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CLOVE (*SYZYGIUMAROMATICUM*): A COMPREHENSIVE REVIEW OF ITS MULTIFACETED APPLICATIONS

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ABSTRACT

Clove (*Syzygiumaromaticum*), a spice derived from the flower buds of a tree in the Myrtaceae family, is renowned for its aromatic properties and diverse applications. This review aims to consolidate current knowledge on clove's phytochemistry, traditional and modern medicinal uses, antimicrobial and antioxidant activities, culinary value, and industrial significance. Special emphasis is placed on its bioactive compounds, particularly eugenol, which underpins many of its biological effects. the paper also discusses the safety profile and potential future applications of clove in pharmaceuticals and functional foods.[1,5]

1. INTRODUCTION

Clove is one ofthe most valuable spices native to the Maluku Islands (Indonesia) and widely used globally. Beyond its distinctive aroma and flavor, clove possesses a remarkable range of bioactive properties, making it an important natural product in traditional medicine and modern pharmacology. Clove in particular has attracted the attention due to the potent antioxidant and antimicrobial activities standing out among the other spices.

Figure clove.

Cultivation and Collection

Clove tree is evergreen and 10 to 20 m in height. The plant requires moist, warm and equable climate with well-distributed rainfall. It is propagated by means of seeds. The seeds are sown in well-drained suitable soil at a distance of about 25 cm. The plants should be protected against pests and plant diseases. Initially it has to be protected from sunlight by growing inside a green house or by con-structing frames about 1 m high and covering them with banana leaves. As the banana leaves decay gradually more and more sunlight falls on the young seedlings and the seeds are able to bear full sunlight when they are about 9 months old. The seedlings when become 1 m high, they are transplanted into open spaces at a distance of 6 m just before the rainy season. The young clove trees are protected from sun even for a longer period by planting banana trees in between. The drug can be collected every year starting from6 years old till they are 70 years old.[27,29,32]

Fig. Cultivation and Collection of clove.

2. *Botanical and Phytochemical Overview*

Botanical Description

- Scientific name:*Syzygiumaromaticum*(L.)
- Family: Myrtaceae
- Partused: Flower buds(commonly),also leaves and stems

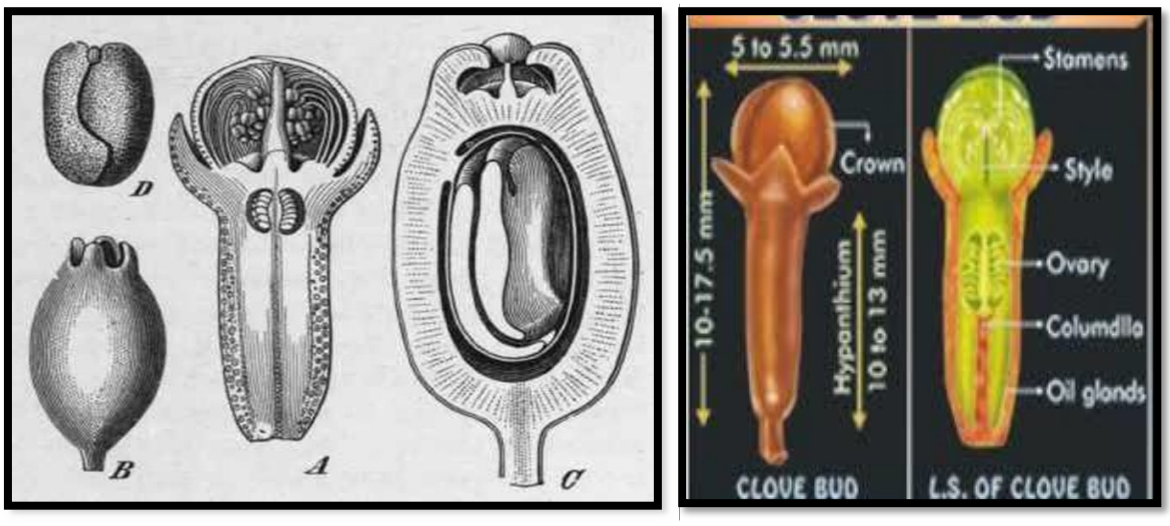
Phytochemical Constituents

Clove contains a complex mixture of volatile and non-volatile compounds:

