

Review

Coriander (*Coriandrum sativum* L.): Processing, nutritional and functional aspects

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Coriander (*Coriandrum sativum* L.) being an annual herb is most commonly used for seasoning purpose. Its plant seeds, leaves and roots are edible, although they have very distinct flavors and uses. The herb has a light and fresh flavor. Coriander can be used as whole plant and can be processed because of its perishable nature of leaves and to increase the palatability of ripe fruits (seeds) before using it as flavoring agent in different food preparations. Whole plant of coriander mainly fresh leaves and ripe fruits are used for culinary purposes. Coriander leaves have different taste than its seeds, with citrus overtones. Coriander plant is a rich reservoir of micronutrients and nutritional elements which leads us to focus our study on this herb. Coriander is very low in saturated fat however, contains good amount of linoleic acid which is a good source of α -tocopherol and vitamin K. Leaves of plant are rich source of vitamins while seeds are rich in polyphenols and essential oils. Coriander taste is devoted to its essential oil comprising a significant content of linoleic and furanocoumarins (coriandrine and dihydrocoriandrine). Coriander is also well known for its antioxidant, anti-diabetic, anti-mutagenic, anti-anxiety and antimicrobial activity along with analgesic and hormone balancing effect that promotes its use in foods due to numerous health benefits and its protective effect to preserve the food for longer period. The aim of present study was to highlight the processing, nutritional and functional aspects of coriander.

Key words: Coriander, processing, fatty acids, antioxidant content, anti-diabetic, anti-mutagenic, anti-anxiety, diuretic activity, metal detoxification, anti-hyperglycemic activity.

INTRODUCTION

Coriander (*Coriandrum sativum* L.) which belongs to the family Apiaceae (Umbelliferae) is mainly cultivated from its seeds throughout the year (Mhemdi et al., 2011). India is the biggest producer, consumer and exporter of coriander in the world with an annual production of around three lakh tonnes. It is an annual, herbaceous plant which originated from the Mediterranean and Middle Eastern regions and known as medicinal plants. It contains an essential oil (0.03 to 2.6%) (Nadeem et al., 2013). All parts of this herb are in use as flavoring agent and/or as traditional remedies for the treatment of different dis-

orders in the folk medicine systems of different civilizations (Sahib et al., 2012). Coriander closely resembles flat leaf parsley. This resemblance makes many people confused between the two however, coriander has strong fragrance and parsley has mild fragrance. It grows best in dry climates however it can grow in any type of soil like light, well drained, moist, loamy soil, and light to heavy black soil (Verma et al., 2011). Its seeds are almost ovate, globular and have a mild, sweet, slight pungent like citrus flavor with a hint of sage. The most important constituents of its seeds are the essential oil and fatty oil

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(Coskuner and Karababa, 2007).

It is highly reputed ayurvedic medicinal plant commonly known as “Dhanya” in India. This plant is highly aromatic and has multiple uses in food and in other industries. Plants have played a critical role in maintaining human health and civilizing the quality of human life for thousands of years (Dhankar et al., 2011). It is also used to flavor sausages. All parts of plant are edible, fresh leaves can be used for garnishing and are common ingredient in many foods like chutneys and salads. The green herb is also employed for the preparation of either steam-distilled essential oil or the solvent extracted oleoresin (Nadia and Kandi, 2012). Fresh juice of coriander is extremely advantageous in curing many deficiencies related to vitamins and iron. One to two teaspoons of its juice, added to refreshing buttermilk, is incredibly beneficial in curing many diseases. Fresh leaves can be eaten as such because of various health benefits however, if it is not harvested freshly seeds mature and ripen in late summer developing delicate aroma which are then used as dried spice. Moreover, this plant is used to cure diseases like digestive tract disorders, respiratory tract disorders, urinary tract infections. Coriander has been reported to possess many pharmacological activities like antioxidant (Darughe et al., 2012), anti-diabetic (Eidi et al., 2012), anti-mutagenic (Cortes et al., 2004), anti-lipidemic (Sunil et al., 2012), anti-spasmodic (Alison et al., 1999).

Dried coriander fruit is an important ingredient in pickle making. It is sometimes used to mask odd flavors (Parthasarathy et al., 2008). Its fruits contain vegetable oil with a high concentration of monounsaturated fatty acids, especially of petroselinic acid. This oil can be extracted using various techniques; most commonly three different techniques are used: steam distillation, organic solvent extraction (soxhlet), supercritical fluid extraction (Mhemdi et al., 2011). Moreover, coriander oil is used as an antimicrobial agent as it possesses broad spectrum antimicrobial activity (Silva et al., 2011). This oil can be encapsulated in alginates, chitosan etc. so as to enable isolation, protection, transport and release of its active components like vitamins, flavours, peptides, minerals, fatty acids, polyunsaturated fatty acids, antioxidants, enzymes and living cells (Cristian, 2013). Coriander powder and its essential oil are considered as natural food preservatives including antibacterial, antifungal and antioxidant properties (Politeo et al., 2007). The commercial value of its essential oil depends on its physical properties, chemical composition and aroma quality.

