to frost
Parts used	Leaf, bark, flower, fruit, seed kernel, seed oil, twig, gum and root bark

Neem is native to the Indian subcontinent and has been planted widely across the tropics and subtropics. It copes well with dry conditions and degraded soil, which is why it is popular for afforestation, shade and windbreaks. It is propagated mainly by seed, and fresh seeds have to be sown quickly because they lose viability within a few weeks. The chemical composition of neem changes with geography, season, age of the tree, the plant part used and the method of extraction. This natural variation is one of the biggest challenges for pharmaceutical standardisation, which is discussed in Section 3.5.

3.2 Traditional and Ethnomedicinal Uses

Neem appears in classical Ayurvedic texts such as the Charaka Samhita and Sushruta Samhita, where it is described as bitter, astringent and cooling.[1,4] It is recommended for *kushtha* (skin disease), *jwara* (fever), *krimi* (worm infestation), *prameha* (urinary and metabolic disorders) and for wound care. It is also used in the Unani and Siddha systems. Common traditional preparations include leaf paste, leaf juice, bark decoction, neem oil, neem-based ghee (*nimba ghrita*) and powdered mixtures. The *datun*, a neem twig that is chewed and used as a natural toothbrush, is still a familiar practice in many rural areas. The traditional uses of the different plant parts are listed in Table 2.

Table 2. Traditional uses of different parts of neem.

Plant part	Traditional preparation	Traditional use
Leaf	Paste, juice, decoction, poultice	Skin diseases, boils, ulcers, fever, intestinal worms, eye disorders, diabetes
Bark	Decoction, powder	Fever, malaria, skin disease, gum and dental problems
Seed / oil	Cold-pressed oil, ointment	Scabies, ringworm, rheumatic pain, lice, wound dressing, topical antiseptic
Flower	Infusion, dried powder, food use	Digestive tonic, bile and phlegm disorders, appetite stimulant
Fruit	Pulp, juice, dried fruit	Piles, urinary disorders, bronchial complaints, purgative
Twig	Chewing stick (datun)	Oral hygiene, gum health, toothache
Gum	Aqueous solution, powder	Tonic, demulcent, preparation of herbal pills

It is important to remember that traditional use is only a starting point and not proof that something works. Still, traditional knowledge is a very useful guide for choosing plants for scientific study, and for neem several traditional claims, such as antimicrobial, wound-healing, anti-inflammatory and oral-care actions, have been backed up by experimental work.

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3.3 Phytochemistry



Figure 2. Phytochemical investigation of neem constituents.

More than 300 compounds have been isolated from different parts of neem.[2,6] They fall into two broad groups. The first is the isoprenoids, which include diterpenoids and triterpenoids such as the protolimonoids, limonoids, and the azadirachtin-type and nimbin-type compounds. The second is the non-isoprenoids, which include proteins and amino acids, polysaccharides, sulphur-containing compounds, polyphenolics such as flavonoids and their glycosides, tannins, coumarins and aliphatic compounds. The seed kernel is the richest source of limonoids, the leaves are rich in flavonoids and phenolics, and the seed oil is made up mainly of triglycerides of oleic, stearic, palmitic and linoleic acids. The key bioactive constituents and their reported activities are summarized in Table 3.

Table 3. Key bioactive constituents of neem and their reported activities.

Compound	Class	Main source	Principal reported activity
Azadirachtin	Limonoid	Seed kernel	Insect antifeedant and growth regulator; basis of botanical biopesticides; some antimalarial and anticancer reports
Nimbin	Limonoid	Seed, leaf	Anti-inflammatory, antipyretic, antifungal, antihistaminic
Nimbidin	Limonoid mixture	Seed oil	Anti-inflammatory, antiulcer, antibacterial, hypoglycaemic
Salannin	Limonoid	Seed, leaf	Insect antifeedant, anti-inflammatory
Gedunin	Limonoid	Seed, bark	Antimalarial, anticancer (Hsp90 modulation reported in cell studies)
Nimbolide	Limonoid	Leaf, flower	Antiproliferative and pro-apoptotic in many cancer cell lines; anti-inflammatory
Quercetin, kaempferol, rutin	Flavonoids	Leaf, flower	Antioxidant, antimicrobial, anti-inflammatory
β-Sitosterol	Phytosterol	Leaf, seed	Anti-inflammatory, hypolipidaemic
Polysaccharides (GIa, GIb, GIIa)	Polysaccharides	Bark, leaf	Immunomodulatory, anti-inflammatory (reported in animal models)

