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Clove: A review of a precious species with multiple uses

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Abstract

Clove (*Syzygium aromaticum*) is one of the most valuable spices that have been used traditionally as food preservative and for many therapeutic purposes. Clove is native of Indonesia but it has also been cultured in several parts of the world including Pakistan. This plant represents one of the richest sources of phenolic constituents as eugenol, and eugenol acetate and posseses great potential for pharmaceutical, cosmetic, food and agricultural applications. This article includes main studies reporting the phytochemical profile and pharmacological activities of clove and eugenol. The antioxidant and antimicrobial activities of clove are higher than many fruits, vegetables and other spices. Toxicological studies are also mentioned. The different studies reviewed in current work authenticate the traditional use of clove as food preservative and medicinal plant.

Key words: *Syzygium aromaticum*, eugenol, antioxidant

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1. Botany

1.1. Introduction

Clove (*Syzygium aromaticum*) a precious spice, is a member of *Mirtaceae* family which has been employed for centuries as food preservative and medicine because of its antimicrobial and antioxidant properties. *Syzygium* is the largest genus of *Mirtaceae* family, comprising of about 1200 to 1800 species of flowering plants, which are widely distributed in tropical and subtropical areas of Asia, Africa, Madagascar, and throughout Pacific and Oceanic regions [1]. Cloves contain appreciable amounts of volatile oil (used for flavouring foods and pharmaceuticals), which is mainly confined in aerial parts of plant. The yield and composition of volatile oil are variable and are thought to be linked to growing conditions, genetic factors, different chemotypes, geographic origins, and differences in the nutritional status of plant [2-4]. Clove is known by different vernacular names in different languages. It is known as qaranful (Arabic), Karamfil (Bulgarian), Ding xiang (Chinese), Kruidnagel (Danish), Garifalo (Greek), Mikhaki (Georgian), Nelke (German), Szegfu (Hungarian), Cengkeh (Indonesian), Choji (Japanese), Jeonghyang (Korean), Krustnaglinas (Latvian), Lwaang (Nepalese), Carvo de India (Portuguese), Mikhak (Persian), Kala (Pashto), Gvosdika (Russian), Clavo (Spanish), Carenfil (Turkish), Garn ploo (Thai), Dhing huong (Vietnamese), and Laung (Urdu/Punjabi/Hindi) [5].

1.2. History

Clove is an ancient spice, which is believed to be originated in the first century, before Christ. The first clue about clove's fragrance was given by the ancient Chinese (207 B.C. to 220 A.D.). At that time, a Chinese Physician wrote that court visitors were required to hold clove in their mouth to prevent the Emperor from visitor's bad breath. Cloves were traded to Europe by the Arabs in 4th century A.D. The origin and source of clove was a mystery, until the discovery of Indonesia or Moluccas Island, by Portuguese, in 16th century. In 17th century A.D., cloves were introduced to Sri Lanka. In 18th century A.D., cloves were established in India by East India Company. In European countries, there is a tradition to make "Pomanders" by studding oranges with clove buds, and to hang them around the homes, during Christmas, for decorative purpose and to spread fragrance.

1.3. Demography/Location

Clove requires damp tropical and sub-tropical environments for growth. It has been cultivated in the following countries: Indonesia, Sri-Lanka, India, Tanzania, Malaysia, Madagascar, and Pakistan.

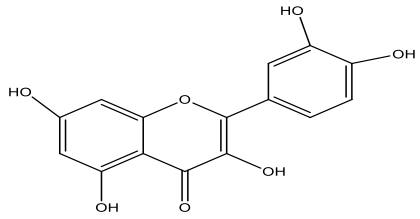
1.4. Botany, Morphology, Ecology

Clove is a scented dried bud of *Syzgium aromaticum* tree, used as seasoning in food cuisines. *S. aromaticum* is an evergreen tree which grows upto a height of 8 to 12m; having large quadrangle leaves and cheerful flowers arranged in form of clusters. Young flower buds are of pale color and slowly changes to green, which changes to bright red when buds are ready for harvesting. Harvesting should be done when buds have 1.5–2 cm length, long calyx terminating in four closed petals (forming a tiny ball in the

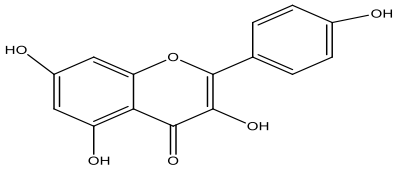
core) and spreading sepals. Clove growth requires well-drained, loamy, and organic matter rich soils. Constant temperature above 10ºC is crucial, while, optimum temperature is around 20 to 30 ºC. This species cannot tolerate water logged conditions. Areas having annual rainfall of 150 to 300 cm are best for its growth [5].