Coriander may sometimes be affected by certain diseases and pests like wilt (*Fusarium oxysporum*) and stem gall. The powdery mildew is effectively controlled by spraying sultaf (0.25%). There are no direct control measures for wilt. It is very difficult to control stem-fall (Verma et al., 2011). To check its quality, automatic quality assessment techniques have been developed in Indian spice industries. Quality analysis of its seed was

done by image morphological operations (Rohit et al., 2011). It is reported as a non destructive and less time consuming method. With image analysis area, major and minor axis length for counting normal seed, seed having pedestals and foreign element for a given sample were calculated. This technique replaces quality assessment by human sensory methods which is time consuming and less accurate.

PROCESSING

Although coriander is consumed in an unprocessed form; however, its good quantity is also being processed to facilitate the international trade, profitability and palatability. Harvesting is the primary process of collecting the crop and should be done at optimum time period to ensure production of plant material and the best quality of finished spice product (Douglas et al., 2005). It matures in two to three months after sowing. Its smaller-seed requires a longer growing period of approximately 120 days. Depending upon the end use, it can either be harvested green or left to ripe them until fruits turn brown.

Green coriander fruits have sharper and more pronounced flavor than ripe seeds. Mature brown seeds can be used and grind to form powder. Seed heads are cut along with certain inches of stalk or plant may be pulled out with roots and hang in bags upside down, when seeds are fully dry these tend to detach from stalk, collected and store in cool, dry location or ground to obtain a fine powder. In order to remove field heat and prolong shelf life after harvesting, it is necessary to pre-cool harvested coriander before transportation. This can be done by vacuum cooling. Vacuum cooling is achieved through boiling part of the moisture of the product under vacuum conditions. This cooling has a significant effect on amount of vitamin C and shelf life (Apichart et al., 2012).

Coriander may sometimes be irradiated to reduce microbial load before consumption. Irradiation dose of 0.5 kGy of gamma radiations results in reducing aerobic mesophilic count to 99.9%, while the initial total coliform bacteria decreased from 871,000 cfu/g to less than 100 (Cruz-Zaragoza et al., 2011). The microbiological results are lower than the limit levels. Seeds may be also threshed out and dried in sun, winnowed and stored in bags. Usually coriander is sun dried because of cost concerns.

Its seeds after drying may be stored as whole or infused to make delicious vinegar. After harvesting, leaves are properly washed and kept in shade for drying. Drying is followed by powdering in disintegrator and micro pulverizer. Its ground powder is used as a spice in blends. Ground coriander spice loses flavor quickly when stored. This disintegrated product is then standardized, packed and finally distributed. Drying is carried out by number of ways like sun drying, microwave drying, freeze

drying etc. Mainly drying depends on air temperature, greater the air temperature much faster drying will be accomplished. One of the important aspects during drying or thermal processing of its leaves is the loss of chlorophyll content. The most common change that occurs in green vegetables during thermal processing is the conversion of chlorophyll to pheophytins, causing a colour change from bright green to olive-brown, which is undesirable to the consumer. Blanching prior to drying can greatly reduce chlorophyll loss. Loss of chlorophyll content of its foliage can also be prevented by opting microwave drying instead of sun drying. It was found that microwave-dried samples had higher chlorophyll content and the green color was preserved better than for the air-dried and freeze-dried samples (Alibas, 2006). This is because microwave drying of coriander is faster than other conventional drying methods which are gradual and slow to reach the final moisture content. Microwave drying is able to reduce the coriander moisture content to the 12% (wb) target within 21 to 22 min (Shaw et al., 2007).

Ripe seeds of coriander may be sometimes processed to obtain essential oil. This oil is mainly obtained by steam distillation, super critical CO₂ extraction etc. Oil extraction from its seeds was studied with carbon dioxide and propane as solvents, under sub and supercritical conditions. The ratio of solvent to seed (g/g) required to achieve a complete oil extraction was between 20 and 40 using CO₂ at pressures of 200 and 300 bar and temperature of 35°C. A complete oil recovery was attained with propane or propane-rich solvents at 25°C and 50, 80 and 100 bar. The solvating power of propane and propane-containing solvents was proved to be much higher than that of CO₂ (Illes et al., 2000).

