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Review

Phytochemistry, pharmacology and medicinal properties of *Coriandrum sativum* L.

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***Coriandrum sativum* L. commonly known as "Coriander" is an annual herb, indicated for a number of medical properties in traditional medicine. For a long time, *C. sativum* has been used in traditional medicines as an anti-inflammatory, analgesic, and antibacterial agent. Its essential oil is also used as a natural fragrance with some medicinal properties. *C. sativum* has recently been shown to have antioxidant, antidiabetic, hepatoprotective, antibacterial, and antifungal activities. Volatile components, flavonoids, and isocoumarins are the main constituents of *C. sativum*. 2-decenoic acid, E-11-tetradecenoic acid, and capric acid were identified as the major components for *C. sativum* leaves essential oil. The seed oil contained linalool and geranyl acetate. Due to the easy collection of the plant and being widespread and also remarkable biological activities, this plant has become both food and medicine in many parts of the world. This review presents comprehensive analyzed information on the botanical, chemical, and pharmacological aspects of *C. sativum*.**

Key words: *Coriandrum sativum*, apiaceae, phytochemistry, pharmacology.

INTRODUCTION

Coriandrum sativum L. commonly known as "Coriander" is an annual small plant like parsley which dates back to around 1550 BC, and is one of the oldest spice crops in the world (Coskuner and Karababa, 2007). It belongs to Apiaceae family in the order of Apiales that contains about 300 genera and more than 3000 species (Asgarpanah et al., 2012).

C. sativum probably originated from Eastern Mediterranean and it is spread as a spice plant to India, China, Russia, Central Europe, and Morocco, and has been cultivated since human antiquity (Small, 1997). India is the largest producer of coriander which is used extensively in curry powder (Coskuner and Karababa, 2007). Coriander has been known as "Geshniz" in Iran.

C. sativum is an annual, herbaceous plant that grows 25 to 60 cm in height. It has thin, spindle-shaped roots, erect stalk, alternate leaves (Figure 1), and small, pinkish-white flowers. The plant flowers from June to July and yields round fruits consisting of two pericarps (Burdock and Carabin, 2009). These fruits are almost ovate globular and there are many longitudinal ridges on the surface. The length of this fruit is 3 to 5 mm and the color, when dried, is usually brown, but may be green, straw-colored or off white (Figure 2) (Coskuner and Karababa, 2007).

The plant is grown widely all over the world for seed, as a spice, or for essential oil production (Bhuiyan et al., 2009). The whole or ground seed (fruit) is an ingredient of pickling spices also used to flavor various commercial foods, particularly, to prepare some instant soups and dishes, in many cakes, breads and other pastries, alcoholic beverages, frozen dairy desserts, candy, and puddings. The fruit's essential oil is a common ingredient in creams, detergents, surfactants, emulsifiers, lotions, and perfumes (Coskuner and Karababa, 2007). There are two varieties of *C. sativum*: *vulgare* Alef. and *microcarpum* DC. These varieties differ in the fruit size and oil yield: *vulgare* has fruits of 3 to 5 mm diameter and yields 0.1 to 0.35% essential oil, while *microcarpum* fruits are 1.5 to 3 mm and yield 0.8 to 1.8% essential oil (Small, 1997).

The green leaves of coriander are known as "cilantro" in the United States, and are consumed as fresh herb in

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Figure 1. *C. sativum* L. (Coriander).

Figure 2. *C. sativum* fruits (seeds).

preparing chutneys, sauces, in flavoring curries and soups. The fruits are mainly responsible for the medical use of coriander and have been used as a drug for indigestion, against worms, rheumatism, and pain in the joints (Wangensteen et al., 2004). The fruit extract is used in lotions and shampoos as an antibacterial agent

