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ANALYZING THE ANTIMICROBIAL PROPERTIES OF PIPER BETLE L. IN COMBATING MICROBIAL INFECTIONS.

Biotechnology

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ABSTRACT

Piper betle L., commonly known as betel vine or Piper betel Blanco, is a significant cash crop that belongs to the Piperaceae family. It serves both medicinal and economic functions, often referred to as "green gold." Traditionally, extracts from betel leaves were frequently incorporated into food preparation. The therapeutic properties of betel leaves and their components have been acknowledged for a long time, including their ability to aid digestion, address inflammatory diseases, enhance wound healing, and eliminate bad breath. Extracts and essential oils derived from betel leaves are rich in various bioactive compounds, including polyphenols and terpenes. The presence of phenolic compounds positions betel leaves as a crucial medicinal herb. Furthermore, these leaves are abundant in various phytochemicals and nutritional elements known as bioactive compounds (BAC). These compounds demonstrate several significant pharmacological properties, including antibacterial, antidiabetic, antiulcer, anti-inflammatory, and anticancer activities.

KEYWORDS

Piper betle L., betel leaves, antimicrobial properties, nutritional elements

INTRODUCTION

In India, Piper betle L., often referred to as Paan, is part of the Piperaceae family. Approximately 40 of the more than 100 varieties of this plant are cultivated in India and other Southeast Asian countries. Betel is a dioecious, evergreen herb that thrives in warm, humid conditions (Verma A et al., 2004). The heart-shaped leaves have an aromatic quality attributed to their essential oil content, and their flavor can vary from sweet to pungent (Pradhan D et al., 2013). There are eight categories of phytochemicals found in these leaves: phenols, glycosides, alkaloids, flavonoids, steroids, saponins, tannins, and terpenoids. In India, the annual consumption of betel leaves ranges between 15 and 20 million, with the country cultivating them across 50,000 hectares annually (Mazumder et al.,2016). This cultivation yields a total value of 9 billion rupees. The main bioactive compounds present in betel leaves include β-caryophyllene, eugenol, hydroxychavicol, estragole, 1,8-cineole, α-pinene, β-pinene, caryophyllene, and hydroxy catechol (Biswas et al., 2022) (Parkpoom et al.,2016).

Nutritional Composition

Betel leaves are considered highly nutritious, offering a rich supply of essential vitamins and minerals (Bhaviskar et al., 2017). They also contain enzymes such as catalase and diastase, along with notable levels of essential amino acids like arginine, lysine, and histidine (De & P et al., 2018). These leaves are packed with bioactive compounds, trace vitamins and minerals, essential oils, and fast-acting phytochemicals, which contribute to their beneficial effects on the heart, liver, and brain (Pradhan D et al., 2013).

In particular, betel leaves are abundant in flavonoids and polyphenols (Taukoorah et al., 2016). When consumed with slaked lime, the bioavailable calcium content increases. The potassium nitrate concentration in dried leaves ranges between 0.26% and 0.42%, which is considered substantial (Annamalai et al., 2016).

Component	Quantity (per 100 gm)
Moisture	85-90%
Chlorophyll	0.01-0.25%
Protein	3-3.5%
Minerals	2.3-3.3%
Fat	0.4-1.0%
Fibre	2.3%
Vitamin C	0.005-0.01%
Carbohydrate	0.5-10%
Iodine	3.4 µg/100 mg
Thiamine	10–70 µg/100 g
Phosphorous	0.05–0.6%
Iron	0.005–0.007%
Vitamin A	1.9–2.9 mg/100 g
Riboflavin	1.9–30 µg/100 g
Potassium	1.1–4.6%
Tannin	0.1–1.3%
Nitrogen	2.0–7.0%
Nicotinic acid	0.63–0.89 mg/100 g
Energy	44 kcal
Calcium	0.2–0.5%

Phytochemical Properties

Betel leaves contain a diverse array of phytochemicals such as alkaloids, phenolic compounds, flavonoids, essential oils, tannins, and steroids (Satyal P, et al., 2012)

ACTIVE COMPOUNDS	PROPERTIES
Flavonoids [quercetin, kaempferol, and myricetin]	possess antioxidant, anti-inflammatory, and antimicrobial qualities, enhancing their therapeutic potential.
Phenolics [caffeic and ferulic acids]	provide antioxidant effects, boosting their health benefits.
Essential oils [eugenol, chavicol, cineole, and terpenes]	contribute to aroma and flavor while offering antimicrobial and anti-inflammatory advantages
Tannins	These compounds impart an astringent flavor and provide antioxidant and antimicrobial properties.
Steroids [β-sitosterol]	are associated with health benefits such as cholesterol reduction and inflammation alleviation.
Vitamins and Minerals [vitamin C, calcium, iron, and phosphorus]	improve their nutritional profile.

