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Research paper

Studies on the phytochemicals of clove and their biological activities

R. Hema Krishna*

Department of Chemistry, Vignan's Lara Institute of Technology and Science, Vadlamudi, Andhrapradesh, India-522213
**Corresponding author E-mail: hkravuri32@gmail.com*

Abstract

Cloves are a fragrant spice made from the dried flowers of the clove tree. In the past, spices used to be worth their weight in gold, and cloves were no exception. Today, cloves remain a popular spice that gives many dishes subtly sweet warmth. A drop of clove oil is 400 times more powerful as an anti-oxidant than wolf berries or blueberries. Cloves contain a lot of manganese, a mineral that helps your body manage the enzymes that help repair your bones and make hormones. Manganese can also act as an antioxidant that protects your body from harmful free radicals (unstable atoms that cause cell damage). Cloves are a fragrant, dense spice that can be added to both savory dishes (such as curries) and sweet desserts (such as pumpkin pie). They're full of powerful nutrients that help protect your cells from damage. Some natural compounds in cloves interfere with medicines or cause side effects that can be life-threatening. So, it's safest to only cook or bake with cloves and enjoy this spice's health benefits that way. Clove is utilized in cosmetics, medicine, gastronomy, and agriculture due to its abundance of bioactive components such as gallic acid, flavonoids, eugenol acetate, and eugenol. Clove essential oil has been revealed to have antibacterial, antinociceptive, antibacterial activities, antifungal, and anticancerous qualities. Anti-inflammatory chemicals, including eugenol and flavonoids, are found in clove that help decrease inflammation and alleviate pain. The anti-inflammatory and analgesic qualities of clove oil have made it a popular natural cure for toothaches and gum discomfort. Due to its therapeutic potential, it has been used as a bioactive ingredient in coating fresh fruits and vegetables. This research article outlines the potential food processing applications of clove essential oil. The chemical structures of components, bioactive properties, and medicinal potential of clove essential oil, including phytochemical importance in food, have also been thoroughly addressed.

Keywords:*Clove; Aromatic Plant;Antioxidant;Antimicrobial Activity;Antinociceptive;Antiviral.*

1. Introduction

Clove may be looked upon as a champion of all the antioxidants known till date. Syzygium aromaticum (S. aromaticum) (synonym: Eugenia cariophylata) commonly known as clove (Devakusumamu or Lavangam is in Telugu language), is a median size tree (8-12 m) from the Mirtaceae family native from the Maluku islands in east Indonesia. The clove tree produces flower buds in clusters that are pale in color at first, become green, and then bright red, when they are ready for harvesting. Phenological stages of fruit development of clove see in Fig 1.(A) bud sprouting, (B) flower buds in an inflorescence, (C) fully opened flowers, (D) the stage where perianths and anthers already dropped, (E) unripe green fruits and (F) ripe fruits. The clove tree is an evergreen that grows up to 8–12 meters (26–39 ft) tall, with large leaves and crimson flowers grouped in terminal clusters. The flower buds initially have a pale hue, gradually turn green, then transition to a bright red when ready for harvest. Cloves are harvested at 1.5–2 centimeters (5⁄8–3⁄4 in) long, and consist of a long calyx that terminates in four spreading sepals, and four unopened petals that form a small central ball.

Clove stalks are slender stems of the inflorescence axis that show opposite decussate branching. Externally, they are brownish, rough, and irregularly wrinkled longitudinally with short fracture and dry, woody texture. Mother cloves (anthophylli) are the ripe fruits of cloves that are ovoid, brown berries, unilocular and one-seeded. Blown cloves are expanded flowers from which both corollae and stamens have been detached. Exhausted cloves have most or all the oil removed by distillation. They yield no oil and are darker in color.

Fig. 1: Phenological Stages of Fruit Development of Clove.

For centuries the trade of clove and the search of this valuable spice stimulated the economic development of this Asiatic region [1]. The clove tree is frequently cultivated in coastal areas at maximum altitudes of 200 m above the sea level. The production of flower buds, which is the commercialized part of this tree, starts after 4 years of plantation. Flower buds are collected in the maturation phase before flowering. The collection could be done manually or chemically-mediated using a natural phytohormone which liberates ethylene in the vegetal tissue, producing precocious maturation [2]. Nowadays, the larger producer countries of clove are Indonesia, India, Malaysia, Sri Lanka, Madagascar and Tanzania specially the Zanzibar island [3]. In Brazil, clove is cultured in the northeast region, in the state of Bahia in the regions of Valença, Ituberá, Taperoá, Camamu and Nilo Peçanha, where approximately 8000 hectares are cultivated, producing near 2500 tons per year[4], [5].