- **Essentialoils(15–20%)**: Primarily **eugenol**(upto80–90%), eugenylacetate, β-caryophyllene
- **Tannins**
- **Triterpenoids**
- **Flavonoids**
- **Phenolicacids**

Morphology of Clove(*Syzygium aromaticum*)

Clove is a **flower bud** obtained from the ever green tree *Syzygium aromaticum*,belongingto the **family Myrtaceae**. It is known for its characteristic aromatic and pungent flavor ,due to its rich essential oil content, particularly **eugenol**.



Figure–morphology of clove.

1. *Tree Morphology*

- **Height:** 10–20meterswhen fullymatured.
- **Type:** Evergreen, medium-sized tree with a conicaltocylindrical crown.

- **Bark:** Smoothandgraywithalightbrowninner bark.
- **Wood:** Hardanddurablewithalightaromatic scent.

2. ***LeafMorphology***

- **Arrangement:** Opposite
- **Shape:** Elliptictoovate

Size: 7–12 cmlong, 3–6 cmwide

- **Color:** Darkgreen, glossyontheupper surface; lighterunderneath
- **Texture:** Leathery with aprominentmidribandaromaticoilglands
- **Smell:** Stronglyaromaticwhencrushed

3. ***Flower Morphology (CloveBuds)***

Cloves are harvestedasun opened flower buds.

- **Peduncle(flower stalk):**Slender and short, about1–2cmlong
- **Bud Shape:** Cylindrical or slightly conical with a swollen base anda four-toothedcalyx
- **Size:**1.5–2cmin length
- **Color:** Green when immature, turning bright red as they mature, and dark brown when dried

- **Parts**
  - **Calyx:** Tubular with four prominent sepals forming a crown-like tip
  - **Petals:** 4small, palepetals covering the developing stamens, which drop off when the bud blooms
  - **Stamens:** Numerous, enclosed within the petals in unopened buds
  - **Pistil:** Single, centrally placed

4. ***Fruit Morphology (I fallowed to mature)***

- **Type:** Oblong berry (rarely seen in commerce as buds are harvested early)
- **Color:** Dark purple to black when ripe
- **Seeds:** One or two

5. ***Root System***

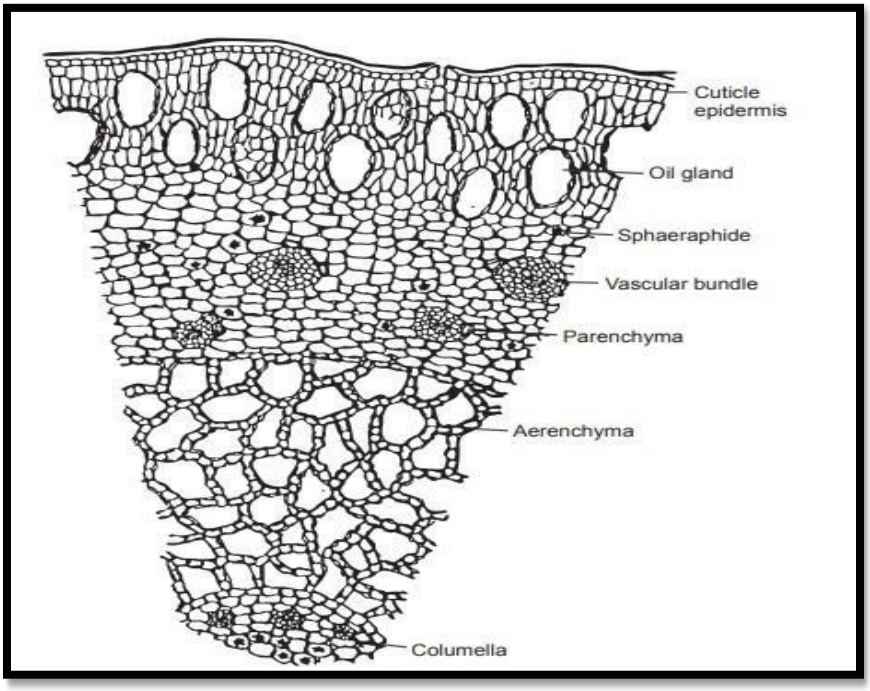
- **Type:** Tap root system with strong lateral branches
- **Function:** Anchors the tall tree and facilitates nutrient uptake in tropical, well-drained soils