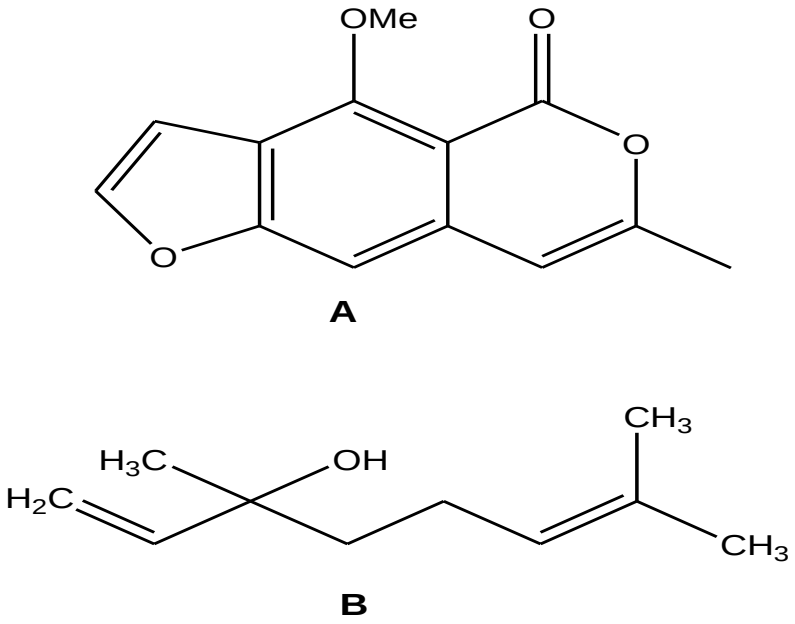

Figure 3. Structures of (A) coriandrin and (B) linalool from *C. sativum*.

(Bhuiyan et al., 2009). There are records that it is effective for relief of insomnia, anxiety, and convulsion (Emamghoreishi and Heidari-Hamedani, 2008). It is also used for sub-acid gastritis, diarrhea, and dyspepsia of various origins as well as for its digestive stimulation, stomachic, and antibilious properties (Platel and Srinivasan, 2004). In folk medicine, coriander is used against intestinal parasites (Wichtl, 1994). Coriander has been reported to possess strong lipolytic activity (Leung and Foster, 1996), and, as a member of Apiaceae family, its use has been suggested with caution, because of potential allergic reactions from furanocoumarins (Burdock and Carabin, 2009). Coriander leaves are widely used as folk medicine as carminative, spasmolytic, digestive, and galactagogue. It has the advantage of being more stable and of retaining its agreeable odor longer than any other oil of its class (Eikani et al., 2007).

A number of chemical constituents such as volatile constituents, flavonoids, isocoumarins, and coriandrones have been isolated from different parts of the plant (Taniguchi et al., 1996). From current pharmaceutical studies, additional pharmaceutical applications of *C. sativum* have revealed antibacterial (Silva et al., 2011a), antifungal (Silva et al., 2011b), antioxidant (Wangensteen et al., 2004), hepatoprotective (Sreelatha et al., 2009), antihelmintic (Eguale et al., 2007), anticonvulsant (Emamghoreishi and Heidari-Hamedani, 2008), protection of gastric mucosal damage (Al-Mofleh et al., 2006), hypocholestrolemia (Dhanapakiam et al., 2008) and antileishmania (Rondon et al., 2011), gut modulatory, blood pressure lowering, and diuretic (Jabeen et al., 2009) activities among others.

Since review and systemic analysis of chemistry, pharmacology, and clinical properties of *C. sativum* have not been reported, we were prompted to provide the currently available information on the traditional and local knowledge, ethno biological and ethno medicinal issues, identification of pharmacologically important molecules, and pharmacological studies on this useful plant. The aim of this paper is to introduce *C. sativum* as a potent medicinal plant by highlighting its traditional applications as well as the recent findings for novel pharmacological and clinical applications.

CHEMICAL COMPOSITION

The odor and flavor of mature fruits and fresh herbage are completely different. While aliphatic aldehydes (mainly C10 to C16 aldehydes) with fetid-like aroma are predominant in the fresh herb oil (Potter, 1996), major components in the oil isolated from coriander fruit include oxygenated monoterpenes and monoterpene hydrocarbons (Bhuiyan et al., 2009).

The most important constituents of coriander fruits are the essential oil and fatty oil. The essential oil content of dried coriander fruits varies between 0.03 and 2.6%, while the fatty oil content varies between 9.9 and 27.7%. Other constituents including crude protein, fat, crude fiber, and ash contents vary from 11.5 to 21.3%, 17.8 to 19.15%, 28.4 to 29.1%, and 4.9 to 6.0%, respectively (Coskuner and Karababa, 2007).

The essential oil content of the dried coriander fruits varies from 0.1 to 0.36%. Linalool (40.9 to 79.9%) (Figure 3), neryl acetate (2.3 to 14.2%), γ-terpinene (0.1 to 13.6%), and α-pinene (1.2 to 7.1%) were identified as the