Clove is utilized in cosmetics, medicine, gastronomy, and agriculture due to its abundance of bioactive components such as gallic acid, flavonoids, eugenol acetate, and eugenol. Clove essential oil has been revealed to have antibacterial, antinociceptive, antibacterial activities, antifungal, and anticancerous qualities. Anti-inflammatory chemicals, including eugenol and flavonoids, are found in clove that help decrease inflammation and alleviate pain. The anti-inflammatory and analgesic qualities of clove oil have made it a popular natural cure for toothaches and gum discomfort. Due to its therapeutic potential, it has been used as a bioactive ingredient in coating fresh fruits and vegetables. This review article outlines the potential food processing applications of clove essential oil. The chemical structures of components, bioactive properties, and medicinal potential of clove essential oil, including phytochemical importance in food, have also been thoroughly addressed .The clove essential oil is generally recognized as safe substance when consumed in concentrations lower than 1500 mg/kg. On the other hand, the World Health Organization (WHO) established that the daily quantity acceptable of clove per day is of 2 .5 mg/kg of weight in humans. Clove represents one of the major vegetal sources of phenolic compounds as flavonoids, hidroxibenzoic acids, hidroxicinamic acids and hidroxiphenylpropens. Eugenol is the main bioactive compound of clove, which is found in concentrations ranging from 9381.70 to 14650.00 mg per 100 g of fresh plant material [6].With regard to the phenolic acids, gallic acid is the compound found in higher concentration (783.50 mg/100 g fresh weight). However, other gallic acid derivates as hidrolizable tannins are present in higher concentrations (2375.8 mg/100 g)[1]. Other phenolic acids found in clove are the caffeic, ferulic, elagic and salicylic acids. Flavonoids as kaempferol, quercetin and its derivates (glycosilated) are also found in clove in lower concentrations. Concentrations up to 18% of essential oil can be found in the clove flower buds. Roughly, 89% of the clove essential oil is eugenol and 5% to 15% is eugenol acetate and β-cariofilenolhas shown in Fig 2. [7]. Another important compound found in the essential oil of clove in concentrations up to 2.1% is α-humulen. Other volatile compounds present in lower concentrations in clove essential oil are β-pinene, limonene, farnesol, benzaldehyde, 2-heptanone and ethyl hexanoate[7]. In the light of above, we thought it worthwhile to compile an up-to-date review article on clove covering its, synonyms, chemical constituents, phytopharmacology and medicinal uses.

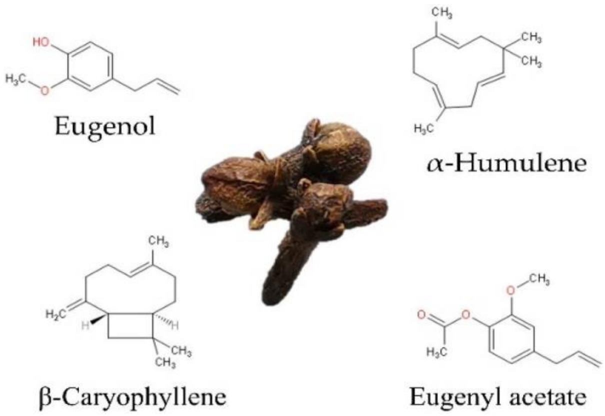


Fig. 2: Chemical Structure of Main Compounds of Clove Essential Oil.

2. Phytochemicals in clove

The biologically active Phytochemicals are sourced from edible and medicinally important plants and are important molecules being used for the formulation of thousands of drugs. These Phytochemicals have great benefits against many ailments particularly the inflammatory diseases or oxidative stress-mediated chronic diseases. Eugenol is a versatile naturally occurring molecule as phenolic monoterpenoid and frequently found in essential oils in a wide range of plant species. Eugenol bears huge industrial applications particularly in pharmaceutics, dentistry, flavoring of foods, agriculture, and cosmeceutics. It is being focused recently due to its great potential in preventing several chronic conditions. The World Health Organization (WHO) has declared Eugenol as a non mutant and generally recognized as safe (GRAS) molecule. The available literature about pharmacological activities of Eugenol shows remarkable anti-inflammatory, antioxidant, analgesic, and antimicrobial properties and has a significant effect on human health. The current manuscript summarizes the pharmacological characteristics of Eugenol and its potential health benefits. Clove is one of the richest sources of phenolic compounds such as eugenol, eugenol acetate, and gallic acid [8-9]. The main constituents of clove essential oil include eugenol (76.7%), β-caryophyllene (17.4%), α-humulene (2.1), and eugenol acetate (1.2%)

3. Bioactive compounds of clove extract

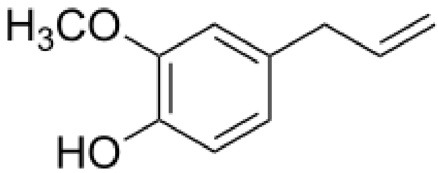
Clove is a spice that is rich in bioactive compounds, which are responsible for its numerous health benefits. The main bioactive compounds found in cloves are eugenol, acetyl eugenol, and caryophyllene. The bioactive compounds found in cloves have led to the development of novel pharmaceuticals and nutraceuticals[9]. The composition of clove extracts is shown in Table 1. The explanation and application of bioactive compounds from clove extract are shown below

Table 1: Composition of Active Compounds from Clove Extract [9]

Compound	Concentration Range (mg/g)
Eugenol	480–630
Acetyl eugenol	22–37
β-Caryophyllene	14–17
α-Humulene	2.2–2.9
α-Caryophyllene oxide	2.5–3.0
α-Murolene	1.6–2.0
γ-Murolene	1.2–1.8
β-Selinene	0.9–1.4
α-Selinene	0.7–1.2
δ-Cadinene	0.6–1.1
Caryophyllene oxide	0.8–1.0
α-Trans-bergamottin	0.7–0.9
α-Pinene	0.3–0.6
Limonene	0.3–0.5
β-Pinene	0.2–0.4
Methyl eugenol	0.1–0.4

4. Eugenol (C10H12O2)

Eugenol appears as clear colorless pale yellow or amber-colored liquid. Odor of cloves. Spicy pungent taste. The compound eugenol is responsible for most of the characteristic aroma of cloves.Eugenol comprises 72–90% of the essential oil extracted from cloves, and is the compound most responsible for clove aroma. Complete extraction occurs at 80 minutes in pressurized water at 125 °C (257 °F).