Summary of Diagnostic Features

Organ	KeyFeatures
Bud	Aromatic, unopenedflowerbud; darkbrown; 1.5–2cm long
Leaf	Opposite, leathery, aromatic, elliptic with oil glands
Tree	Evergreen, 10–20mtall, conical crown
Flowers	Small, tetramerous, borneinterminalclusters
Fruit	Oblongberry, rarelyharvested
Odor	Strong, spicyaromadue to high eugenol content

Microscopical Features of Clove(Syzygium aromaticum)

Microscopic examinationis vital for confirming the identity and purity of crude plant drugs. In the case of clove buds, both **transverse section (T.S.)** and **powder microscopy** are commonly analyzed.



Figure– microscopy of clove.

1. Transverse Section of Clove Bud

A transvese section (T.S.) of the clove bud shows the following distinct tissues:

a. Epidermis

- Single layer of rectangular cells.
- Covered with a **cuticle**.
- **Multicellular covering trichomes** (occasionallyobserved).

b. Hypodermis

- 2–3 layers of **collenchymatous** cells beneath the epidermis.
- Provides mechanical strength.

c. Oil Glands (Secretory Cavities)

- Prominent feature in the cortex.
- **Large schizolysigenous glands** containing **volatile oil(eugenol)**.
- Appears as clearor yellowish circular areas.

d. Parenchymatous Cortex

- Thin-walled, loosely packed cells.
- Contain **starchgrains**, **calcium oxalate crystals (drusesorprisms)**.

e. Vascular Bundles

- Located centrally.
- **Open and collateral**, with xylem directed in wards and phloemoutwards.
- Surrounded by parenchyma aand fiber bundles.

f. Pith Region

- Composed oflarge, thin-walled parenchymatous cells.
- May contain starch grains and oil cells.[4;6,9]

10. CHEMISTRY (DRUG PROFILE)

Clove is a vital source of phenolic compounds such as flavonoids, hydroxycinamic acids, hydroxybenzoic acids, and hydroxyphenyl propenes. Eugenol is the chief bio active constituent ofclove, which is presentin concentration sranging from 9 381.70 to 14 650.00 mg/100 g of fresh plant weight. With regard to the phenolic acids, gallic acid is found in higher concentration (783.50mg/100 gfreshweight).[6] Other phenolic acids found in clove are caffeic, ferulic, elagic and salicylic acids. Flavonoids including kaempferol, quercetin and its derivates (glycosilated) are also found in trace amounts. Appreciable amounts of essential oil are present in aerial parts of clove. Chemical profile of this oil isgenerallyfoundbyGCMSanalysis.[711] Good quality clove bud

Contains volatile oil(15to20%), which mainly comprises of eugenol(70to 85%), eugenyl acetate (10 to 15%), and beta-caryophyllene (5 to 12%). Other minor constituents including methyl amyl ketone, kaempferol, gallotannic acid, α-humulene, βhumulene,

methyl salicylate, crategolicacid, and benzaldehyde are responsible for the characteristic pleasant fragrance of clove.[9,22,24]