main components in the oil of the coriander fruits cultivated in Iran (Nejad et al., 2010), while linalool (37.7%), geranyl acetate (17.6%), and γ-terpinene (14.4%) were characterized as the main ones in Bangladesh coriander cultivars (Bhuiyan et al., 2009). The leaf oil contained mostly aromatic acids, including 2-decenoic acid (30.8%), E-11-tetradecenoic acid (13.4%), capric acid (12.7%), undecyl alcohol (6.4%), tridecanoic acid (5.5%), and undecanoic acid (7.1%) as major constituents (Bhuiyan et al., 2009). Analysis of Kenya coriander leaves essential oil showed the presence of 2E-decenal (15.9%), decanal (14.3%), 2E-decen-1-ol (14.2%), and n-decanol (13.6%) as the main ones (Matasyoh et al., 2009). The commonly known phytochemicals from *C. sativum* are volatile components, flavonoids, isocoumarins, fatty acids, sterols, and coriandrones, coumarins, catechins, polyphenolic compounds (Taniguchi et al., 1996; Sriti et al., 2009; Al-Mofleh et al., 2006).

Two new isocoumarins, coriandrone A and B were isolated from the aerial parts of *C. sativum* together with two known isocoumarins, coriandrin and dihydrocoriandrin (Baba et al., 1991) (Figure 3). Three new isocoumarins, coriandrones C, D, and E were also isolated from *C. sativum* whole plants (Taniguchi et al., 1996).

Caffeic acid, protocatechinic acid, and glycitin were characterized as the major polyphenolics of coriander aerial parts (Melo et al., 2005).

POTENTIAL OF *C. SATIVUM* IN PHYTOTHERAPIES

Antibacterial and antifungal properties

C. sativum essential oil has been reported to inhibit a broad spectrum of micro-organisms (Silva et al., 2011b). The effective antibacterial activity of *C. sativum* essential oil against *Staphylococcus aureus* and Gram-negative bacterial strains including *Escherichia coli*, *Klebsiella pneumoniae*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa* and two clinical multidrug-resistant *Acinetobacter baumannii* isolates has been shown. The primary mechanism of action of coriander oil is membrane damage, which leads to cell death (Silva et al., 2011b). Aliphatic (2E)-alkenals and alkanals characterized from the fresh leaves of *C. sativum* were found to possess bactericidal activity against the food-borne bacterium, *Salmonella choleraesuis* subsp. *choleraesuis* with the minimum bactericidal concentration (MBC) of 6.25 µg/ml (34 µM) and 12.5 µg/ml (74 µM), respectively (Kubo et al., 2004).

Coriander essential oil has a fungicidal activity against the *Candida* strains tested with minimal lethal concentrations (MLC) values equal to the MIC value and ranging from 0.05 to 0.4% (v/v). The fungicidal effect is as a result of cytoplasmic membrane damage and subsequent leakage of intracellular components such as DNA (Silva et al., 2011a). The efficacy of *C. sativum* essential oil has also been shown against *Candida* species isolates from the oral cavity of patients with periodontal disease. 2-hexen-1-ol, 3-hexen-1-ol and cyclodecane were characterized as the active constituents in the oil (Furletti et al., 2011).

Antioxidant activity

An antioxidant is defined as ‘any substance that, when present at low concentrations as compared to those of an oxidizable substrate, significantly delays or prevents oxidation of that substrate’ (Rhee et al., 2009; Halliwell and Gutteridge, 1995; Wiseman et al., 1997; Mates et al., 1999). Antioxidants are of interest to biologists and clinicians, because they help to protect the human body against damages induced by reactive free radicals generated in atherosclerosis, ischemic heart disease, cancer, Alzheimer's disease, Parkinson's disease, and even in aging process (Aruoma, 2003; Hemati et al., 2010). There are many evidences that natural products and their derivatives have efficient anti-oxidative characteristics, consequently linked to anti-cancer, hypolipidemic, anti aging, and anti-inflammatory activities (Rhee et al., 2009; Halliwell and Gutteridge, 1995; Wiseman et al., 1997; Hogg, 1998; Mates et al., 1999; Aruoma, 2003; Cho et al., 2006).

Anti-oxidative capacities of different parts of *C. sativum* were evaluated by three methods, including determining its effect on scavenging the diphenylpicrylhydrazyl (DPPH) radical, inhibition of 15-lipoxygenase (15-LO), and inhibition of Fe^{2+} induced porcine brain phospholipid peroxidation. The leaves showed stronger antioxidant activity than the fruits. Positive correlations were found between total phenolic content in the extracts and antioxidant activity (Wangensteen et al., 2004).

