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Review Article

***Tectona grandis* L. F. (Teak): A Comprehensive Review of Its Phytochemistry, Pharmacological Potential, Biotechnological Applications, and Future Prospects**

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ABSTRACT

Tectona grandis L.f. is a well-known tropical hardwood species of great economic and pharmacological importance. Research on *T. Grandis* has been extended beyond its economic value in recent years, notably into the areas of phytochemicals, biological activities, and environmental applications. Data from both contemporary and classical studies has been collated here to present an integrated overview of teak's secondary metabolites, methods of extraction, pharmacology, and molecular perspectives. Active principals comprising flavonoids, phenolics, terpenoids, and quinones have been noted to exhibit activities such as antioxidant, antimicrobial, anticancer, hepatoprotective, and anti-inflammatory. More current applications in nanotechnology, bioremediation, and sustainable material science highlight teak's versatility. Additionally, genetic adaptations against biotic and abiotic stresses can also be elucidated from transcriptomic studies. Safety, toxicity, patent trends, and research gaps have been addressed in the article with the view of guiding future pharmacognostic research on *T. Grandis*.

INTRODUCTION

Plants have traditionally been a vital source of pharmacologically active compounds and have constituted the backbone of both traditional and modern therapeutics. Among these, *Tectona grandis* L.f., known as teak, from the family Lamiaceae, is especially valued for its very durable timber and varied bioactive components.

Teak has traditionally been used in Ayurveda, Unani, and folk medicine for its leaves, bark, roots, and seeds, which show several therapeutic results. Recent studies on phytochemicals indicate that this plant possesses flavonoids, phenolics, quinones, and terpenoids, which are responsible for its pharmacological activity.

Because of the current need for plant-derived drugs and natural bioresources, a review of the

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phytochemical and pharmacological profile of teak is extremely essential to support its application in evidence-based medicine.

BOTANICAL AND ETHNOPHARMACOLOGICAL BACKGROUND

Tectona grandis is a large deciduous tree distributed across South and Southeast Asia, ranging from India to Myanmar, Thailand, and Indonesia.

The species grows up to an altitude of 1200 meters and prefers well-drained alluvial soils; rainfall ranges from 1200-2500 mm annually (Fathima et al., 2024). The wood of the tree is golden-brown, oily, and very resistant to decay.

In traditional medicine, teak has been used as an antipyretic, diuretic, and wound-healing agent, and its leaves are employed in the treatment of bronchitis, skin disorders, and diabetes (Budianto et al., 2023; Goswami et al., 2009). Ethnobotanical records from India and Southeast Asia particularly stress its application in treating inflammation, liver ailments, and microbial infections.

PHYTOCHEMICAL CONSTITUENTS

Phytochemical studies using GC–MS, HPLC, and LC–MS methods have shown the presence of flavonoids, phenolic acids, quinones, terpenoids, and fatty acids in *T. Grandis*.

The main bioactive compounds comprise lapachol, tectoquinone, betulinic acid, quercetin, gallic acid, luteolin, and squalene. The phenolic and flavonoid contents of the leaf extracts were estimated to be 4.3% and 3.9% w/w, respectively. These constitute the antioxidant and antimicrobial potentials of the plant.

Compound	Class reported	Biological Activity
Lapachol	Naphthoquinone	Antitumor, antiulcerogenic
Quercetin	Flavonoid	Antioxidant, anti-inflammatory
Gallic acid	Phenolic acid	Antimicrobial, hepatoprotective
Betulinic acid	Triterpenoid	Cytotoxic, anti-HIV
Squalene	Steroid precursor	Antioxidant, skin protective
Luteolin	Flavonoid	Antidiabetic, neuroprotective.

EXTRACTION AND ANALYTICAL TECHNIQUES

The extraction of bioactive compounds from teak is done using methanol, ethanol, and water. Various analytical methods have been employed, such as HPLC, GC–MS, and LC–MS (Asdaq et al., 2022).

Recent advances include the use of reversed-phase HPLC for quantification of phenolics and LC–MS/MS in identifying flavonoid glucuronides.

