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Review article

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Syzygium aromaticum: A Useful Precious Spice.

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ABSTRACT

Syzygium aromaticum, also known as clove and previously classified as *Eugenia caryophyllata,* belongs to Myrtaceae family that originates from the Maluku Islands in eastern Indonesia. Cloves have been utilized for centuries in traditional medicine to address a range of health concerns, including vomiting, flatulence, nausea, and issues associated with the liver, intestines, and stomach. Clove extracts and essential oils demonstrate significant antibacterial activity, particularly against multidrug-resistant pathogens. Clove also exhibits potent antifungal efficacy against pathogens like *Candida albicans, Fusarium oxysporum*, and *Rhizoctonia bataticola*. The antioxidant potential of clove, primarily attributed to eugenol and other phenolic compounds, underscores its capacity to manage oxidative stress-related disorders. Additionally, clove possesses anti-inflammatory, antimutagenic, and anticancer properties, supporting its role in metabolic regulation, allergy management, and cancer prevention. These findings highlight clove's potential as a natural alternative in antimicrobial therapy, clinical applications, and food preservation, making it a valuable candidate for modern pharmacotherapy. Along with these properties, clove also possesses many of the useful constituents primarily eugenol, β caryophyllene, and eugenyl acetate.

Keywords: *Syzygium aromaticum*, Clove, Phytoconstituents, Pharmacological activity.

INTRODUCTION

The use of medicinal plants for healing has been practiced since ancient times. Evidence from various sources such as written records, preserved monuments, and original plant medicines shows the strong connection between humans and their quest for natural remedies. The knowledge of medicinal plant usage has been gained through years of battling illnesses, leading people to discover the therapeutic properties present in various parts of plants. Modern science has acknowledged the effectiveness of these plants and has integrated a variety of plant-based medications into contemporary pharmacotherapy. These medications were recognized by ancient civilizations and have been utilized for thousands of years. (Petrovska,2012) In this context, it is important to note that Indian plants are recognized as a vast source of various pharmacologically active principles and compounds that are commonly used in home remedies for multiple ailments. This review aims to provide detailed information on the phytochemicals, ethnomedicinal uses, and pharmacological activities of *Syzygium aromaticum*, commonly known as clove.

Syzygium aromaticum, also known as clove and previously classified as *Eugenia caryophyllata*, is a medium-sized tree (8-12 meters) from the Myrtaceae family that originates from the Maluku Islands in eastern Indonesia. For many centuries, the trade of cloves and the quest for this precious spice have been significant. (Rojas *et al.*,2014). Cloves are primarily grown in Indonesia, but they are also cultivated in India, Malaysia, and Sri Lanka. However, the production levels in these Asian countries are relatively low compared to those in other regions. Notably, Madagascar, Tanzania particularly the island of Zanzibar and the West Indies are significant producers of cloves, contributing to a more substantial share of the global market. (chomchalow,1996) Cloves have been utilized for centuries in traditional medicine to address a range of health concerns, including vomiting, gas, nausea, and issues associated with the liver, intestines, and stomach. They are also recognized for their nerve-stimulating properties. In tropical Asia, cloves have been noted for their effectiveness against various pathogens, including those responsible for scabies, cholera, malaria, and tuberculosis. In the Americas, they have traditionally been employed to combat food-related pathogens and to manage infections caused by viruses, worms, candida, as well as various bacterial and protozoan ailments. besides the uses of clove, clove essential Clove oil is considered as monster antioxidant due to its unusually high antioxidant activity (Bowmik *et al*., 2012).