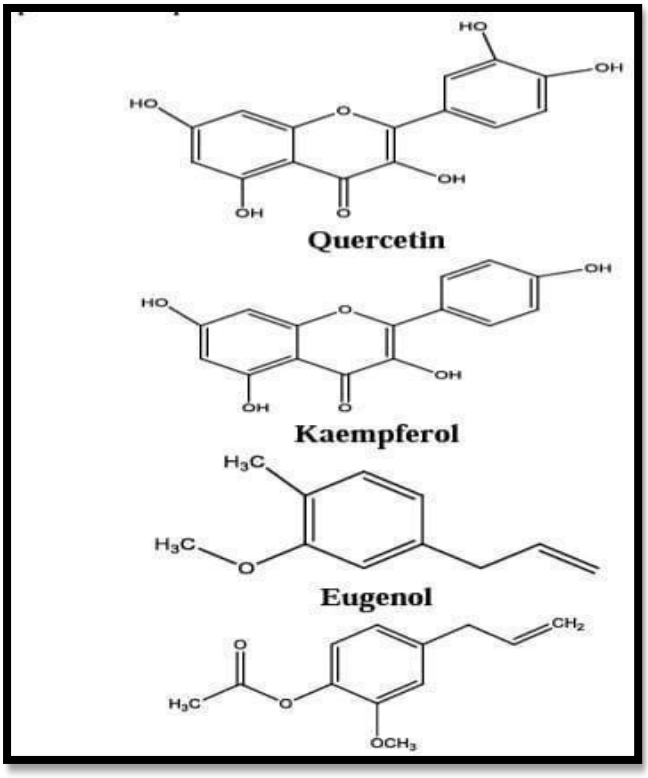


Figure – shows structures of some important compounds of clove.

Chemicaltest of clove[35]

Test	Fresh Leaf Extract	Powdered Leaf Extract	Commercial Eugenol
Bromine Test	Pale yellow coloured precipitate	Pale yellow coloured precipitate	Pale yellow Coloured precipitate
Bayer's Test	Muddy brown Precipitate	Muddy brown precipitate	Muddy brown precipitate
Litmus Test	No colour change	Blue colour changes to red	No colour change

Fig.- Chemical test of clove

3. Medicinal and Pharmacological Properties

Anti microbial Activity

- Clove oil exhibits strong antibacterial, antifungal, andantiviralproperties.
- Effective against *E.coli, S.aureus, Candida albicans*, and many food borne pathogens.

Antioxidant Potential

- High ORAC(Oxygen Radical Absorbance Capacity) value.
- Eugenol scavenges freeradicals, protects lipids and proteins from oxidative damage.

Anti-inflammatory Effects

- Suppresses COX-2and other inflammatory mediators.
- Useful in treating inflammatory conditions and pain.

Analgesic and Anesthetic Action

- Traditionally used in dentistry for toothache relief.
- Eugenol acts as a local anesthetic.[8]

Anticancer Potential

- Invitro and invivostudies suggest antiproliferative effects against various cancer cell lines.
- Induces apoptosis and cell cycle arrest.[6]

Anti diabetic and Antihyperlipidemic Activity

- Improves insulin sensitivity and lipid profile in animal models.
- Reduces glucose absorption in the intestine.[22,16]

4. Traditional and Culinary Uses

Culinary Applications

- Widely used in Asian, African, and Middle Easterncuisines.
- Used inspice blends, pickles, desserts, and beverages.

Traditional Medicine

- Employedin Ayurvedic, Unani, and Chinese medicine for digestive, dental, and respiratory conditions.[23]

5. *Industrial and Cosmetic Uses*

Perfumery and Cosmetics

- Clove oil is used in fragrances, soaps, and tooth paste due to its aromatic and antimicrobial properties.

Food Preservation

- Acts as a natural preservative due to its antimicrobial and antioxidant effects.

Veterinary and Agricultural Uses

- Used as an insect repellent and inpest control formulations.[22,12]

6. *Safety, Toxicology, and Dosage*

- Generally recognized as safe (GRAS)by the FDA.
- Over use or concentrated forms can cause mucosal irritationor liver toxicity.
- Recommended to be used within therapeutic limits(e.g., essential oil≤2.5mg/kg body weight).[12,16]

8. *Future Perspectives and Research Opportunities*

- **Nanotechnology**: Encapsulation of clove oil for controlled release and enhanced stability.
- **Functional Foods**: Fortification in health beverages, oral health products.
- **Synergistic Formulations**: Combined with other natural agents to enhance therapeutic efficacy.[5]