2. Chemistry

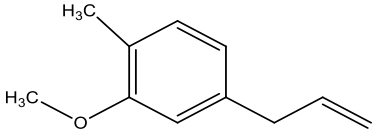
Clove is a vital source of phenolic compounds such as flavonoids, hydroxycinamic acids, hydroxybenzoic acids, and hydroxyphenyl propenes. Eugenol is the chief bioactive constituent of clove, which is present in concentrations ranging from 9 381.70 to 14 650.00 mg/100 g of fresh plant weight. With regard to the phenolic acids, gallic acid is found in higher concentration (783.50 mg/100 g fresh weight) [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 is generally found by GCMS analysis [7-11]. Good quality clove bud contains volatile oil (15 to 20%), which mainly comprises of eugenol (70 to 85%), eugenyl acetate (10 to 15%), and beta-caryophyllene (5 to 12%). Other minor constituents including methyl amyl ketone, kaempferol, gallotannic acid, α-humulene, β-humulene, methyl salicylate, crategolic acid, and benzaldehyde are responsible for the characteristic pleasant fragrance of clove [12]. Figure 1 shows structures of some important compounds of clove.



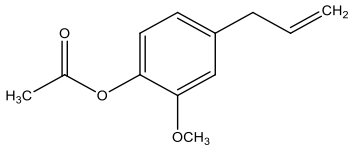
Quercetin



Kaempferol



Eugenol



Eugenol acetate

Fig.1. Structures of some important phytochemicals found in *Syzygium aromaticum* L.

3. Post-harvest technology

Clove trees begin to flower in four years and the full bearing stage is achieved only in 15 years. Flowering period varies from September-October to December-January depending on tree locality. Clove buds are formed on young branches and take 4-6 months to become ready for harvest. Buds should be harvested when color of petals changes to yellow pink from green. Harvesting can be done by hand or by using stepladder. Harvesting should be done carefully to prevent breakage of branches. An average 15 to 20 year old tree yields 3 to 4 kg of dried clove buds. Optimum time for harvesting clove seeds is 75-90 days after fruit set. After harvesting, clove buds are separated from their stalks by hand and spread on mats for drying. Drying may take 4 to 5 days. Well dried buds are hard, crisp and dark brown, having moisture content (<12%), which can be stored for 1 to 2 years in gunny bags. Approximately, 15-20% volatile oil can be produced from dried buds [13].

4. General uses

Cloves have many uses ranging from culinary to medicine. Clove is a valuable kitchen spice which can be used for studding onions, tomatoes, salads, herbal teas, and soups. It is also used to flavor meat products, cookies, chewing gums, spiced fruits, pickles, chocolates, soft drinks, puddings, sandwiches, pastries, and candies. Volatile oil is used to impart essence to perfumes soaps, toothpastes, and pharmaceuticals. In Indonesia, mixture of clove and tobacco in a ratio of 1:2 is used to make a special cigarette “Kretek”. Clove possesses antibacterial potential and is used in a variety of mouth washes, dental creams, throat sprays, and tooth pastes to kill pathogens. It is also used to relive sore gums. Mixture of eugenol (major bioactive constituent of clove) and zinc oxide is used for short-term filling of dental cavities [14]. Clove oil has anti-inflammatory properties due to the presence of flavonoids. Pure clove oil is used in aromatherapy of arthritis and rheumatism. Paste of clove powder and honey is used to cure skin conditions. Paste of water and clove powder boosts healing process of bites and cuts. Clove is used to treat various digestive disorders including loose motion, flatulence, nausea, and dyspepsia. Clove oil improves body defense system and help to fight against invading microbes. It is also used to cure Onychomycosis and Athlete’s foot disease. Inhalation of clove essential oil soothes various respiratory conditions such as asthma, cold, cough, sinusitis, and bronchitis. Cloves have anticancer potential and are used to cure skin and lung carcinoma. Clove is good for diabetic patients as it controls the blood level of glucose. Eugenol prevents the formation of blood clots. Topical application of clove oil relieves muscular cramps. Cloves also prevent the breakdown in eye’s retina, which slows down muscles degeneration and assists vision in the old age. Sniffing of clove aroma reduces lethargy, restlessness, and headaches. Application of one drop of clove oil can soothe headaches.

Clove improves memory by relieving mental fog, drowsiness, and depression. Clove oil is mosquito repellent [15]. Antioxidant potential of clove is higher than many other medicinal plants. One drop of clove oil is 400 times more potent than blueberries. Cloves are used as part of herbal formulations to cure animals. The clove oil has potential of curing ear infection in dogs and cats. Peppermint tea with a sprinkle of cloves and ginger has been used to treat vomiting in dogs; 1 tbsp or more, according to the size of the animal, being given 3 times daily.