The pharmacological activities of Clove

Antibacterial activity

Several studies have demonstrated the potent antibacterial activity of *Syzygium aromaticum* (clove) extracts against a variety of bacterial pathogens. Sofia *et al.* (2007) reported significant inhibition zones against foodborne pathogens including *Escherichia coli, Staphylococcus aureus*, and *Bacillus cereus* with inhibition ranges between 11–19 mm. Similarly, Pandey & Singh (2011) conducted an in vitro study to evaluate the antibacterial activity of *Syzygium aromaticum* (clove) against food-borne pathogens and clove extract showed significant antibacterial activity. The tested organisms included *Staphylococcus aureus, Pseudomonas aeruginosa,* and *Escherichia coli.* Saeed *et al.* (2013) noted strong antibacterial properties of methanolic clove extracts against food spoilage bacteria like *Listeria monocytogenes and Bacillus subtilis*. Demirpek *et al.* (2009) found clove extracts effective against methicillin-resistant *Staphylococcus aureus* (MRSA) at concentrations of 1000 and 500 mg/mL, with 11% of isolates sensitive at 250 mg/mL. Rath & Padhy (2014) screened methanolic extracts of 26 commonly used Indian spices including clove against nine species of uropathogenic multi-drug-resistant bacteria. Clove extract showed a notable(29mm) zone of inhibition against *E. aerogenes.* Salisu *et al.* (2022) highlighted the broad-spectrum efficacy of clove extracts against MDR uropathogenic bacteria with many showing resistance to seven or more commonly used antibiotics. In antimicrobial tests, diethyl ether, ethanolic, and aqueous extracts of cloves demonstrated broad-spectrum activity, with effectiveness increasing at higher concentrations (200 mg/ml). similarly, Marouf *et al.* (2023) examined the antibacterial properties of clove against multidrug-resistant uropathogenic *E. coli* (MDR-UPEC). The findings revealed that the antibacterial activity of clove extract was dependent on its concentration, producing inhibition zones of 7–10 mm for uropathogenic strains. Like clove bud extract clove essential oil also showed its antibacterial potential. Mehboobi et.al (2006) evaluated the bactericidal activity of *Syzygium aromaticum*, lavender, and geranium against multi-drug resistant 11 strains of *Pseudomonas aeruginosa* isolates and Clove oil was determined to be more effective among the three. Zengin *et al.* (2014) investigated the antimicrobial activities of clove essential oils (EOs) and their application in minced beef. The results showed that EOs effectively inhibited bacterial growth, especially against *Salmonella typhimurium* and *Coliforms* in minced beef. Abdullah *et.al* (2015) conducted comparative antibacterial study of *Syzygium aromaticum* oil and *Rosmarinus officinalis* L. against four MDR bacteria, clove essential oil showed a wide and significant zones of inhibition ranging from10 mm to 28mm. Wongsawan *et al.* (2019) assessed the bactericidal properties of clove oil (*Syzygium aromaticum*) against multidrug-resistant *Streptococcus suis* strains isolated from human patients and slaughtered pigs with findings indicating that clove oil exhibited varying inhibition levels depending on the concentration.These studies collectively indicate that *Syzygium aromaticum* possesses substantial antibacterial potential, particularly against drug-resistant and foodborne and uropathogens, making it a promising candidate for natural antimicrobial applications.

Antifungal activity

The increasing resistance of fungal pathogens to conventional antifungal treatments necessitates the exploration of natural alternatives. Clove oil, derived from *Syzygium aromaticum*, has demonstrated significant antifungal efficacy against a broad spectrum of fungi in multiple studies. Beg and Ahmed (2001) reported that clove oil exhibited inhibition zones of 55–65 mm against *Alternaria alternata, Fusarium chlamydosporum, Helminthosporum oryzae,* and *Rhizoctonia bataticola*. Higher concentrations of clove oil led to significant lysis of conidia, with various percentages of lysis observed depending on concentration and incubation times. Clove oil effectively inhibited mycelial mat formation in liquid culture even after seven days, showcasing its efficacy as an antifungal agent. Similarly, Ranasinghe *et al.* (2002) found that clove oil effectively inhibited post-harvest pathogens of bananas, including *Colletotrichum musae*, and Pinto *et al.* (2009) observed that clove oil and its primary component, eugenol, inhibited clinical strains of *Candida, Aspergillus*, and *dermatophytes*, even those resistant to fluconazole. Rana *et al.* (2011) noted inhibition zones of 12–22 mm against various fungi, indicating varying degrees of sensitivity. Mansourian *et al.* (2014) found that clove oil surpassed nystatin in inhibiting *Candida albicans* isolated from denture stomatitis, while Sharma *et al.* (2016) demonstrated that clove oil completely inhibited *Fusarium oxysporum* at 125 ppm, causing morphological changes, leading to shriveled hyphae and disrupted spores. Clove oil-treated samples showed significant alterations in surface morphology compared to untreated samples, indicating the impact of clove oil on fungal growth and structure. Furthermore, Muchembled *et al.* (2017) highlighted clove oil's effectiveness against *Venturia inaequalis*, a major apple pathogen causing apple scab, and Butzge *et al.* (2020) confirmed its activity against *Rhodotorula mucilaginosa*, which can lead to various infections, ranging from skin issues to severe conditions such as meningitis and endocarditis. These studies collectively underscore the potent antifungal properties of clove oil and its primary constituent, eugenol, suggesting its potential as a natural alternative to synthetic antifungal agents in both clinical and agricultural applications.