Its oil has a characteristic odor of linalool and warm aromatic flavor. This oil is approved for food use by FDA (Food and Drug Administration), FEMA (Foreign Exchange Management Act) and Council of Europe (Silva et al., 2011). In order to preserve the warm aromatic flavor and prevent nutrient loss upto end use, this oil is encapsulated mainly in alginates or chitosans. The aqueous solution of sodium alginate is transformed in gel under the action of calcium ions which form the intermolecular cross-links with the carboxyl groups of guluronate, leading to the well-known "egg-box" structure providing best possible protection to coriander essential oils. The coriander plant is mainly used for making sauces and salsas; on the other hand the fruits are blended into powder for flavouring various products like meat, fish, sodas, pickles, bakery and curry recipes (Ravi et al., 2007).

Its leaves may also be processed to form various products like purees and pastes which are tremendously used nowadays in fast food industries. After harvesting of fresh mature plant, degradation of its components starts. Such degradations may be prevented by processing and converting harvested leaves into product formulation like

purees, pastes, sauces salsas etc. Coriander sauce gives an intense flavor and deep green color but is not spicy. In case of powder formation, freshly harvested leaves are blanched at 90°C for at least 2 min so as to inactivate peroxidase enzyme, dried and then ground to uniform size and preserved for further use (Ahmed et al., 2003). Fresh coriander leaves were steam- and water-blanched at 100°C and at 90 and 100°C, respectively, for one to ten minutes, and subsequently comminuted to form a paste. Pasty products obtained from its fruits were processed after water-blanching applying the same time-temperature regimes. Among the eleven phenolics characterized in leaves by high-performance liquid chromatography coupled to mass spectrometric detection, several caffeic acid derivatives, 5-feruloylquinic and 5-p-coumaroylquinic acids were tentatively identified. In fruits, ten phenolics were detected, whereas rutin, a dicaffeic acid derivative and two feruloylquinic and caffeoylquinic acid isomers were newly detected. Upon steam-blanching for one minute, phenolic contents and antioxidant capacities remained virtually unchanged. In contrast, water-blanching and extended steam-blanching even yielded increased levels compared to the unheated control, whereas short-time water-blanching resulted in higher values than prolonged heat treatment. Thus, short-time water-blanching was recommended as the initial unit in the processing of coriander leaves and fruits into novel pasty products (Kaiser et al., 2013). A chronological progression for better understanding of different processing aspects of coriander is depicted in Table 1.

NUTRITIONAL ASPECTS

Coriander nutrition is basically due to its green leaves and dried fruits. Like all other green leafy vegetables, its leaves are a rich source of vitamins, minerals and iron. Its leaves contain high amount of vitamin A (β -carotene) and vitamin C. The green herbs contain vitamin C upto 160 mg/100 g and vitamin A upto 12 mg/100 g (Girenko, 1982). It is very low in saturated fat and cholesterol and a very good source of thiamine, zinc and dietary fiber. Green coriander contains 84% water.

MAJOR CHEMICAL CONSTITUENTS

Its seeds contain upto 1.8% volatile oil according to origin. The distilled oil (coriander oil BP) contains 65 to 70% of (+)-linalool (coriandrol), depending on the source (Anju et al., 2011).

MINOR CHEMICAL CONSTITUENTS

It includes: Monoterpene hydrocarbons viz α - pinene, β - pinene, limonene, γ -terpinene, p-lymene, borneol, citron

Table 1. Chronological progression of different processing aspects of coriander.

Salient feature	Processing method	Researcher
Increased protection of active components of oil	Encapsulation	Cristian et al. (2013)
Higher values of phenolic components and antioxidant activities as compared to prolonged heat treatment	Water-blanching	Kaiser et al. (2013)
Significant effect on amount of vitamin C and shelf life	Vacuum cooling	Apichart et al. (2012)
Moisture content reduction	Drying	Shaw et al. (2007)
Product formulation like sauces, salsas etc. to increase shelf life.	Thermal processing	Ravi et al. (2007)
Prevention of loss of chlorophyll in foliage	Microwave drying	Alibas et al. (2006)
Immature fruit contain higher volatile oil than ripe fruit	Harvesting	Douglas et al. (2005)
Reported to cause inactivation of peroxidase enzyme at 90°C for 2 min.	Blanching	Ahmed et al. (2003)
Greatly reduces chlorophyll losses	Blanching	Ahmed et al. (2001)

linalol, Xmphoe, Geraniol and Geranylacetate; Heterocyclic compounds viz – pyrazine, pyridine, thiazole, furan, tetrahydrofuran derivatives; Isocoumarin viz coriandrin, dihydrocoriandrin, coriandrones A-E, glazonoids; Phthalides viz -neochidilide, Z-digustilide; Phenolic acids and sterols, flavonoids (Wallis, 2005). Carotenoids are of ubiquitous occurrence in all plants with higher concentrations in reproductive organs. In green leafy vegetables, carotenoids, particularly β -carotene is deposited mainly in leaves. Carotenoids can also be processed and used as coloring agents as well as good source of antioxidants. Besides other roles, carotenoids chiefly function as scavengers of the free radicals produced by chlorophylls during photo-oxidation.