5. Pharmacological uses

5.1. Antimicrobial activity

Antimicrobial properties of *Syzygium aromaticum* and *Rosmarinus officinalis* essential oils were tested against multidrug resistant isolates including *Pseudomonas aeruginosa, Enterococcus feacalis,* Acinetobacter baumannii, and *Staphylococcus aureus*, and two controlled strains *Pseudomonas aeruginosa*-ATCC27853 and *Staphylococcus aureus*-ATCC29213, using agar well diffusion model. Both oils exhibited significant inhibition against tested strains, with minimum inhibitory concentrations ranging from 0.312-1.25% (v/v) for clove oil, and 0.312- 5% (v/v) for rosemary oil [16]. A comparative analysis was carried out to evaluate the antiseptic potential of clove extract (ethanolic) and clove oil against some food borne pathogens. Ten bacterial and seven fungal strains were tested using agar well diffusion method. Sodium propionate was used as a standard food preservative. Results revealed the greater antimicrobial effect of clove oil, when compared to extract and sodium propionate. In another study, clove oil was tested against five dermophytes including *Trichophyton rubrum*, *Epidermophyton floccosum*, *Microsporum canis*, *Microsporum gypseum*, and *Trichophyton mentagrophytes.* Maximum inhibitory effect (≈60%) against all fungal strains was shown at dose of 0.2mg/ml [17]. Antibacterial activity of six spices (clove, mint, cinnamon, ginger, mustard, and garlic) was evaluated against *Escherichia coli*, *Bacillus cereus,* and *Staphylococcus aureus*, using dilution, cup, and paper disc diffusion assays. Results revealed the maximum inhibitory action of clove, mustard, and cinnamon at 1% concentration. Garlic showed good inhibitory action at 3% concentration. However, mint and ginger had negligible inhibition at same concentration [18]. Essential oils of *Piper nigrum*, *Syzygium aromaticum, Pelargonium graveolens*, *Myristica fragrans*, *Origanum vulgare, and Thymus vulgaris* were evaluated for antimicrobial activity against twenty five bacterial strains, including food borne, animal, and plant pathogens.considerable inhibitory action was observed by the volatile oils in a dose dependent behavior [19].

5.2. Cytotoxic activity

Anti-oxidant, genotoxic and cytotoxic potentials of borneol and eugenol (clove oil derivative) were evaluated as the capability of modulating resistance against DNA damaging effects of H_2O_2, on different strains of human cells: malignan hepatome cells (HepG2), malignan colon cells (caco-2) and non malignan human fibroblast (VH10). Results revealed the remarkable anti-oxidative potential of eugenol at all the tested doses. It was also verified that the citotoxic potential of eugenol was more powerful than borneol. With regard to toxicity, eugenol exhibited strong DNA damaging effects on human fibroblast (VH10), medium damaging effects on colon cells (caco-2) and non genotoxic effects on hepatome cells (HepG2) [20].

5.3. Antioxidant activity

A study was performed to assess the antioxidant potential of aqueous and alcohol extracts of some selected spices including onion, garlic, pepper, cinnamon, mint, ginger, and clove. Generally phenolic and flavonoids are responsible for antioxidant activities of the oil [21]. All spices inhibited lipid oxidation in a dose dependent manner. Among all, clove showed maximum, whereas, onion showed minimum inhibitory potential [22]. Antioxidant activities of clove, sage, and oregano essential oils were evaluated using DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical quenching, BCB (β-carotene bleaching), and FRP (Fe(lll) reducing power) methods. Butylated hydroxytoluene was used as standard antioxidant. Essential oils were added to soybean oil at doses of 0.006 and 0.01g/ml, for thirty days, at accelerated oxidation level. Among all examined oils, the clove oil showed more potent ($p<0.05$) antioxidant activity followed by oregano and sage oils [23].

5.4. Antiviral activity

Eugenin isolated from clove bud essential oil exhibited a potent inhibitory effect against herpes simplex virus at a dose of 10µg/ml [24].

5.5. Hepatoprotective activity

Hepatoprotective potential of clove aqueous extract was evaluated at doses of 0.1 and 0.2g/kg, using paracetamol intoxicated hepatic damage assay, in Wistar albino rats. The degree of hepatic damage was evaluated by increased levels of cytopalsmic enzymes (aspartate aminotransferase and alanine aminotransferase). Clove extract restored the normal concentrations of enzymes in serum [25].

5.6. Analgesic activity

Eugenol was administrated intravenously and intragastrically to rabbits to examine its analgesic effect. Paracetamol was a standard drug. Eugenol showed greater fever reducing potential than paracetamol [26].

5.7. Anesthetic activity

Anesthetic effect of eugenol was studied in *Oncorhynchus mykiss* (juvenile rainbow trout). Anesthesia induction and recovery times were compared with standard drug, tricaine methanesulfonate (MS-222). Eugenol induced anaesthesia at relatively lower concentration than standard drug. Moreover, the recovery time was 6-10 times longer for fishes exposed to eugenol than those exposed to same doses

of tricaine methanesulfonate. Above study suggested the anesthetic use of clove oil derivative "Eugenol" [27].

6. Toxicity

The clove oil is considered safe when consumed in doses (<1.5g/kg). However, the WHO (World Health Organization) established the acceptable dose of clove 2.5 mg/kg/day in humans. The toxicity of clove oil was evaluated in aquarium fish species, *Poecilia reticulata* and *Danio rerio*. *The* LD_{50} values were (18.2±5.52) mg/ml and (21.7±0.8) mg/ml in *Danio rerio* and *Poecilia reticulate*, *respectively*, at 96 h [28].

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