Literature Review

Clove (*Syzygiumaromaticum*) has been the subject of extensive research due to its wide range of biological activities and applications. This literature review synthesizes findings from contemporary studies on the chemical composition, pharmacological properties, traditional uses, and potential industrial applications of clove.[33,38]

1. Phytochemical Composition

Multiple studies have identified **eugenol** as the predominant bioactive compound in clove, comprising up to 80–90%ofthe essential oilcontent (Chaiebet al., 2007;Kamatouet al., 2012). Other notable constituents include **eugenyl acetate, β-caryophyllene, gallic acid, flavonoids**, and**tannins**. These compounds are largely responsible for clove's anti oxidant, antimicrobial, and anti-inflammatory effects.[12,33]

2. Antioxidant Activity

Clove exhibits one of the highest antioxidant capacities among spices, as measured by assays like DPPH, ABTS, and FRAP (Shan et al., 2005). A comparative study by Gulcin et al. (2012) revealed that cloveessentialoilsignificantlyreducesoxidativestressbyneutralizing free radicals and inhibiting lipid peroxidation. This property has been linked to the protective effects of clove against chronic diseases such as cancer and cardiovascular disorders.

3. Antimicrobial Properties

Several investigations have validated the strong antimicrobial efficacy of clove oil against a broad spectrum of pathogens. For example, Hammer et al.(1999) found clove oil to be highly

effective against *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. The mechanism is thought to involve disruption o microbial cell membranes due to the lipophilic nature of eugenol.

4. Anti-inflammatory and Analgesic Effects

Studies such as those by Danielet al. (2009) and Park et al. (2014) have shown that clove extract inhibits the activity of cyclo oxygenase (COX) enzymes, leading to reduced production of pro- inflammatory mediators like prostaglandins. In traditional medicine, clove has been widely used as a natural painkiller, particularly in dental applications.

5. Anticancer Potential

Emerging research highlights clove's potential in cancer prevention and treatment. Jaganathan and Supriyan to (2012) reported that clove extract induces apoptosis and inhibit proliferation in human breast and colon cancer cells. The mechanisms proposed include cell cycle arrest, mitochondrial dysfunction, and modulation of oxidative stress.

6. Antidiabetic and Lipid-lowering Effects

Animal studies have demonstrated that clove extracts can improve glycemic control and lipid profiles. A study by Ramadanet al. (2011) reported that clove supplementation decreased fasting blood glucose, total cholesterol, and triglycerides in diabetic rats, possibly due to its insulin- enhancing and antioxidant activities.

7. Traditional and Culinary Uses

Ethno botanical records support clove's use in Ayurveda, Unani, and traditional Chinese medicine for treating digestive issues, respiratory disorders, and oral infections (Trease &Evans, 2002).In addition, clove is extensively used in culinary traditions around the world, not just for flavor, but also for its preservative qualities.[37,35]

8. Industrial and Cosmetic Applications

Clove is increasingly being used in the **cosmetics**, **food preservation**, and **pharmaceutical** industries. The antimicrobial and a romatic properties make clove oil aningredient in toothpastes, mouthwashes, perfumes, and soaps. Research by Burt (2004) emphasized the potential of clove oil as a natural food preservative due to its ability to inhibit spoilage microorganisms.[12,3,15]

9. Safety and Toxicity

Although generally ecognizedas safe(GRAS) by the U.S. FDA, clove oil can be toxic in high doses or with prolonged use. Eugenol has been reported to cause hepatic toxicity at very high concentrations (Prashar et al., 2006). Hence, dose standardization and safety profiling remain critical for clinical applications.[13,19]

ADULTERANTS

The clove is generally adulterated by exhausted clove, clove fruits, blown cloves and clove stalks. The exhausted cloves are those from which volatile oil is either partially or completely removed by distillation. Exhausted cloves are darker in colour and can be identified as they float on freshly boiled and cooled water. Clove fruits are dark brown in colour and have less volatile oil content. These can be identified by the presence of starch present in the seed of the fruit. Blown Cloves are entirely developed clove flowers from which corolla and stamens get separated. While sepa- ration, sometimes the stalks are incompletely removed and the percentage of volatile oil in clove stalk is only5%. As clove stalks contain prism type of calcium oxalate crystals and thick-walled stone cells which are absent in clove the clove stalk canal so be detected.[37,40,36,39]