Ultrasound-assisted and microwave-assisted extraction methods provide more rapid extraction rates with lower energy costs. Eugenol is a naturally occurring phenolic molecule found in several plants such as cinnamon, clove, and bay leaves. It has been used as a topical antiseptic as a counter-irritant and in dental preparations with zinc oxide for root canal sealing and pain control. Although not currently available in any FDA-approved products (including OTC), eugenol has been found to have anti-inflammatory, neuroprotective, antipyretic, antioxidant, antifungal and analgesic properties. Its exact mechanism of action is unknown; however, it has been shown to interfere with action potential conduction. There is a number of unapproved over-the-counter (OTC) products available containing eugenol that advertises its use for the treatment of toothache. Eugenol, also called clove oil, is aromatic oil extracted from cloves that is used widely as a flavoring for foods and teas and as herbal oil used topically to treat toothache and more rarely to be taken orally to treat gastrointestinal and respiratory complaints. Eugenol in therapeutic doses has not been implicated in causing serum enzyme elevations or clinically apparent liver injury, but ingestions of high doses, as with an overdose, can cause severe liver injury [10]. Eugenol is an allyl chain-substituted guaiacol, i.e. 2-methoxy-4-(2-propenyl)phenol. Eugenol is a member of the allylbenzene class of chemical compounds. It is a clear to pale yellow oily liquid extracted from certain essential oils especially from clove oil, nutmeg, cinnamon, and bay leaf. It is slightly soluble in water and soluble in organic solvents. It has a pleasant, spicy, clove-like odor. Eugenol is used in perfumeries, flavorings, essential oils and in medicine as a local antiseptic and anesthetic. It was used in the production of isoeugenol for the manufacture of vanillin, though most vanillin is now produced from petrochemicals or from by-products of paper manufactures [11-12]

Eugenol is a phenylpropanoid formally derived from guaiacol with an allyl chain substituted para to the hydroxy group. It is a major component of clove essential oil, and exhibits antibacterial, analgesic and antioxidant properties. It has been widely used in dentistry to treat toothache and pulpitis. It has a role as an allergen, a human blood serum metabolite, a sensitiser, a volatile oil component, a flavouring agent, an EC 1.4.3.4 (monoamine oxidase) inhibitor, a radical scavenger, an antibacterial agent, an antineoplastic agent, an apoptosis inducer, an anesthetic, an analgesic, a voltage-gated sodium channel blocker, a NF-kappaB inhibitor and an anti-inflammatory agent. It is a phenylpropanoid, a monomethoxybenzene, a member of phenols and an alkenylbenzene. It is functionally related to a guaiacol [13-14].

5. Application of eugenol in dentistry

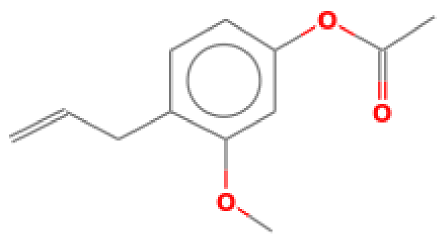
Eugenol, an important part of the clove, is certainly an essential part of the dentist's kit because of analgesic, local anesthetic, anti-inflammatory, and antibacterial effects. It is used in the form of a paste or combination as dental cement, filler, and curative material. Eugenol-containing dental materials are frequently used in clinical dentistry. When zinc oxide-eugenol (ZOE) is applied to a dentinal cavity, small quantities of eugenol diffuse through the dentin to the pulp. Low concentrations of eugenol exert anti-inflammatory and local anesthetic effects on the dental pulp. Moisten a cotton pellet with 1 or 2 drops of medication and using the tweezers, place in the cavity for approximately 1 minute. Avoid touching tissues other than the tooth cavity. Apply the dose not more than four times daily or as directed by a dentist or physician. Eugenol inhibits N-methyl-d-aspartate (NMDA) receptors which are involved in pain sensitivity. Eugenol is similar in chemical structure to capsaicin and therefore its effect on a vanilloid receptor should not be ignored. Clove oil has been used for centuries to treat tooth pain. Dabbing a little diluted oil on the gums may help ease pain and inflammation. While eugenol, the active ingredient in clove oil, has long been used in Eastern and Western medicine, the FDA does not believe that the evidence supporting its use is strong. Clove oil should not be used if you are pregnant or breastfeeding, have bleeding a disorder, or have impending surgery. Children should also avoid clove oil [15].

