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"A Review On the Piper Betel Leaf Plant "

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Abstract

Piper betle L. (Family: Piperaceae) is an economically and medicinally significant plant widely cultivated in tropical Asia, particularly India. Traditionally, its leaves are valued for aromatic, stimulant, and therapeutic properties and are used in Ayurveda, Unani, and Siddha systems of medicine. Phytochemical studies reveal that P. betle leaves contain diverse bioactive compounds, including phenolics, flavonoids, alkaloids, terpenoids, and essential oils rich in eugenol, hydroxychavicol, and chavibetol. These compounds are responsible for a broad spectrum of pharmacological activities, such as antimicrobial, antioxidant, anti-inflammatory, antidiabetic, anticancer, antiulcer, and antihistaminic effects. Scientific evidence supports its traditional applications in oral hygiene, wound healing, and gastrointestinal and respiratory health. This review consolidates current literature on the botany, phytochemistry, traditional uses, and pharmacological properties of Piper betle L., highlighting its therapeutic potential and emphasizing the need for further pharmacognostic and clinical investigations.

Keywords

Piper betle leaf, Phytochemistry, Traditional medicine, Pharmacological activities.

I. Introduction

Piper betel L. (Family: Piperaceae) is a perennial, evergreen, and dioecious creeper cultivated mainly in India and other tropical regions of Asia. (1) It is an economically and culturally important plant, valued for its aromatic heart-shaped leaves, which are traditionally used for both mastication and medicinal purposes. The plant is believed to have originated in the Malaysian-Indonesian region and is now widely cultivated across India, Sri Lanka, Bangladesh, Thailand, and Malaysia .(2)In traditional systems of medicine such as Ayurveda, Unani, and Siddha, the leaves of Piper betel are described as carminative, stimulant, antiseptic, and aromatic. They are used to treat ailments like bad breath, cough, indigestion, wounds, and inflammation. (3) The Sanskrit texts refer to the plant as Nagavalli or Tambula, signifying its long-standing use in Indian culture and medicine.Phytochemical investigations have revealed that Piper betel leaves contain a variety of bioactive compounds, including eugenol, chavibetol, hydroxychavicol, chavicol, estragole, allylpyrocatechol, and terpenes, as well as flavonoids, alkaloids, and tannins .(4) These compounds contribute to its diverse pharmacological profile. Essential oils from betel leaves, rich in phenolic constituents, are responsible for their characteristic aroma and biological effects.Scientific studies have demonstrated that Piper betel exhibits a wide range of pharmacological activities, such as antimicrobial, antioxidant, anti-inflammatory, antidiabetic, anticarcinogenic, hepatoprotective, and immunomodulatory effects .(5)These activities have been attributed to the synergistic action of its phytochemicals, particularly phenolic compounds like hydroxychavicol and eugenol, which exhibit strong free radical scavenging and antimicrobial properties.(5)

II. Vernacular Name

- Sanskrit: Nagavalli, Tambula
- Hindi: Paan
- Marathi: Pan

- Bengali: Paan
- Tamil: Vetrilai
- Telugu: Tamalapaku
- Malayalam: Vettila
- Kannada: Veeleyadele
- Assamese: Tambul
- Sinhala (Sri Lanka): Bulath
- Thai: Plu
- Indonesian / Malay: Sirih
- English: Betel leaf.(6)

III. Toxonomical classification

Betel leaf comes from the Betel pepper plant , Piper betel,which is a member of the Piperaceae family that also includes pepper and kava.The betel pepper plant is an evergreen vine that is native to Southeast Asia and is most likely to Malaysia.