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Azadirachtin has a highly oxidised and complex structure and is the most studied limonoid, but it is valued mainly for its action on insects. For human medicine, nimbolide, gedunin, nimbin and nimbidin, along with the polyphenols and polysaccharides, have received the most attention. Because the amount of these compounds differs a lot from one sample to another, chemical fingerprinting by HPLC, HPTLC or LC-MS is essential for any pharmaceutical use.

3.4 Pharmacological Activities

Most of the data on neem's pharmacological effects come from *in vitro* and animal studies, so the strength of evidence in each of the sections below should be read with that limitation in mind.

3.4.1 Antimicrobial activity



Figure 3. Neem leaf paste and bark preparations used in traditional and pharmaceutical practice.

Extracts of neem leaf, bark, seed and oil inhibit a broad range of Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Streptococcus mutans*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Salmonella* species.[4,5] They also act on fungi such as *Candida albicans* and the dermatophytes (*Trichophyton* spp.), and some activity against viruses has been reported in cell-culture studies. The antibacterial effect is attributed to limonoids such as nimbidin and nimbin, and to polyphenols that damage microbial membranes and interfere with enzymes. The minimum inhibitory concentrations are usually much higher than those of standard antibiotics, so neem is better seen as a topical or supporting agent than as a replacement for antibiotics.

3.4.2 Anti-inflammatory, analgesic and antipyretic activity

Nimbidin, nimbin, nimbolide and flavonoids have shown anti-inflammatory effects in carrageenan-induced paw oedema, cotton-pellet granuloma and adjuvant arthritis models.[6] The proposed mechanisms include suppression of the transcription factor NF-κB and reduced expression of cyclooxygenase-2, inducible nitric oxide synthase and pro-inflammatory cytokines. Leaf and bark extracts have also reduced fever and pain in animal tests. These findings support the traditional use of neem in arthritis and fever, but controlled clinical studies are scarce.

3.4.3 Antidiabetic activity

Aqueous and alcoholic leaf extracts have lowered blood glucose in streptozotocin- and alloxan-induced diabetic rodents.[5,7] The proposed mechanisms include better peripheral glucose uptake, protection of pancreatic β-cells, inhibition of intestinal α-glucosidase and improved insulin sensitivity. A small number of human studies suggest a glucose-lowering effect, but they are limited by small sample size and short duration. Patients who are already taking antidiabetic drugs should be careful because of a possible additive hypoglycaemic effect.

3.4.4 Anticancer activity

Nimbolide, gedunin, azadirachtin and neem leaf extracts have inhibited proliferation, migration and invasion of cancer cells, including breast, prostate, colon, lung, pancreatic and oral cell lines, and have slowed tumour growth in xenograft

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and chemically induced carcinogenesis models.[6,7] The reported mechanisms include induction of apoptosis through caspase activation, modulation of the p53 and PI3K/Akt pathways, inhibition of NF-κB and angiogenesis, and antioxidant chemoprevention. Nimbolide in particular is considered a promising lead compound. However, no neem-derived anticancer drug has completed clinical development, so these results should be treated as preliminary.

3.4.5 Antimalarial and antiparasitic activity

Gedunin, nimbolide and extracts of leaf and bark inhibit *Plasmodium falciparum in vitro* and reduce parasitaemia in rodent malaria models.[5] Neem preparations have also shown activity against *Leishmania* species, intestinal helminths and ectoparasites such as lice and scabies mites, which matches their traditional use. These effects are encouraging, but at present neem cannot be recommended as a treatment for malaria, a disease in which delay in effective treatment can be fatal.

3.4.6 Hepatoprotective, cardiovascular and gastrointestinal effects

Leaf and bark extracts have protected the liver in rodents exposed to paracetamol, carbon tetrachloride and other toxicants, with lower serum transaminases and reduced oxidative stress markers. Some studies also report lower blood pressure, reduced lipid levels and antiarrhythmic activity. Bark and nimbidin have shown antiulcer effects by reducing gastric acid secretion and strengthening the mucosal barrier.