6. Hepatotoxicity of eugenol

The low concentrations of eugenol and clove extracts used topically and in herbal products have not been convincingly linked to instances of liver injury, either in the form of serum enzyme elevations or clinically apparent liver injury. In high doses, however, eugenol appears to be a direct cytotoxin and several instances of severe acute liver and kidney injury have been reported after accidental overdose of eugenol containing herbal products, largely in children. Overdoses have been marked by the onset of agitation, decrease in consciousness and coma arising within hours on ingestion (10-30 mL of clove oil). There is typically an accompanying acidosis, respiratory depression and severe hypoglycemia requiring ventilation and intravenous glucose. Liver injury arises 12 to 24 hours after ingestion with marked elevations in serum aminotransferase levels and early coagulation abnormalities. Signs of hepatic failure arise rapidly, and jaundice can develop and deepen. The overall clinical presentation is typical of acute hepatic necrosis and similar to that of acetaminophen, iron or copper overdose. The liver injury generally worsens for several days but then rapidly improves and ultimately resolves within 1 to 3 weeks. Renal dysfunction may also occur but rarely requires intervention or dialysis. Long term injury or effects have not been described. Cases described in the literature have been in infants who swallowed clove oil being used by parents [16-19].

7. Acetyl eugenol

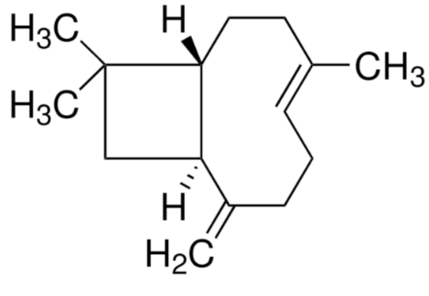
Acetyleugenol is a phenylpropanoid compound found in cloves. It is the second in abundance to the related compound eugenol in certain extract preparations.



Eugenol acetate (Eugenyl acetate), a major phytochemical constituent of the essential oil exhibits antibacterial, antioxidant, and antivirulence activities. Eugenol acetate (Eugenyl acetate), a phytochemical in clove essential oil, against clinical isolates of Candida albicans, Candida parapsilosis, Candida tropicalis, and Candida glabrata. It inhibits aggregation and alters arachidonic acid metabolism in human blood platelets. In high doses, however, eugenol appears to be a direct cytotoxin and several instances of severe acute liver and kidney injury have been reported after accidental overdose of eugenol containing herbal products, largely in children [20].

8. β-Caryophyllene

Caryophyllene, more formally-β-caryophyllene, is a natural bicyclic sesquiterpene that is a constituent of many essential oils, especially clove oil, the oil from the stems and flowers of Syzygium aromaticum, the essential oil of Cannabis sativa, copaiba, rosemary, and hops. Beta-caryophyllene is found in a variety of different spices and herbs. It's an effective anti-inflammatory, antimicrobial, and mood enhancer. You can find this particular terpene in basil, rosemary, cinnamon, oregano, cloves, lavender, and black pepper. Surprisingly, this terpene can also be found in broccoli.

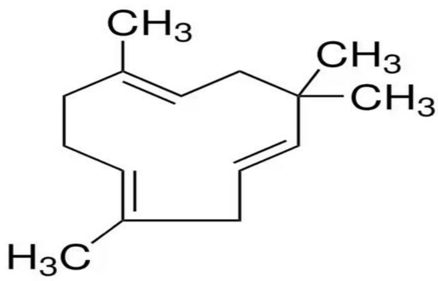


β-Caryophyllene(BCP) has now been shown to be directly beneficial for colitis ,osteoarthritis, diabetes ,cerebral ischemia ,anxiety and depression , and liver fibrosis. β-Caryophyllene has the distinction of being the first known "dietary cannabinoid," a common component of food that has GRAS (Generally Recognized as Safe) status and is approved by the FDA for food use[21-22].

Caryophyllene is a potent component in anti-inflammatory salves and topicals and also has potential anticancer, antibacterial, antifungal, and antiseptic properties. Caryophyllene is unique because of its ability to bind to CB2 cannabinoid receptors in the endocannabinoid system after being consumed orally. Thepolypharmacological properties, including receptor selectivity provide rationale and its drug-like properties; provide more realism for its future in drug discovery and development. Additionally, the antioxidant, anti-stress, and longevity potential provide a nutritional basis of its use to boost the immunity and suppress overt oxidative stress and subsequent hyper inflammatory states. Considering the recognition of safety status by USFDA and its favorable pharmacokinetic and physicochemical properties, BCP itself or plants containing a high amount of BCP may be important for nutritional or dietary usage. BCP and the plants containing BCP as a major ingredient may be candidates for developing novel antiviral and immunomodulator therapies. Much promising research has been conducted on animals to uncover various caryophyllene effects, most notably its possible therapeutic usages. However, more research is needed to understand this terpene's effects on human health, both physical and mental. One notable 2015 study, conducted on human cells and published in the journal Molecules, demonstrated caryophyllene's potential as an anticancer, antimicrobial, and antioxidant agent. Although these findings are very promising, further research in humans is necessary to fully define the best medical uses for caryophyllene[23-25].