- Kingdom: Plantae
- Phylum: Tracheophyta
- Family: Magnoliopsida
- Order: Piperales
- Genus: Piper
- Species:P. Betle L. (7)

IV. Microscopic Description

Stomata of the cyclocytic variety are predominant on the abaxial (lower) surface of the Piper betle's hypostomatic leaf. Its surface bears both glandular trichomes (pearl glands) and non-glandular trichomes, which are involved in secretion and protection. The mesophyll is dorsiventral, consisting of palisade parenchyma on the adaxial side and spongy parenchyma on the abaxial side, facilitating efficient photosynthesis. Secretory cells are present in the cortex and vascular bundles, contributing to the plant's defense mechanisms, and the vascular bundles are collateral and closed, with the xylem positioned adaxially and the phloem positioned abaxially.(8)

V. Macroscopic Description

The leaf of Piper betle is heart-shaped (cordate), measuring approximately 12–18 cm in length and 9–11 cm in width, with a glossy dark green upper surface and lighter green underside. It has a smooth, glabrous texture, an entire margin, and a stout petiole. The leaf emits a characteristic aromatic odor and pungent taste due to essential oils. Microscopic features include cyclocytic stomata, capitate glandular trichomes, and cortical fibers embedded in collenchyma. These traits are consistent across various varieties, with some regional variations in size and aroma .(9)

VI. Phytochemical Review

The phytochemical composition of Piper betle leaf is exceptionally rich and diverse, comprising numerous bioactive constituents that contribute to its medicinal properties. Various studies and reviews have reported that Piper betle leaves contain major classes of phytochemicals, including alkaloids, flavonoids, phenolics, tannins, terpenoids, steroids, glycosides, saponins, and coumarins .(1) The essential oil of Piper betle leaf is dominated by phenolic compounds such as hydroxychavicol, eugenol, chavibetol, chavicol, safrole, and estragole, which are mainly responsible for its characteristic aroma and potent pharmacological activities .(10) Furthermore, volatile compounds like 1,8-cineole, α-pinene, β-pinene, α-humulene, β-caryophyllene, and phytol have been detected, exhibiting strong antioxidant and antimicrobial properties .(11)The leaf also contains fatty acids such as hexadecanoic acid (palmitic acid) and stearic acid, along with secondary metabolites like 3-butylphenol, bis-hydroxychavicol dodecanoyl ester, and allyl-3-methoxy-4-hydroxybenzene, which enhance its therapeutic efficacy .(12) Quantitative analyses have revealed that hydroxychavicol may constitute up to 40–50% of the leaf's essential oil, making it a major active component responsible for the plant's antioxidant, antimicrobial, anticancer, and anti-inflammatory properties .(13) Overall, these diverse phytochemicals make Piper betle a pharmacologically valuable medicinal plant, widely recognized in traditional medicine for treating infections, inflammation, and oxidative stress-related disorders .(14)

VII. Traditional uses

Piper betel leaf (Piper betle L.) has been widely used in traditional medicine for its therapeutic and cultural applications. The leaves are commonly chewed to improve oral hygiene and freshen breath .(15) and are used to treat gum swelling and halitosis .(16) They act as a digestive aid, helping with indigestion, constipation, and flatulence due to their carminative properties .(17) Traditionally, betel leaves have been used to relieve respiratory ailments such as coughs, bronchitis, and asthma .(15) Topically, the leaves are applied for wound healing, treatment of boils, abscesses, cuts, and various skin infections, as well as to alleviate pain and inflammation, including headaches and rheumatism .(16) Furthermore, betel leaf is recognized for its aphrodisiac effects and has been utilized in folk medicine for contraceptive purposes .(17) Beyond medicinal uses, the leaves play a significant role in cultural and ceremonial practices, including religious rituals and weddings .(15)

VIII. Pharmacological Activity

1.Antimicrobial Activity:

The Piper betle leaf exhibits significant antimicrobial properties attributed to its rich content of phenolic and aromatic compounds such as hydroxychavicol, chavibetol, eugenol, and allylpyrocatechol. Several studies summarized in reviews have reported that extracts of P. betle possess broad-spectrum antibacterial activity against both Gram-positive and Gram-negative bacteria including Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, and Klebsiella pneumoniae.(18) The antimicrobial mechanism involves the disruption of bacterial cell wall permeability and inhibition of essential metabolic enzymes, leading to cell death .(4) The methanolic and ethanolic extracts of P. betle have also been reported to exhibit strong antifungal effects against Candida albicans and Aspergillus niger, with hydroxychavicol being identified as the main antifungal agent .(15)Furthermore, essential oil derived from P. betle leaves shows potent inhibitory activity against oral pathogens such as Streptococcus mutans and Porphyromonas gingivalis, supporting its traditional use in oral hygiene and mouth fresheners .(19) The antimicrobial potency of P. betle leaf extract varies depending on the solvent used, with methanolic and ethanolic extracts showing higher activity than aqueous extracts due to greater solubility of active phytochemicals .(20) These findings confirm the leaf's traditional medicinal use in preventing infections and promoting oral and wound healing.

2.Antiinflammatory Activity

The bioactive components of the Piper betle leaf, such as eugenol, chavicol, and hydroxychavicol, play a significant role in the herb's potent anti-inflammatory properties. By suppressing the expression of the cyclooxygenase-2 (COX-2), inducible nitric oxide synthase (iNOS), and nuclear factor-kappa B (NF-B) pathways, these compounds inhibit inflammatory mediators .(21) In animal models, oral administration of P. betle extract significantly reduced carrageenan-induced paw edema and cotton pellet-induced granuloma formation, showing both acute and chronic anti-inflammatory responses .(22) The extract was also reported to decrease lipid peroxidation and enhance the activities of antioxidant enzymes, thereby minimizing oxidative damage associated with inflammation .(23) These findings support the traditional use of P. betle in the treatment of inflammatory conditions by indicating that it has a dual mechanism of action, inhibiting pro-inflammatory mediators and increasing antioxidant defenses simultaneously.

3.Antihistaminic Activity

Due to the presence of bioactive components like eugenol, chavibetol, and hydroxychavicol, Piper betle leaf has been shown to have significant antihistaminic activity. (24) these substances reduce histamine-induced inflammatory responses by inhibiting histamine release from mast cells. In animal models, ethanolic extracts of P. Betle have been shown to significantly reduce histamine-induced bronchospasm and paw edema, indicating that they have potent H1-receptor antagonistic activity .(25) Additionally, the extract prevents degranulation and the subsequent release of histamine and other inflammatory mediators by stabilizing mast cell membranes .(26) This mechanism suggests that P. Betle may act both by direct inhibition of histamine receptors and through suppression of histamine biosynthesis, validating its traditional use in managing allergic and respiratory conditions such as asthma and rhinitis.

4.Antioxidant Activity

Due to its abundance of phenolic and flavonoid compounds like eugenol, chavicol, and hydroxychavicol, which effectively neutralize free radicals and prevent oxidative damage to biomolecules, the leaf of the piper betle has potent antioxidant properties .(27) P. betle's methanolic extract has been shown to have potent reducing and radical-quenching properties, as evidenced by its significant DPPH, FRAP, and nitric oxide scavenging activities .(28) The antioxidant potential of P. betle is further supported by its ability to inhibit lipid peroxidation in liver and brain tissues, thereby protecting cellular membranes against oxidative stress .(29) In addition, it protects against degenerative and inflammatory diseases by enhancing endogenous defense enzymes like catalase and glutathione peroxidase through its antioxidant mechanism.

5.Antimutagenic Effect

Piper betle leaf has been recognized for its antimutagenic and genoprotective effects since early pharmacological studies. Aqueous and ethanolic leaf extracts were shown to inhibit mutagen-induced DNA damage in both bacterial and mammalian cell assays, including the

Ames test and micronucleus formation .(30) This activity is largely attributed to phenolic compounds such as hydroxychavicol and eugenol, which act as potent free radical scavengers and reduce oxidative stress–mediated DNA strand breaks .(31) Furthermore, P. betle has been reported to modulate xenobiotic-metabolizing enzymes, including cytochrome P450 and glutathione S-transferase, thereby enhancing the detoxification of mutagenic compounds.(32) Collectively, these findings establish Piper betle as a promising natural antimutagenic agent with potential applications in chemoprevention.