3.4.7 Wound healing and dermatological use

Topical neem oil, leaf paste and extracts have speeded up wound contraction and epithelialisation in animal models, with increased collagen content and antioxidant enzyme activity.[8] Because neem is both antimicrobial and anti-inflammatory, it is a sensible choice for acne, eczema, scabies, ringworm and minor infected wounds, and it is a common ingredient in herbal soaps, creams and shampoos. Neem oil is also used as a traditional head-lice treatment.

3.4.8 Oral and dental health

Neem twigs, leaf extracts and mouthwashes reduce plaque and gum inflammation and inhibit cavity-causing bacteria such as *Streptococcus mutans* as well as periodontal pathogens. A randomised controlled trial of a neem leaf mouthrinse in patients with chronic gingivitis reported improvement in plaque and gingival indices.[9] Because of this, neem is widely used in herbal toothpastes, chewing sticks and mouthwashes, and it is also being studied in dentistry as an intracanal medicament and a periodontal chip.

3.4.9 Immunomodulatory and reproductive effects

Neem leaf extract and bark polysaccharides have modulated both humoral and cell-mediated immune responses in animal studies, and at some doses they stimulate macrophage activity. In reproductive medicine, neem oil and extracts show spermicidal activity, and vaginal preparations have been studied as non-hormonal contraceptives and as agents against reproductive-tract infections. Animal data also show that high doses of some extracts can reduce fertility, which is an important safety point (see Section 3.6).

3.5 Pharmaceutical Applications

3.5.1 From raw material to standardised extract

Turning neem into a pharmaceutical-grade product needs a controlled series of steps. The raw material first has to be authenticated botanically and tested for contaminants such as heavy metals, pesticide residues, aflatoxins and microbial load. After drying and size reduction, extraction is done with water, ethanol, methanol or ethyl acetate, depending on whether the target is polar polyphenols or less polar limonoids. Seed oil is usually obtained by cold pressing or solvent extraction, and azadirachtin-enriched fractions by solvent partitioning or chromatographic enrichment. Standardisation then depends on marker compounds, for example azadirachtin or nimbin, measured by HPLC together with HPTLC fingerprints, to make sure each batch is consistent.

3.5.2 Conventional dosage forms and products

Representative neem-based pharmaceutical and cosmeceutical products are listed in Table 4.

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Table 4. Representative neem-based pharmaceutical and cosmeceutical products.

Dosage form / product	Neem component	Intended use
Creams, gels and ointments	Oil or leaf extract	Acne, eczema, fungal infections, minor wounds, scabies
Soaps, shampoos, lotions	Oil, leaf extract	Skin hygiene, dandruff, head lice
Toothpastes and mouthwashes	Leaf and bark extract	Plaque, gingivitis, caries prevention
Tablets and capsules	Dried leaf powder or standardised extract	Traditional use for blood sugar support, skin health and as a general tonic
Vaginal creams and pessaries	Oil, polyherbal combinations	Spermicidal and anti-infective preparations (investigational)
Ayurvedic formulations	Leaf, bark, oil, ghrita	Skin disorders, fever, metabolic disorders (classical medicines)
Veterinary products	Leaf, oil, seed cake	Ectoparasite control, wound care in livestock

Topical products are by far the most common and best supported use of neem, because they take advantage of its antimicrobial and anti-inflammatory activity while avoiding systemic toxicity. Oral products made from crude leaf powder are widely sold as dietary or herbal supplements, but their regulatory status and quality differ between countries.

3.5.3 Novel drug delivery systems and nanotechnology

Many neem limonoids and the oil are poorly soluble in water, volatile or unstable in light, and this limits bioavailability and shelf life. Several delivery strategies have been explored to deal with these problems. Nano-emulsions and microemulsions of neem oil improve dispersion and skin penetration. Polymeric and lipid nanoparticles, including chitosan and PLGA systems, protect azadirachtin and nimbolide and allow controlled release. Liposomes, niosomes and phytosomes have been proposed for topical and oral delivery, and hydrogels, nanofibres and films loaded with neem extract have been tested as wound dressings and for periodontal use. Neem leaf extract has also been used as a reducing and capping agent in the "green" synthesis of silver, gold and zinc oxide nanoparticles, which show antibacterial and anticancer activity in laboratory tests. These approaches look promising, but most are still at laboratory stage, and problems of reproducibility, stability, scale-up and nanomaterial toxicology still need to be solved.