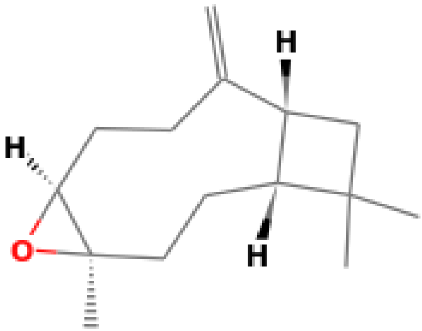
9. α-humulene

Humulene, also known as α-humulene or α-caryophyllene, is a naturally occurring monocyclic sesquiterpene, containing an 11-membered ring and consisting of 3 isoprene units containing three nonconjugated C=C double bonds, two of them being triply substituted and one being doubly substituted. Humulene is found in the flowering cone of the hops plant. It is also present in marsh elders and a wide array of herbs and spices, including; sage, basil, clove, black pepper, coriander, and balsam fir tree. As mentioned earlier, Humulene gives beer its distinctive profile [26-28].
In a study on the properties of the essential oil of balsam fir, alpha humulene was found to be active against the staphylococcus aureus bacteria. Another study showed that alpha humulene promotes the activity of a protein that creates new blood vessels, which is a vital step in healing wounds in the body. Strains high in humulene tend to have a relaxing effect with a chance of couch-locking the user on top of boosting creativity, relieving pain, and calming the mind. Furthermore, terpenes such as beta-caryophyllene and myrcene are known to amplify the effects of cannabinoids. This terpene has analgesic effects, meaning it can help to relieve pain. When taken orally, it has powerful anti-inflammatory properties that have been shown in a study to decrease allergic inflammation in the airways. Humulene may also produce mild sedative effects and may provide antibacterial properties. The ability to fight against and even kill cancer cells. Anti-inflammatory and anti-pain properties to soothe aches and inflammation. The power to kill or repel certain kinds of bacteria. Appetite-suppressant properties to make people feel less hungry [29-30]. α-Humulene is contained in the essential oils of aromatic plants such as Salvia officinalis (common sage, culinary sage), Lindera strychnifoliaUyaku or Japanese spicebush, ginseng species, up to 29.9% of the essential oils of Mentha spicata, the ginger family (Zingiberaceae), 10% of the leaf oil of Litseamushaensis [31].



10. α-Caryophyllene oxide

Caryophyllene oxide is a sesquiterpene that results from the oxidation of β-caryophyllene, which can occur during the harvest's cure. It is also considered non-toxic, non-sensitizing, and has been indicated as an anticoagulant with platelets.

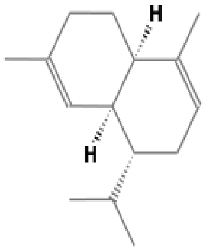


Caryophyllene oxide is present in plants' profiles like eucalyptus, lemon balm, oregano, wormwood, rosemary, guava, black pepper, and clove. It has been used in cosmetics, drugs, food preservatives, and for training drug-sniffing dogs by law enforcement.This terpene interacts with the endocannabinoid system by biding directly with CB2 receptors. Like other terpenes, its benefits include anticancer, anti-inflammatory, analgesic, and anti-bacterial properties. It has been compared to ciclopirox olamine and sulconazole as an antifungal, mainly used in toenail fungus treatment and other skin and nail fungi.This compound serves as a broad-spectrum antifungal in plant defense and as an insecticidal/antifeedant. Caryophyllene oxide is a sesquiterpenoid oxide common to lemon balm (Melissa officinalis), and to the eucalyptus, Melaleucastypheloides, . Caryophyllene oxide is nontoxic and nonsensitizing, and has the distinction of being the component responsible for cannabis identification by drug-sniffing dogs. Caryophyllene Oxide has been identified to be beneficial as:Anticoagulant ,Anticancer ,Antifungaland Anti-Inflammatory [32-35] .

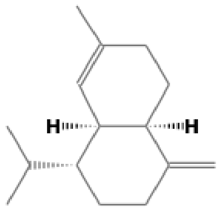
11. α-Muroleneandγ-murolene

These have been shown to have effects on health, including antioxidant and anti-inflammatory activities. Muurolene has also been shown to inhibit protein targets involved in cancer cell proliferation. The compound may be used as an additive for flavorings, fragrances, and other cosmetics[36].

α-Murolene

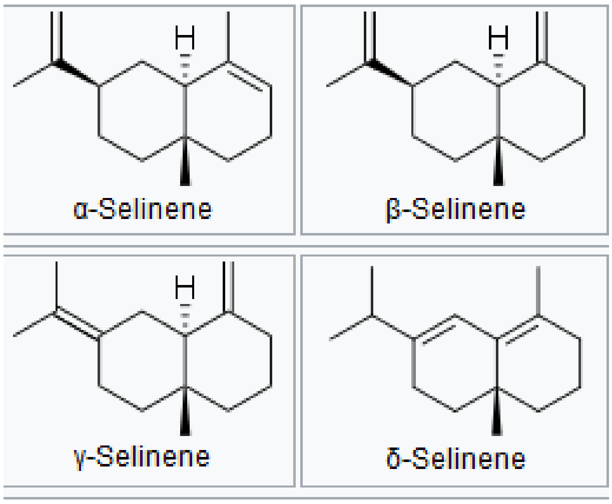


γ-Murolene



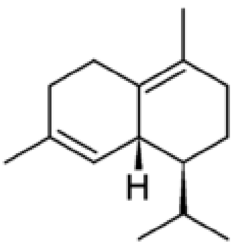
12. α-selineneandβ-selinene

α -Selinene and β-selinene are the most common and are two of the principal components of the oil from celery seeds and clove . γ-Selinene and δ-selinene are less common. Any eukaryoticmetabolite produced during a metabolic reaction in plants, the kingdom that include flowering plants, conifers and other gymnosperms[37].Selinenes are a group of closely related isomeric chemical compounds which are classified as sesquiterpenes. The selinenes all have the molecular formula $C_{15}H_{24}$ and they have been isolated from a variety of plant sources. α-Selinene and β-selinene are the most common and are two of the principal components of the oil from clove . γ-Selinene and δ-selinene are less common[38-39].Alpha-selinene is an isomer of selinene where the double bond in the octahydronaphthalene ring system is endocyclic (2R,4aR,8aR)-configuration.. It has a role as a plant metabolite. It is a selinene and a member of octahydronaphthalenes.