Antioxidant activity

Clove oil (*Syzygium aromaticum*) has been extensively studied for its robust antioxidant properties, primarily due to its high eugenol content and other phenolic compounds. Lee *et al.* (2001) discovered that an aroma extract from clove buds inhibited the oxidation of hexanal for up to 30 days at a concentration of 50 mg/ml and reduced the formation of malondialdehyde in cod liver oil by 93% at 160 mg/ml. Both eugenol and eugenyl acetate exhibited antioxidant activity similar to that of α-tocopherol (vitamin E). Nassar *et al.* (2007) identified eugenol as the major component and reported that clove extracts showed DPPH scavenging effects ranging from 10% to 93%, with notable hepatoprotective effects against paracetamol-induced liver damage in rats. Atawodi *et al.* (2011) highlighted clove's polyphenolic content, including gallic acid and ellagic acid, which contributed to strong antioxidant activities with IC50 values of 2 µl in the xanthine oxidase assay, this antioxidant activity suggests a potential for chemoprevention of diseases associated with oxidative damage, such as cancer and cardiovascular disorders. Mashkor (2015) demonstrated that clove fruits exhibited superior antioxidant potential compared to stems, with a DPPH scavenging activity of 87.50% and a ferric reducing power of 437.29 mg TE/100 g DW. Sameer and Salah (2016) showed that ethanol and water extracts had high phenolic content and strong antioxidant activities, with DPPH scavenging ranging from 25.3% to 91.4% and ABTS scavenging between 49.4% and 99.4%. Radunuz *et al.* (2018) found that encapsulated clove essential oil maintained its DPPH scavenging capacity while reducing odor, attributing its antioxidant efficacy to eugenol and related phenolics. Collectively, these studies reinforce the potent antioxidant capabilities of clove oil, supporting its therapeutic potential and application in oxidative stress management and food preservation.

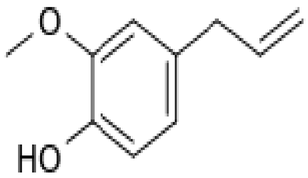
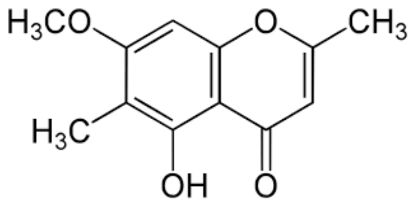
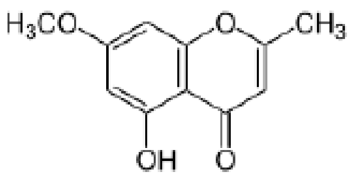
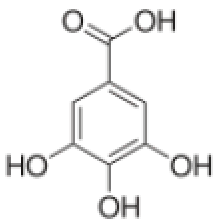
Phytochemical constituents of clove