3.5.4 Neem as a pharmaceutical excipient

Apart from being an active ingredient, neem gum, which exudes from the bark, has been investigated as a natural excipient. It has been evaluated as a tablet binder, suspending agent, thickener and matrix former for sustained-release tablets, as a low-cost alternative to synthetic or imported gums. Neem seed cake and neem-derived polysaccharides have also been explored in formulation research. Natural excipients are attractive because they are biodegradable, cheap and easily available, but they need careful control of purity, microbial quality and batch variation.

3.5.5 Role in drug discovery

Neem is also a source of lead molecules. Nimbolide, gedunin and related limonoids have been used as scaffolds for semi-synthetic modification to improve potency, selectivity and drug-like properties, and chemoproteomic studies have started to identify the cellular protein targets of nimbolide. At the same time, the agricultural importance of azadirachtin has pushed the development of formulation and stabilisation methods that also help pharmaceutical work. So neem-derived compounds serve both as direct herbal medicines and as chemical starting points for drug design.

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3.5.6 Regulation and quality control

Regulatory rules differ widely between regions. In India, neem-based Ayurvedic medicines are regulated under the Drugs and Cosmetics Act, and pharmacopoeial monographs and standards exist for neem leaf and related materials. In other regions neem products may be sold as traditional medicines, dietary supplements or cosmetics. Good agricultural and collection practices (GACP), good manufacturing practices (GMP), validated analytical methods, defined marker compounds and stability studies are the minimum requirements for consistent quality. Adulteration and the use of undeclared ingredients are still a concern in the herbal market.



Figure 4. Foliage of the neem tree, the raw material source for neem-based products.

3.6 Safety and Toxicity

Neem leaf preparations used in customary amounts and topical neem products are generally considered well tolerated, but a few safety concerns need to be stressed.

Neem oil ingestion. Oral neem (margosa) oil has caused severe toxicity in infants and young children, with vomiting, metabolic acidosis, seizures, encephalopathy and liver injury, a picture resembling Reye's syndrome.[10] Neem oil must never be given by mouth to children and should be stored out of their reach.



Figure 5. Neem oil in a bottle with neem leaves; oral neem oil is hazardous to children.

Pregnancy and fertility. Neem shows antifertility and abortifacient activity in animals, so its internal use should be avoided during pregnancy and by couples who are trying to conceive.

Hypoglycaemia and drug interactions. Neem may add to the effect of antidiabetic medicines and may interact with immunosuppressants, so patients on such therapy should consult a physician.

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Allergy and skin reactions. Contact dermatitis has been reported with topical neem oil in some people, so a patch test is advisable.

Dose, duration and quality. High doses and long-term use of crude extracts have produced liver and kidney changes in animal toxicity studies, and contaminated or adulterated products add further risk.

Overall, the available data suggest a favourable safety margin for topical use and traditional leaf use, but systematic long-term human safety studies are lacking.

3.7 Literature Survey

The medicinal properties and pharmaceutical applications of neem have been extensively discussed in the scientific literature. Previous studies have focused on its traditional medicinal uses, phytochemical constituents, pharmacological activities, safety and potential applications in modern medicine. Key studies are summarized in Table 5.

Table 5. Summary of key literature on neem.