These techniques ensure reproducibility and precise identification of secondary metabolites, which are essential in pharmacognostic studies.

PHARMACOLOGICAL ACTIVITIES

Tectona grandis shows a wide spectrum of pharmacological activities, evidenced by in vitro and in vivo studies. The methanolic and aqueous extracts exert strong antioxidant activities due to phenolic compounds (Budianto et al., 2023).

Lapachol and its derivatives have been found to be cytotoxic and antitumour agents (Goswami et al., 2009). Leaf extracts facilitate the processes of wound healing and hepatoprotection (Asdaq et al., 2022). Besides, antibacterial activity has also been



reported against *Staphylococcus aureus*, *E. Coli*, and *Pseudomonas aeruginosa*.

Antimicrobial and antibacterial: The extracts of teak exhibit activity against bacteria, including *Staphylococcus aureus*.

Anti-inflammatory: The leaves and bark have been traditionally used for various inflammatory conditions, supported by research demonstrating activity against pro-inflammatory cytokines such as TNF- α and IL-1 β .

Antioxidant: The extracts from *T. grandis* exert strong antioxidant capabilities that may protect against cellular damage.

Antidiabetic: Evidence suggests that teak has the potential to control blood sugar levels through possible α -glucosidase inhibition, an enzyme involved in glucose metabolism.

Wound healing: The extracts of leaves have shown significant activity in wound healing, improving tissue regeneration and enhancing the tensile strength of newly formed skin tissue.

Anti-asthmatic: The plant possesses an antiasthmatic action, possibly explained by its antihistaminic and anti-inflammatory effects.

Anthelmintic: The activity of *T. grandis* against parasitic worms is supported by traditional uses and studies.

MOLECULAR AND TRANSCRIPTOMIC INSIGHTS

Recent transcriptomic studies have identified that teak, upon infestation by defoliator herbivores, triggers the activation of stress-responsive genes like ZFP2, ERF-1, and CAT1 (Venkatesh et al., 2024).

These genes enhance lignin synthesis and antioxidant enzyme activity, thus conferring resistance to oxidative stress. Other physiological responses reported are increased catalase and polyphenol oxidase levels, while chlorophyll is decreased under stress conditions. Such findings pinpoint teak's potential in the direction of genetic improvement related to pest-resistant varieties.

BIOTECHNOLOGICAL AND INDUSTRIAL APPLICATIONS

Beyond pharmacology, *T. Grandis* has become a promising source for nanotechnology and green chemistry.

Biosynthesized silver and gold nanoparticles, obtained from teak leaf extracts, showed considerable antimicrobial and anticancer activities. Pigments from teak leaves also offer their use as natural colorants in cosmetics and textiles, which act as environmentally friendly alternatives to artificial dyes. Teak leaf powder acts as an efficient adsorbent in dye and pollutant removal from industrial effluents.

TOXICOLOGY AND SAFETY

In fact, toxicological assessments have demonstrated that the aqueous and methanolic extracts of *T. Grandis* are safe up to 5000 mg/kg in rodents, without mortality or even behavioral changes (Asdaq et al., 2022).

On the other hand, occupational exposure to teak dust may cause contact dermatitis or respiratory irritation (Verma et al., 2001). Thus, while extracts are pharmacologically safe, wood processing requires protective measures.

PATENTS AND COMMERCIALIZATION

Patents in the literature are for teak-derived compounds used in formulations for wound



healing, antioxidant cosmetics, and herbal hepatoprotectives. Certain patented compositions combine T. Grandis extracts with curcumin or aloe vera to elicit synergistic activity. As more and more patents are being granted, it indicates the increasing awareness of teak as a multifunctional bioresource.

CONCLUSION

Tectona grandis L.f. is a rich source of pharmacologically active compounds with established antioxidant, antimicrobial, hepatoprotective, and anti-inflammatory activities. The approaches of molecular biology, green synthesis, and pharmacognostic studies created greater insight into the bioactivity of this species.

Standardization of extracts, clinical validation, and exploration of metabolites that have so far been minimally studied are priorities for future research. This convergence between biotechnology and traditional medicine places teak as a sustainable model for drug discovery and ecological innovation in view.

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