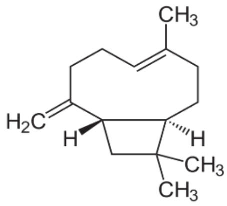
13. δ-cadinene

A member of the cadinene family of sesquiterpenes in which the double bonds are located at the 4-4a and 7-8 positions, and in which the isopropyl group at position 1 is cis to the hydrogen at the adjacent bridgehead carbon (the 1R,8aS-enantiomer). δ-cadinene shows potent anticancer effects against human ovary cancer cells through the mediation of apoptosis, nuclear membrane rupture, cell cycle arrest and caspase activation [40-42].



14. Caryophyllene oxide

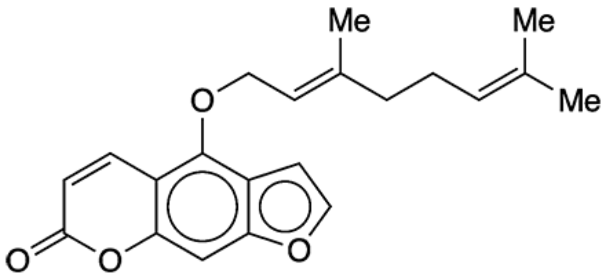
Caryophyllene more formally (−)-β-caryophyllene, (BCP), is a natural bicyclic sesquiterpene that is a constituent of many essential oils, especially clove oil, the oil from the stems and flowers of Syzygium aromaticum (cloves).



This compound serves as a broad-spectrum antifungal in plant defense and as an insecticidal/antifeedant. Beta caryophyllene is known for its analgesic applications, which means that it helps with pain. Additionally, you can expect some stress relief and mood elevation when you consume cannabis products high in beta caryophyllene, resulting in a laid back and euphoric experience. In particular, this compound binds to CB2 receptors and can support the immune system, relieve pain, reduce inflammation and can help to soothe and relax the patient. Therefore, this terpene can be found in strains of cannabis that are prescribed to those living with anxiety and chronic pain. Like other terpenes, its benefits include anticancer, anti-inflammatory, analgesic, and anti-bacterial properties. It has been compared to ciclopirox olamine and sulconazole as an antifungal, mainly used in toenail fungus treatment and other skin and nail fungi [43-48].

15. α-trans-bergamottin

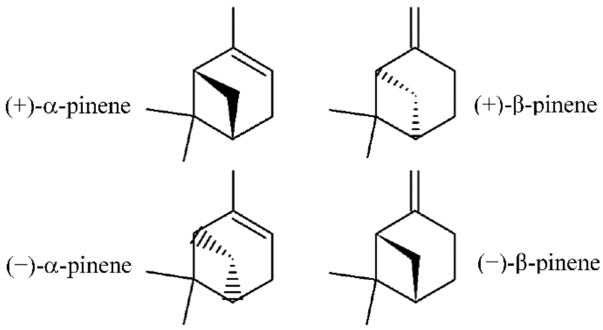
Bergamotenes are a group of isomeric chemical compounds with the molecular formula $C_{15}H_{24}$. The bergamotenes are found in a variety of plants, particularly in their essential oils.



Bergamotenes and their related structures (Bergamotane sesquiterpenoids) have been shown to possess diverse biological activities such as antioxidant, anti-inflammatory, immunosuppressive, cytotoxic, antimicrobial, antidiabetic, and insecticidal effects. Many terpenes have an anti-bacterial effect, and bergamotene is no different. A basil-centered essential oil containing α-trans-bergamotene demonstrated inhibition of E. Coli and Staphylococcus bacteria growth, both of which can cause nasty stomach pain, vomiting, and fatigue. Bergamottin, a natural furanocoumarin abundantly present in clove, has been demonstrated to exhibit anticancer effects in a variety of human cancers, including chronic myelogenous leukemia , multiple myeloma , skin cancerand breast cancer[50-53] .

16. α-pinene andβ-pinene

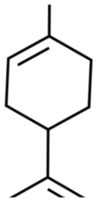
Pinene is a collection of unsaturated bicyclic monoterpenes. Two geometric isomers of pinene are found in nature, α-pinene and β-pinene. Both are chiral. As the name suggests, pinenes are found in pines. The racemic mixture of the two forms of pinene is found in some clove oils [54].



Pinene is often associated with energizing cultivars (strains) that help people stay alert and focused. You may find that strains high in pinene support an energetic, euphoric, or creative cannabis experience. drug pinene is used for a wide range of pharmacological activities have been reported, including antibiotic resistance modulation, anticoagulant, antitumor, antimicrobial, antimalarial, antioxidant, anti-inflammatory, anti-Leishmania, and analgesic effects [55-56].

17. Limonene

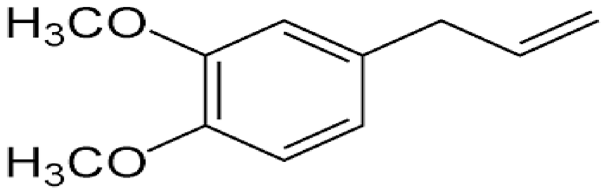
Limonene is, with the possible exception of α-pinene, the most frequently occurring natural monoterpene. It is a major constituent of the oils of citrus fruit peel, clove and is found at lower levels in many fruits and vegetables [57].



