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Clove (*Syzygium aromaticum*): a precious spice

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PEER REVIEW

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Comments

In the review, the authors 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.

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ABSTRACT

Clove (*Syzygium aromaticum*) is one of the most valuable spices that has been used for centuries as food preservative and for many medicinal purposes. Clove is native of Indonesia but nowadays is cultured in several parts of the world including Brazil in the state of Bahia. This plant represents one of the richest source of phenolic compounds such as eugenol, eugenol acetate and gallic acid and possesses 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. 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.

KEYWORDS

Spice, Clove, Aromatic plant, Volatile, Antioxidant, Dengue fever, Larvicidal

1. Introduction

Spices as clove, oregano, mint, thyme and cinnamon, have been employed for centuries as food preservatives and as medicinal plants mainly due to its antioxidant and antimicrobial activities. Nowadays, many reports confirm the antibacterial, antifungal, antiviral and anticarcinogenic properties of spice plants. Clove in particular has attracted the attention due to the potent antioxidant and antimicrobial activities standing out among the other spices[1].

Syzygium aromaticum (*S. aromaticum*) (synonym: *Eugenia*

cariophyllata) commonly known as clove, is a median size tree (8–12 m) from the Mirtaceae family native from the Maluku islands in east Indonesia. For centuries the trade of clove and the search of this valuable spice stimulated the economic development of this Asiatic region[2].

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

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using a natural phytohormone which liberates ethylene in the vegetal tissue, producing precocious maturation[3].

Nowadays, the larger producer countries of clove are Indonesia, India, Malaysia, Sri Lanka, Madagascar and Tanzania specially the Zanzibar island[2]. 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].

2. Chemical compounds isolated from clove

Clove represents one of the major vegetal sources of phenolic compounds as flavonoids, hidroxibenzoic acids, hidroxicinamic acids and hidroxiphenyl propens. 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 -cariofileno[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.

3. Biological activities

Clove is an important medicinal plant due to the wide range of pharmacological effects consolidated from traditional use for centuries and reported in literature. A review of several scientific reports of the most important biological activities of clove and eugenol is presented in the following paragraphs.

3.1. Antioxidant activity

Recently, the United States Department of Agriculture in collaboration with Universities and private companies create a database with the polyphenol content and antioxidant activity of different kind of foods. Based on this database, Pérez-Jiménez *et al.* classified the 100 richest dietary sources of polyphenols[8]. Results indicate that the spice plants are the kind of food with higher polyphenol content followed by

fruits, seeds and vegetables. Among spices, clove showed the higher content of polyphenols and antioxidant compounds.

In another work published by Shan *et al.*[1], the main phenolic compounds in 26 spices were identified and quantified by high performance liquid chromatography, followed by the *in vitro* antioxidant activity analysis by the ABTS method. Results showed the high correlation between the polyphenols content and the antioxidant activity. Clove (buds) was the spice presenting higher antioxidant activity and polyphenol content, (168.660 $\pm$ 0.024) tetraethylammonium chloride (mmol of Trolox/100g dried weight) and (14.380 $\pm$ 0.006) g of gallic acid (equivalents/100g of dried weight) respectively. The major types of phenolic compounds found were phenolic acids (gallic acid), flavonol glucosides, phenolic volatile oils (eugenol, acetyl eugenol) and tannins. It was highlighted the huge potential of clove as radical scavenger and as a commercial source of polyphenols.

The antioxidant activity of clove and caraway were screened using various *in vitro* models, such as b-carotene-linoleate, ferric thiocyanate, 1,1-diphenyl-2-picryl hydroxyl (DPPH) radical, hydroxyl radical and reducing power model systems concluding that the antioxidant activity of clove and caraway is comparable with butylated hydroxytoluene (BHT), a synthetic compound commonly employed as food preservative Bamdad *et al.*[9]. According to Gülçin *et al.*[10], the antioxidant activity of clove oil compared with synthetic antioxidants measured as the scavenging of the DPPH radical decreased in the following order: clove oil>BHT> α -tocopherol>butylated hydroxyanisole>Trolox.

The antioxidant activity of aqueous extracts of clove has been tested by different *in vitro* methods as 2,2-diphenyl-1-picrylhydrazyl (DPPH); 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), oxygen radical absorbance capacity, ferric reducing antioxidant power, xanthine oxidase and 2-deoxyguanosine. Clove and plants as pine, cinnamon, and mate proved its enormous potential as food preservative among the other 30 plants analyzed[11].

Ethanol and aqueous extracts of clove and lavender at concentrations of 20, 40 and 60 μ g/mL showed inhibitions up to 95% when tested as metal quelants, superoxide radical capture and scavenging of the DPPH radical. The powerful antioxidant activity of both extracts may be attributed to the strong hydrogen donating ability, metal chelating ability and scavenging of free radicals, hydrogen peroxide and superoxide[12].

Gülçin studied the antioxidant activity of eugenol by several *in vitro* methods and discusses the structure-activity relationship[13]. Compared to butylated hydroxyanisole, BHT, Trolox and α -tocopherol, eugenol presented higher antioxidant activity in most of the methods tested, DPPH, ABTS, N,N-dimethyl-p-phenylenediamine, CUPRAC and ferric reducing assay. It was remarked that plant polyphenols are multifunctional in the sense that they can act as reducing agents, hydrogen atom donators, and singlet

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