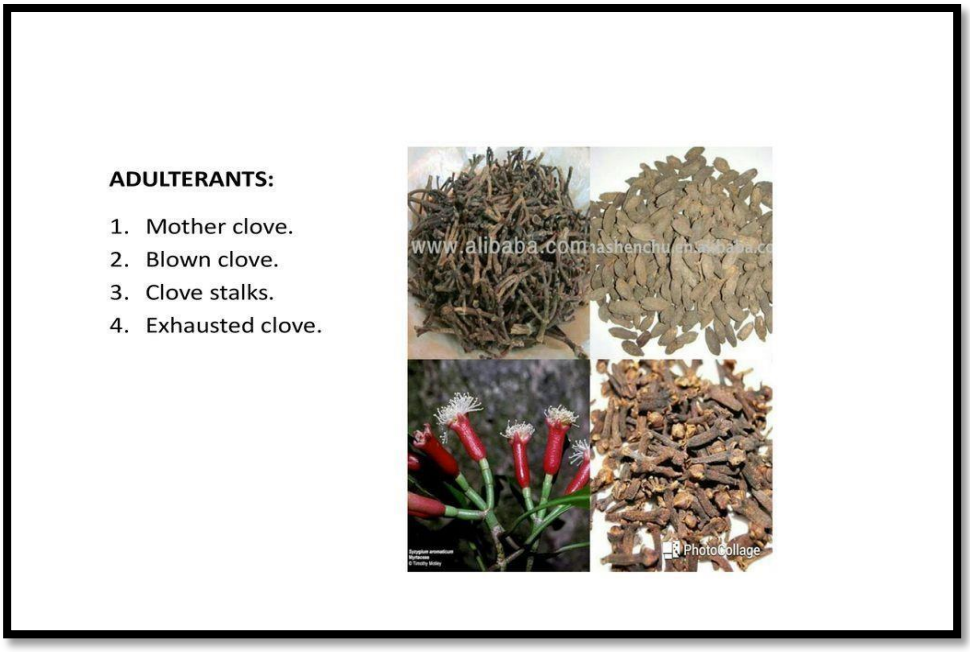


Fig. Adulte rants 0F Clove.

CONCLUSION

Clove is a powerful natural product with broad-spectrum pharmacological, culinary, and

industrial uses. With on going research into its bioactivity and mechanisms of action, clove holds significant promise in integrative medicine and novel therapeutic formulation

Herbs are staging comeback and in the present days herbal products represent safety and security as compare to synthetic drug which leads toward research in herbal medicines. The traditional knowledge may play important role if a holistic approach, and involvement and participation of tribes for documentation, preservation and use for the benefit of humankind, before it is lost for ever. Clove is a remarkable spice with a rich history of use across many cultures for culinary, medicinal, and practical purposes. Its unique, warm flavor enhances a wide variety of dishes, and its powerful medicinal properties have made it a valued ingredient in traditional remedies for pain relief, digestive health, and more. Beyond its uses in food and medicine, clove serves as a natural insect repellent and a key component in aromatherapy and skincare. Whether used for its flavor, healing benefits, or aromatic qualities, clove continues to play an important role in both everyday life and traditional practices. Its versatility and effectiveness in somany areas highlight why it remain saprized ingredient around the world. The fruit of the plant Syzygium aromaticum has been used since centuries in every part of the globe. It has pharmacological benefits like anti- microbial, anti-inflammatory, anti-noceptive, hepato protective, anti-stress, and anesthetic. Clove has proved to be a good antioxidant as well. The single drop of its oil is many times stronger and effective as compared to Other antioxidants like blue berries and wolf berries. Base donall the above information it is found to be a very effective plant with many proved benefits having least adverse effects. The proved biological activities suggest the development of more herbal products containing clove as an ingredient which are useful medicinally for humans as well as for animals.[11,17,21,]

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