The therapeutic effects of limonene have been extensively studied, proving anti-inflammatory, antioxidant, antinociceptive, anticancer, antidiabetic, antihyperalgesic, antiviral, and gastroprotective effects, among other beneficial effects in health. opically, limonene can cause sensitivity and is best avoided. Like most volatile fragrance components, limonene also has strong antioxidant benefits and has also been shown to calm skin; however, when exposed to air these highly volatile antioxidant compounds oxidize and become capable of sensitizing skin. In addition to their commercial use as food flavorings, the limonenes are used in industrial cleaning solvents, wetting agents, air fresheners, and fragrances in personal care products [58-60].

18. Methyl eugenol

Methyl eugenol is a natural chemical compound classified as a phenylpropene, a type of phenylpropanoid. It is the methyl ether of eugenol and is important to insect behavior and pollination. It is found in various essential oils.



Methyl eugenol is found in a number of plants and has a role in attracting pollinators. Methyl eugenol (allylveratrol) is a natural chemical compound classified as a phenylpropene, a type of phenylpropanoid. It is the methyl ether of eugenol . Methyleugenol is used as a flavouring agent in jellies, baked goods, non-alcoholic beverages, chewing gum, candy, puddings, relishes and ice cream. It is also widely used as a fragrance ingredient in perfumes, toiletries and detergents. Methyleugenol has been used as an anaesthetic in rodents [60-63].

19. Biological activities of clove

Clove (Syzygium aromaticum) is one of the most valuable spices that have been used for centuries as food preservative and for many medicinal purposes. This plant represents one of the richest sources of phenolic compounds such as eugenol, eugenol acetate and gallic acid and posses great potential for pharmaceutical, cosmetic, food and agricultural applications. This review includes the main studies reporting the biological activities of clove and eugenol. The antioxidant and antimicrobial activity of clove is higher than many fruits, vegetables and other spices and should deserve special attention [64]. A new application of clove as larvicidal agent is an interesting strategy to combat dengue which is a serious health problem in Brazil and other tropical countries. Pharmacokinetics and toxicological studies were also mentioned. The different studies reviewed in this work confirm the traditional use of clove as food preservative and medicinal plant standing out the importance of this plant for different applications [65] .

20. Nutrients per serving

The composition of the clove varies according to the agro climatic conditions under which it is grown, processed and stored. The dried clove bud contains carbohydrates, fixed oil, steam-volatile oil, resins, tannins, proteins, cellulose, pentosans and mineral elements. Carbohydrates comprise about two-thirds of the weight of the spice. The dried dark and flower buds also contain nutrients like proteins, minerals, vitamins, etc. Nutrient composition of clove is depicted in Table 2.

Table 2: Nutrient Composition of One teaspoon (1 tsp = 2.10 g) of Ground Cloves:[67]

Protein (g)	0.13
Total lipid (fat) (g)	0.42
Carbohydrate, by difference (g)	1.29
Energy (kcal)	6.78
Sugars, total (g)	0.05
Fiber, total dietary (g)	0.72
Calcium, Ca (mg)	13.57
Iron, Fe (mg)	0.18
Magnesium, Mg (mg)	5.54
Phosphorus, P (mg)	2.2
Potassium, K (mg)	23.14
Sodium, Na (mg)	5.1
Zinc, Zn (mg)	0.02
Copper, Cu (mg)	0.01

Manganese, Mn (mg)	0.63
Selenium, Se (mcg)	0.12
Vitamin A, IU (IU)	11.13
Retinol (mcg)	0
Carotene, beta (mcg)	1.76
Carotene, alpha (mcg)	0
Vitamin E (alpha-tocopherol) (mg)	0.18
Cryptoxanthin, beta (mcg)	9.83
Lycopene (mcg)	0
Lutein + zeaxanthin (mcg)	0
Vitamin C, total ascorbic acid (mg)	1.7
Thiamin (mg)	0
Riboflavin (mg)	0.01
Niacin (mg)	0.03
Vitamin B-6 (mg)	0.01
Folate, total (mcg)	1.95
Vitamin B-12 (mcg)	0
Vitamin K (phylloquinone) (mcg)	2.98
Folic acid (mcg)	0
Folate, DFE (mcg_DFE)	1.95
Cholesterol (mg)	0
Fatty acids, total saturated (g)	0.11
Fatty acids, total monounsaturated (g)	0.03
Fatty acids, total polyunsaturated (g)	0.15

They're a great source of beta-carotene, which helps give cloves their rich brown color. Carotenes, a family of pigments, act as important antioxidants and provitamins. Carotene pigments can convert into vitamin A, an important nutrient for keeping your eyes healthy. Some health benefits of cloves include: Lower inflammation. i. Cloves contain many compounds known for their anti-inflammatory properties, with eugenol being the most important. It's been shown to reduce your body's inflammatory response, which can lower your risk of health issues such as arthritis and help manage symptoms. ii. Fewer free radicals. Cloves are full of antioxidants, including eugenol. Antioxidants help your body fight free radicals, which damage your cells. By removing free radicals from your system, the antioxidants found in cloves can help lower your risk of developing heart disease, diabetes, and certain cancers. iii. Reduced ulcers. Some studies show that cloves may help protect your stomach from ulcers. Most ulcers are caused by thinning of the layers of mucus that protect your stomach lining. Early research shows that eating cloves in large amounts can thicken this mucus, lowering your risk of getting ulcers and helping to heal ulcers that you already have. iv. Improved liver function. Cloves may also help your liver work better. Some studies have shown that eugenol found in cloves can also help reduce signs of liver cirrhosis and fatty liver disease [66-68].