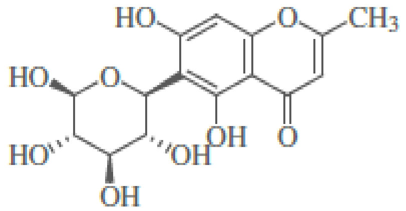
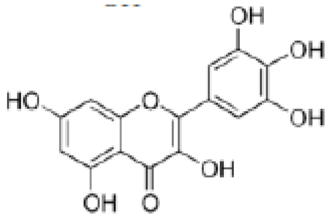
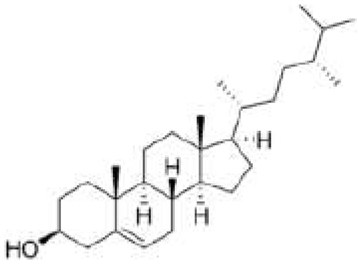
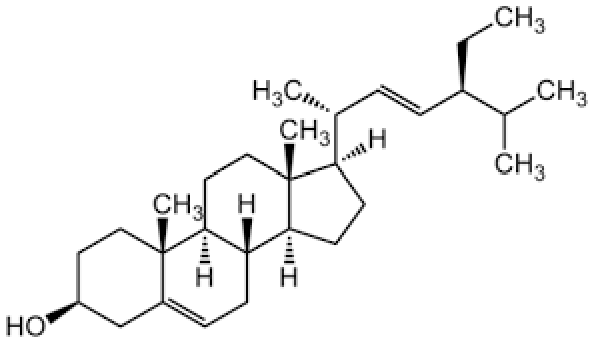
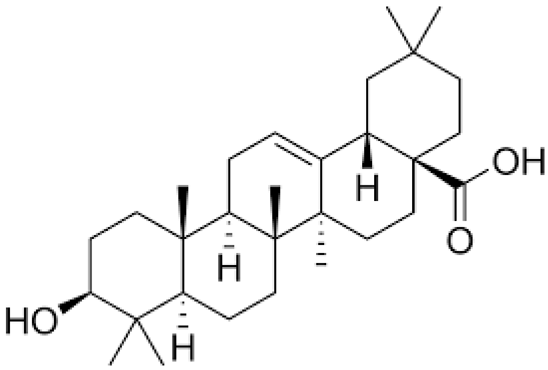
Xu *et al.* (2018) analysed chemical composition of essential oil of clove (Syzygium aromaticum) by GC and GC-MS. In total, 22 components in essential oil were identified, representing 95.80% of the total amount. The eugenol (76.23%) was found to be the major component of the essential oil, followed by β-caryophyllene (11.54%), caryophyllene oxide (4.29%), and eugenyl acetate (1.76%). Mittal *et al.* (2014) given a comprehensive review of about 15 phytoconstituents and their pharmacological and given in Table no.1.

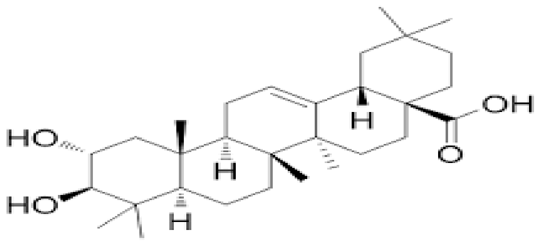
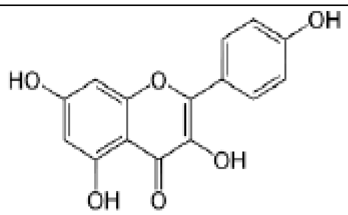
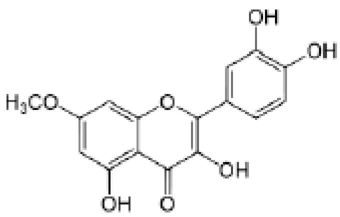
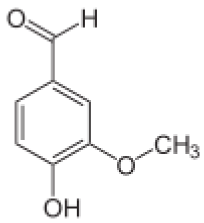
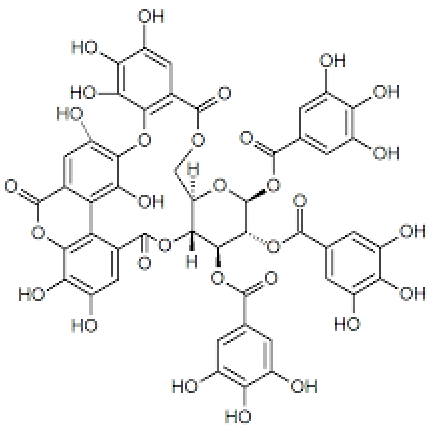
Other