6.Antibacterial Activity

The piper betle leaf has a lot of antibacterial power against a lot of harmful microorganisms. Extracts, essential oils, and bioactive compounds from the leaves have been shown to inhibit both Gram-positive and Gram-negative bacteria, including multidrug-resistant strains such as Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa. According to studies (33) aqueous and ethanolic leaf extracts effectively inhibit the growth of S. aureus, indicating their potential as a natural antibacterial agent. The antibacterial efficacy is attributed to the rich phytochemical composition of the leaves, including phenols, flavonoids, essential oils, alkaloids, saponins, tannins, and steroids, which collectively contribute to its bactericidal properties .(34) These results lend credence to the idea that Piper betle leaf extracts could be used as a natural treatment for bacterial infections.

7.Antiulcer Activity

Numerous experimental studies have demonstrated that the leaf of the piper betle has significant antiulcer activity. In animal models, ethanol and hydroalcoholic extracts of the leaves were found to prevent gastric lesions, boost antioxidant defenses, and lessen oxidative damage, all of which indicate that they have potent gastroprotective effects .(35) In addition, these extracts were as effective as standard antiulcer medications like ranitidine in a number of experimental ulcer models in rats .(36) Bioactive compounds like phenols, flavonoids, and essential oils, which play a role in free radical scavenging, cytoprotection, and modulation of gastric secretions, are responsible for the antiulcer activity. The traditional use of Piper betle as a natural gastroprotective agent is supported by these findings taken as a whole.

8.Antidiabetic Activity

In both experimental and review studies, the leaf of the piper betle has been shown to have significant anti-diabetic activity. In streptozotocin- and alloxan-induced diabetic rats, ethanolic and aqueous extracts of the leaves were found to reduce blood glucose levels in a dose-dependent manner, comparable to that of standard medications like glibenclamide .(37) The extracts also improved lipid profiles by normalizing elevated liver enzymes and lowering triglycerides, total cholesterol, LDL, and VLDL while raising HDL levels.(38) These antidiabetic effects are largely attributed to bioactive phenolic compounds such as hydroxychavicol and eugenol, which possess antioxidant properties that reduce oxidative stress, a key contributor to diabetes pathogenesis .(39) The use of Piper betle as a natural antidiabetic with potential therapeutic benefits is supported by these findings taken as a whole.

9.Anticancer Activity

In numerous preclinical studies, the leaf of the piper betle has demonstrated significant anticancer potential. Hydroxychavicol, the primary bioactive component of the leaf, shows antiproliferative activity against a number of cancer cell lines, including prostate, glioma, breast, and colorectal cancers as well as chronic myelogenous leukemia (CML) .Modulation of mitochondrial membrane potential, activation of the c-Jun N-terminal kinase (JNK) and mitogen-activated protein kinase (MAPK) pathways, induction of endoplasmic reticulum (ER) stress, and generation of reactive oxygen species (ROS) are some of the mechanisms by which the anticancer effects are mediated.(40) Additionally, dose-dependent reductions in cell viability have been observed for both aqueous and ethanolic Piper betle leaf extracts' cytotoxic effects on KB oral carcinoma cells .(41) Collectively, these findings support the potential of Piper betle leaf and its bioactive constituents as natural anticancer agents.

IX. Conclusion

Piper betle L. is a medicinally important plant with extensive therapeutic and ethnomedicinal applications. Its leaves are rich in bioactive phytochemicals, particularly phenolic compounds such as hydroxychavicol and eugenol, which exhibit notable antimicrobial, antioxidant, anti-inflammatory, and antidiabetic activities. Traditional uses for oral, respiratory, and gastrointestinal health are strongly supported by modern pharmacological evidence. The synergistic effects of its diverse constituents underlie its therapeutic efficacy. Despite extensive preclinical research, further studies are warranted to isolate active compounds, elucidate their molecular mechanisms, and validate efficacy and safety through clinical trials. Overall, Piper betle L. holds significant promise as a source of natural therapeutic agents and functional herbal formulations.

X. References

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