21. Side effects of cloves

Cloves pack a powerful flavor. Eugenol can sometimes interact with certain drugs, such as the blood thinner warfarin. Small amounts of cloves as spice should be safe. Hypoglycemia. This is when your blood sugar levels drop too low. If you have diabetes, the eugenol in cloves can help lower blood glucose to safe levels. But too much clove can cause hypoglycemia (low blood sugar) which can be harmful. Essential oil toxicity. Clove essential oil has a lot more eugenol than whole or ground cloves do. Swallowing pure clove oil can be toxic and make you dizzy or cause other symptoms. Rarely, it can lead to a coma [69-70].

22. Benefits of clove oil

Throughout history, people have used clove oil to soothe toothaches. Some cosmetics and medicines use eugenol for its antibacterial, antifungal, and antiviral abilities. i. Cloves for toothache-Clove oil have been used to ease toothache as far back as 1649. It's still a popular treatment today, thanks to eugenol. Eugenol is a natural anesthetic (numbing agent). Although clove essential oil is good for treating pain, there isn't enough proof that it also kills the bacteria causing the issue. ii. Treating dental erosion: Some high-acid foods and drinks may break down your tooth enamel (the hard, outer layer of your teeth). One study found that the eugenol in clove oil, when applied to teeth, may reverse or lessen these effects. But more research is needed to fully explore clove oil as a treatment or way to prevent tooth enamel erosion [70-72].

23. Side effects of clove oil

Eugenol at high doses can damage your liver or trigger allergic reactions in some people. So, it's important to take clove oil only in safe doses and keep it out of reach of babies and children. i.Toxic effects on the liver-Clove oil can be toxic when you take too much (typically 10-30 mL, or roughly 2-6 teaspoons). Symptoms can include agitation (feeling irritated, tense, or confused), decreased alertness, and coma. There might get these symptoms within hours of swallowing the essential oil. Signs of liver injury, including jaundice (yellowing of the skin or eyes), can show between 12 and 24 hours after it's eaten. Babies are most likely to experience liver damage [73-74].

24. Allergic reactions

Even when used on the skin or mouth, eugenol can cause allergic reactions. For more than 100 years, dentists have used eugenol mixed with different compounds for many procedures, like making molds of your teeth. Eugenol has been shown to cause mild to severe allergy symptoms in some people. Signs of an allergic reaction to dental eugenol can include redness and soreness where it was applied to your gums. Some people react with a rash or welts on other parts of their body [75].

25. Conclusions

1) In this research, the author demonstrated the main studies reporting the biological activities of clove (S.aromaticum) and eugenol. Based on the information presented, it could be concluded that clove represents a very interesting plant with an enormous potential as food preservative and as a rich source of antioxidant compounds. It's proved biological activities suggest the development of medicinal products for human and animals uses.
2) Based on the information presented, it could be concluded that clove represents a very interesting plant with an enormous potential as food preservative and as a rich source of antioxidant compounds. It's proved biological activities suggest the development of medicinal products for human and animals uses and confirm why this plant has been employed for centuries.
3) The current research summarized the potential health benefits and effectiveness of Eugenol (EUG) as a therapeutic agent which can be used in medicines and food for the treatment of inflammatory and oxidative stress-oriented disorders. The antioxidant, anti-inflammatory, antipyretic, analgesic, antiparasite, and antimicrobial properties of EUG are well described. It has a great role in neuroprotection, enhances skin permeability, relieves pains, and has a role in temporary dental filler formation (ZnO+EUG). EUG has no known toxicity in smaller quantities, but at higher concentrations, it behaves as prooxidant; hence, a strong anticancer activity is shown by this molecule. Furthermore, diverse applications of EUG such as its pharmacological importance in regulating blood cholesterol and lipid levels are also discussed. Future studies involving a specified dose range of EUG to cure different ailments are recommended to highlight this molecule for the development of drugs.
4) The FDA hasn't approved clove extract as a treatment for any medical condition. Many more studies are needed before we understand all the health benefits of cloves. Talk to your doctor before you take cloves in any form. Doing so can interfere with other medicines you take, cause an allergic reaction, or lead to severe side effects.
5) The potential applications and future perspectives of clove extracts in the food and beverage industry are vast and promising. However, some limitations or challenges may arise in the production and utilization of clove extracts, such as variability in the chemical composition of the extracts, possible toxicity at high doses, and limited knowledge of the mechanism of action of specific bioactive compounds. To address these challenges, further research is needed to better understand the composition and activity of clove extracts, optimize extraction methods, and develop innovative applications in food and beverages. Additionally, regulatory measures and quality control standards should be established to ensure the safety and efficacy of clove extracts in the industry. Future prospects for the use of different extraction methods are also discussed. Overall, the valorisation of clove has the potential to create new economic opportunities, promote sustainable practices, and expand the use of this versatile and beneficial spice beyond its traditional applications.

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