Sr. No.	Author(s) and year	Key finding	Ref.
1	Schmutterer, 1990	Investigated the properties and potential of natural pesticides from neem and established the importance of azadirachtin in botanical pest control, an application that also showed the broader industrial value of neem constituents.	[3]
2	Sinniah and Baskaran, 1981	Reported cases of poisoning associated with ingestion of margosa (neem) oil, highlighting the need for safety evaluation, dosage control and care in the route of administration.	[10]
3	Biswas et al., 2002	Reviewed the biological activities and medicinal properties of neem, including antimicrobial, anti-inflammatory and antidiabetic effects, and its potential in preventing and managing disease.	[4]
4	Brahmachari, 2004	Presented a comprehensive review of neem and its chemical constituents, particularly limonoids and their biological activities, and its importance in natural product research.	[2]
5	Subapriya and Nagini, 2005	Reviewed the medicinal properties of neem leaves, discussing their phytochemical composition and reported antioxidant, antimicrobial and anticancer activities.	[7]
6	Botelho et al., 2008	Conducted a double-blind, randomized, controlled trial of a neem-leaf mouthrinse in chronic gingivitis and reported improved plaque and gingival indices.	[9]
7	Kumar and Navaratnam, 2013	Examined the historical development and contemporary medicinal uses of neem, linking traditional practice with modern scientific investigation.	[1]
8	Tiwari et al., 2014	Reviewed the potential of neem in safeguarding human and animal health, including veterinary and human healthcare applications.	[8]

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Sr. No.	Author(s) and year	Key finding	Ref.
9	Alzohairy, 2016	Reviewed the therapeutic role of neem and its active constituents in disease prevention and treatment, emphasizing the need for further scientific evaluation.	[5]
10	Gupta et al., 2017	Explored the traditional importance of neem and the molecular mechanisms of its biological activities, including effects on inflammatory pathways.	[6]

IV. DISCUSSION

Neem is a tree with a very long history of medicinal use in India, and almost every part of it is used in traditional practice. More than 300 compounds have been isolated from it, with limonoids such as nimbolide, gedunin, nimbin and nimbidin, flavonoids and polysaccharides getting the most attention for human health. Laboratory and animal studies support antimicrobial, anti-inflammatory, antidiabetic, wound-healing, anticancer, antimalarial and other effects, but human trials are few, and only oral and dental care and skin use have reasonably good support so far. Pharmaceutically, neem is used in creams, soaps, toothpastes, mouthwashes, tablets and Ayurvedic formulations, and it is also being studied in nanoformulations, as a natural excipient and as a source of lead molecules. Product quality varies widely, and safety needs attention, especially because neem oil taken by mouth is dangerous for children and neem should be avoided internally during pregnancy.

The existing literature demonstrates that neem contains several biologically active compounds and has potential applications in antimicrobial preparations, oral healthcare, dermatology and pharmaceutical formulation. However, much of the available evidence is based on laboratory experiments and animal studies. Variations in plant composition, extraction methods, dosage and product quality also create challenges for standardization. Further clinical trials, pharmacokinetic investigations and systematic toxicity studies are needed to establish the safety, efficacy and therapeutic value of standardized neem preparations.

4.1 Challenges and Future Perspectives

Despite the huge volume of laboratory research, neem has not yet produced a clinically approved, neem-derived drug for systemic disease. Several obstacles, and the opportunities that come with them, stand out.

The first is clinical evidence. Well-designed, adequately powered randomised controlled trials with standardised preparations are needed for the most promising uses, which are oral and dental health, skin disease and glycaemic control. The second is standardisation, since the wide variation in chemical composition calls for fingerprint-based standards, defined marker compounds and reproducible extraction processes. Third, very little is known about the pharmacokinetics of neem limonoids in humans, especially nimbolide and gedunin, including how they are absorbed, metabolised and distributed in tissues.

Delivery technology is another area. Nanoformulations, hydrogels and targeted systems may overcome poor solubility and instability, but they need proper toxicology and scale-up studies. Modern chemical biology and systems pharmacology can also help identify the protein targets of the major limonoids, which would support rational lead optimisation. Finally, cultivation, quality seed sources and fair use of traditional knowledge should go hand in hand with any commercial development.

V. CONCLUSION

Neem is one of the most extensively studied medicinal trees, and the experimental literature supports many of its traditional uses, particularly in antimicrobial, anti-inflammatory, wound-healing and oral-care applications. Its pharmaceutical importance rests on a chemically rich profile of limonoids, flavonoids and polysaccharides, a long

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record of topical use, and its potential as a source of lead compounds, delivery-system materials and natural excipients. At the same time, most of the evidence is preclinical, product quality is variable, and some preparations, especially neem oil taken by mouth, can be dangerous. The next stage of neem research should focus on standardised preparations, well-designed clinical trials, pharmacokinetic studies and strong quality control, so that this traditional plant can be turned into safe and effective modern medicines.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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