Chewing betel leaves stimulates saliva production, which in turn increases the presence of enzymes like peroxidase and lysozyme, along with antibodies that help inhibit bacterial growth in the mouth. Additionally, it promotes the secretion of gastric juices and pancreatic lipase, aiding the digestive process. The leaf's bioactive compound content varies depending on factors such as plant genotype, seasonal changes, and environmental conditions

Extraction Table

Betel Leaf Extracts	Method	Extracted Compounds	References
Ethanol	Ultrasound assisted extraction (UAE)	Eugenol, isoeugenol, 4-allyl1, 2-diacetoxybenzene, and Hydroxychavicol.	(Ali et al., 2018)
Chloroform	Nuclear Magnetic resonance (NMR)	Dis-methylene squalene deoxy-para-Dione-A, and 1-n-dodecanyloxy resorcinol.	(Atiya et al., 2018)

70% deionized water and ethanol	Soxhlet apparatus	Alkaloids, alcohols, terpenoids, flavonoids, fatty acids, coumarin, phenols, and organic acids	(Foo et al.,2015)

Antimicrobial Properties

Betel leaf extract is rich in sterol-based compounds (Stuper-Szablewska et al., 2023), with its most prominent attribute being its antimicrobial potential. Research indicates that betel leaf exhibits antimicrobial activity against various pathogenic bacteria such as Streptococcus pyogenes, Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa. It also shows bactericidal action against urinary tract pathogens including Enterococcus faecalis, Citrobacter koseri, Citrobacter freundii, and Klebsiella pneumoniae (Chakraborty D & Shah B et al., 2011).

The antimicrobial effect is largely credited to bioactive constituents like chavicol, chavibetol, allyl pyrocatechol, chavibetol acetate, and allyl pyrocatechol diacetate, which make betel leaf a promising natural preservative (Roy, A., & Guha, P et al., 2021). The rising threat of antimicrobial resistance, coupled with limited vaccine availability, highlights the significance of such natural alternatives (Hossain S, Urbi Z, Karuniawati H, et al., 2021).

Additionally, studies testing extracts from betel leaf stalks revealed potent antimicrobial activity against several human pathogens, including Staphylococcus aureus, Vibrio cholerae Ogawa, Klebsiella aerogenes, and Diplococcus pneumoniae (Nair R & Chanda S et al., 2008). Among the solvents used, ethyl acetate and ethanol extracts exhibited the strongest activity, while hexane and benzene showed moderate effectiveness. Methanol extracts were found to outperform aqueous extracts in antimicrobial potency, even when compared to common antibiotics like Piperacillin and Gentamicin. These extracts inhibited a wide range of Gram-positive and Gram-negative bacteria, such as Bacillus cereus, Proteus mirabilis, Salmonella typhimurium, E. coli, and Streptococcus agalactiae.

Antifungal Properties

Traditionally, betel leaf has been utilized to treat ailments such as bad breath, skin infections, abscesses, conjunctivitis, constipation, and joint pain. Modern research supports its antifungal efficacy, demonstrating strong inhibitory effects against fungi like Candida albicans, Aspergillus niger, and Trichophyton mentagrophytes. These effects are largely due to its active compounds—eugenol, chavicol, and various terpenes.

Betel leaf extract has demonstrated inhibitory effects against dermatophytes, the fungi responsible for prevalent skin conditions such as ringworm and athlete's foot. Furthermore, studies suggest that combining betel leaf extract with antifungal agents like fluconazole can enhance therapeutic effectiveness through synergistic action.

Anti-Cancer Properties

The chemopreventive abilities of betel leaves are attributed to their high polyphenolic content, with chlorogenic acid and hydroxychavicol playing pivotal roles in neutralizing carcinogens, particularly those associated with tobacco (Chowdhury U et al., 2020). Red betel leaves, in particular, contain flavonoids like luteolin and apigenin, known for their cytotoxic effects on cancer cells.

Experimental findings using methanolic extracts of red betel leaves have demonstrated significant anti-migratory and cytotoxic effects against metastatic breast cancer cells (Zulharini M et al., 2018). Given that late-stage metastasis significantly increases mortality rates due to heightened matrix metalloproteinase (MMP) expression and invasive cell behavior, betel leaf's role in cancer prevention and intervention appears promising.

Antioxidant Properties

Betel leaf extract is a potent antioxidant source due to its high concentration of phenolic compounds such as catechol and allylpyrocatechol. Manigauha A et al. (2009) reported that methanol-based extracts of betel leaves exhibit significant reducing power and effectively neutralize DPPH radicals, superoxide anions, and facilitate deoxyribose degradation.

Further investigations by Subramani K et al. (2020) showed that the polyphenolic content in betel leaf surpasses that found in tea. Ethanolic extracts, according to Nouri L et al. (2015), are particularly rich in natural antioxidants. Lei D et al. (2003) found that aqueous extracts of betel leaves efficiently scavenge hydroxyl radicals, superoxide ions, and hydrogen peroxide (H_2O_2), making them valuable for oxidative stress management.

CONCLUSION

Betel (Piper betle), a member of the Piperaceae family, has been traditionally recognized for its wide range of therapeutic applications—ranging from promoting oral hygiene and healing wounds to relieving fever and enhancing appetite. It is extensively used in Ayurvedic practices as a stimulant, aromatic agent, and remedy for various ailments, including eye infections, blisters, and bleeding disorders.

India is home to numerous varieties of betel leaves, each known for its potent bioactive profile. Scientific studies have confirmed its broad-spectrum antimicrobial, antifungal, antioxidant, and anti-cancer effects, making it an important resource for modern therapeutic and commercial uses. The presence of phenolic and terpenoid compounds not only imparts a distinctive aroma but also boosts its effectiveness in food preservation and pharmacological applications.

Additionally, betel leaf, classified as a Generally Recognized as Safe (GRAS) ingredient, has found increasing applications in the food, pharmaceutical, and cosmetic sectors.. With its therapeutic versatility and commercial viability, betel leaf continues to hold immense potential in both traditional medicine and contemporary health science.

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Conflict of interest

None

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