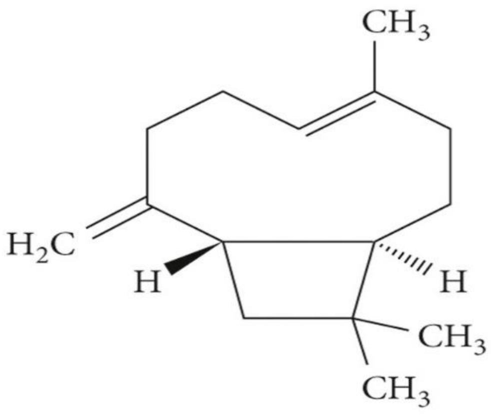
Syzygium aromaticum (clove) exhibits diverse pharmacological activities, including antimicrobial, anti-inflammatory, antimutagenic, and anticancer properties. Cai and Christine (1996) demonstrated the growth-inhibitory activity of clove methanol extracts against oral pathogens, particularly *Porphyromonas gingivalis* and *Prevotella intermedia*, with MIC values ranging from 156–2500 µl/ml. Flavones like kaempferol and myricetin were particularly potent. Kim *et al.* (1998) found that aqueous clove bud extracts (SAFB) inhibited systemic and local anaphylaxis in rats, reducing histamine release and increasing cAMP levels in mast cells. Miyazawa and Hisama (2003) isolated dehydrodieugenol and trans-coniferyl aldehyde, which displayed antimutagenic effects by suppressing umu gene expression in Salmonella typhimurium, with suppression rates of 58% and 63%, respectively. Prasad *et al.* (2004) revealed that clove extract effectively repressed the expression of hepatic gluconeogenic genes PEPCK and G6Pase, suggesting a role in glucose metabolism regulation. Tajuddin (2004) observed that a 50% ethanolic extract of clove significantly enhanced mating behavior and potency in male rats without causing gastric ulceration. Banerjee *et al.* (2005) showed that clove infusion inhibited benzo[a]pyrene-induced lung carcinogenesis, promoting apoptosis via upregulation of p53 and Bax, and downregulation of Bcl-2, COX-2, c-Myc, and Hras. Kumar *et al.* (2014) demonstrated the anticancer potential of clove essential oil against MCF-7 breast cancer cells, with IC50 values of 36.43 μg/mL at 24 hours. Collectively, these studies highlight the multifaceted therapeutic potential of *Syzygium aromaticum*, supporting its applications in antimicrobial therapy, allergy management, cancer prevention, and metabolic regulation.

Table 1: Pharmacological activities of different phytochemicals isolated from S. aromaticum

Bioactive compound	**Chemical structure**	**Pharmacological activity**
1. Eugenol		Antimicrobial, Analgesic, Antioxidant, Anticancer, Anthelmintic, Antiulcer, Anti-inflammatory, Anti-depressant, Bone preserving, antipyretic, Antithrombotic
2. Eugenitin		Antifungal
3. Eugenin		No activity reported
4. Gallic acid		Antimicrobial, Antioxidant Anti-inflammatory

5. Biflorin		Antibacterial Antioxidant, Anticancer
6. Myricetin		Antimicrobial Antioxidant, Anticancer Anti-inflammatory
7. Campesterol		Antibacterial Antinociceptive Anti-carcinogenic
8. Stigmasterol		Antimicrobial Antitumor Acaricidal Block cartilage degradation
9. Oleanolic acid		Anti-diabetic Antimicrobial Anticancer

10. Crategolic acid (Maslinic acid)		Antitumor
11. Kaempferol		Antimicrobial, Antioxidant Anti-inflammatory Anticancer
12. Rhamnetin		Anti-inflammatory, Antioxidant Cardio protective Antifungal
13. Vanillin		Antimicrobial Antioxidant Antidepressant
14. Bicornin		No activity reported

15. β-caryophyllene		Antitumor, anti-apoptotic Anesthetic Anti-lishmanial Anti-inflammatory Antioxidant, antibiotic

CONCLUSION

Syzygium aromaticum holds immense potential in modern medicine due to its diverse pharmacological properties. Its antibacterial, antifungal, antioxidant, and anticancer activities, primarily driven by eugenol and other bioactive compounds, provide a strong foundation for its use in combating multidrug-resistant pathogens and managing oxidative stress-related diseases. The rich ethnomedicinal history of clove, combined with current scientific validation, underscores its relevance as a natural and effective therapeutic agent. Further research into clove's mechanisms of action and clinical applications will enhance its integration into contemporary pharmacotherapy and food preservation practices.

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