Polyphenolic compounds are present in *C. sativum*, and are known to be excellent antioxidants. They have the capacity to reduce free-radical formation by scavenging free radicals and protecting antioxidant defenses. The antioxidant potencies of polyphenolic compounds from *C. sativum* against hydrogen peroxide-induced oxidative damage in human lymphocytes have also been shown. H_2O_2 treatment significantly decreased the activities of antioxidant enzymes, such as superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, glutathione-S-transferase, and caused decreased glutathione content and increased thiobarbituric acid-reacting substances (TBARS). Treatment with polyphenolic fractions (50 µg/ml) increased the activities of antioxidant enzymes and glutathione content and reduced the levels of TBARS significantly. Polyphenolic compounds are effectively responsible for suppression of hydrogen peroxide-induced oxidative stress (Hashim et al., 2005).

Analyses also showed that caffeic acid, protocatechinic acid, and glycitin were present in high concentration

(6.98, 6.43, and 3.27 µg/ml) in coriander aerial parts. They are principal components responsible for the antioxidant activity of the aqueous coriander extract (Melo et al., 2005).

Hepatoprotective activity

C. sativum extract protects liver from oxidative stress induced by carbon-tetrachloride (CCl_4) and thus helps in evaluation of traditional claim on this plant. Pretreatment of rats with different doses of plant extract (100 and 200 mg/kg) significantly lowered serum glutamate oxaloacetate transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT), and TBARS levels against CCl_4 treated rats. Hepatic enzymes like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) were significantly increased by treatment with plant extract, against CCl_4 treated rats. Oral administration of the leaf extract at a dose of 200 mg/kg significantly reduced the toxic effects of CCl_4. The activity of leaf extract at this dose was comparable to the standard drug, silymarin (Sreelatha et al., 2009).

Antidiabetic effects

Sub-chronic oral administration of *C. sativum* extract (20 mg/kg) in obese-hyperglycemic and hyperlipidemic animal model normalized glycemia and decreased the elevated levels of insulin, insulin resistance (IR), total cholesterol (TC), low density lipoprotein (LDL)-cholesterol, and triglycerides (TG). Since *C. sativum* extract decreased several components of the metabolic syndrome and decreased atherosclerotic and increased cardioprotective indices, its extract may have cardiovascular protective effect (Aissaoui et al., 2011).

It has been demonstrated that *C. sativum* extract was able to decrease hyperglycemia and increase glucose uptake and metabolism, and insulin secretion (Gray and Flatt, 1999; Swanston-Flatt et al., 1990).

Safety of *C. sativum* essential oil

Coriander essential oil is obtained by steam distillation of the dried fully ripe fruits (seeds). Based on the results of a 28 day oral gavage study in rats, a no-observed effect-level (NOEL) for coriander oil is approximately 160 mg/kg/day. In a developmental toxicity study, the maternal no-observed adverse effect level (NOAEL) of coriander oil was 250 mg/kg/day and the developmental NOAEL was 500 mg/kg/day. Coriander oil is not clastogenic, but results of mutagenicity studies for the spice and some extracts are mixed. The major component of the essential oil, linalool, is non-mutagenic. Coriander oil has broad-spectrum, antimicrobial activity. Coriander oil is irritating to rabbits, but not to humans; it is not a sensitizer, although, the whole spice may be. Based on the history of consumption of coriander oil without reported adverse effects, lack of its toxicity in limited studies and lack of toxicity of its major constituent, linalool, the use of coriander oil as an added food ingredient is considered safe at present levels of use (Burdock and Carabin, 2009). The median lethal dose (LD_{50}) of *C. sativum* essential oil was determined as 2.257 ml/kg (Özbek et al., 2006).

C. sativum as an oilseed crop grown in Italy was investigated regarding anti-nutritive compounds such as glucosinolates, sinapine, inositol phosphates, and condensed tannins, which can adversely affect the nutritional value of residues from the oilseed processing. All these compounds were found in *C. sativum* fruits in different amounts (Matthäus and Angelini, 2005).

CONCLUSION

The objective of this review has been to show the recent advances in the exploration of *C. sativum* as phytotherapy and to illustrate its potential as a therapeutic agent. With this present information, it is evident that *C. sativum* has pharmacological functions including antioxidant, antibacterial, antifungal, antidiabetic, hepatoprotective, and antihyperlipidemic activities, among others. As this present information shows, it is also possible that the fruit's essential oil or the whole plant extract might be useful in the development of new drugs to treat various diseases. However, the present results suggest a possibility that volatile components and polyphenolics can be further developed as a potential disease-curing remedy. It must be kept in mind that clinicians should remain cautious until more definitive studies demonstrate the quality and efficacy of *C. sativum*. For these reasons, extensive pharmacological and chemical experiments, together with human metabolism will be a focus for future studies. Finally, this review emphasizes the potential of *C. sativum* to be employed in new therapeutic drugs and provides the basis for future research on the application of transitional medicinal plants.

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