Its leaves being good source of β -carotene serve as a precursor of vitamin A. In coriander, β -carotene content, 160 $\mu\text{g}/100\text{ g}$ is present whereas total carotenoid content is 1010 $\mu\text{g}/100\text{ g}$ (Kandlakunta et al., 2008). Its foliage is used in various types of foods especially in diets of people facing vitamin A deficiency. Green foliage contains anthocyanin (Omidbaigi, 2005). Anthocyanins are bioactive flavonoid compounds that prevent body from various chronic diseases. Anthocyanin in foliage acts as antioxidants which are very useful in improvement of nutritional value as well as maintenance of health and well being (Rahimi et al., 2013).

The various nutrients present in coriander leaf and seeds are shown in Table 2. The characteristic aromatic flavor of its seeds comes from many fatty acids and essential volatile oils. According to USDA (2013), cholesterol content of its seeds is nil. Its seeds are considered as an important source of vitamins, minerals and lipids. Among minerals, potassium is present in high amount (1267 mg/100 g) followed by calcium (709 mg/100 g), phosphorus (409 mg/100 g), magnesium (330 mg /100 g), sodium (35 mg/100 g), zinc (4.70 mg/100 g). The folate content in coriander seed is 200 $\mu\text{g}/100\text{ g}$ (fresh weight) (Iwatani et al., 2003). Among the various constituents, vitamin C content is present in ample amount (21 mg/100 g) (Table 2). The different vitamins,

minerals and phyto-chemicals content in leaf is shown in Table 2.

Coriander contains high amount of essential oils that are very important for growth and for proper functioning of brain. The main essential fatty acids present in coriander include linoleic and linolenic acids. Linoleic acids belong to PUFA (polyunsaturated fatty acid) group. Dietary supplementation of coriander seed greatly affects the lipid composition of carcass by decreasing saturated fatty acid (SFA) contents (palmitic and stearic acids) and by increasing monounsaturated and polyunsaturated fatty acid (MUFA and PUFA) (Ertas et al., 2005).

This plant is a potential source of lipids (rich in petroselinic acid) and an essential oil (high in linalool) isolated from the seeds and the aerial parts (Sahib et al., 2012). The high content of fats and protein in the fruits make distillation residues suitable for animal feed. Coriander fruits yield 5 to 7% of ash, 13% resin, astringent principle, malic acid and alkaloids. Coriander oil contains coriandrol, jireniol and vebriniol (Rao et al., 2012).

FUNCTIONAL ASPECTS

The functional properties of coriander cannot be under estimated. Besides nutritional benefits, it is well known for its health or medicinal benefits as well as for additional benefits like it acts as antimicrobial agent. The type of meat and temperature did not influence the antimicrobial activity of the oil; indicating the potential of coriander oil to serve as a natural antimicrobial compound against *Campylobacter jejuni* in food (Rattanachaikunsopon and Phumkhachorn, 2010). The most important and well characterized functional aspect involves antioxidant activity.

ANTIOXIDANT ACTIVITY

Coriander is a good source of polyphenols and phyto-chemicals due to its high antioxidant activity. Reactive

Table 2. Nutrient composition of coriander leaf and seeds as per USDA (National Nutrition Data base, 2013).

Nutrient	Amount (per 100 g)	
	Coriander leaf	Coriander seed
Water	7.30 g	8.86 g
Energy	279 kcal	298 kcal
Protein	21.93 g	12.37 g
Total lipid (fat)	4.78 g	17.77 g
Carbohydrate, by difference	52.10 g	54.99 g
Fiber, total dietary	10.40 g	41.9 g
Calcium, Ca	1246 mg	709 mg
Iron, Fe	42.46 mg	16.32 mg
Magnesium, Mg	694 mg	330 mg
Phosphorus, P	481 mg	409 mg
Potassium, K	4466 mg	1267 mg
Sodium, Na	211 mg	35 mg
Zinc, Zn	4.72 mg	4.70 mg
Vitamin C, total ascorbic acid	566.7 mg	21.0 mg
Thiamin	1.252 mg	0.239 mg
Riboflavin	1.500 mg	0.290 mg
Niacin	10.707 mg	2.130 mg
Vitamin B-12	0.00 µg	0.00 µg
Vitamin A, RAE	293 µg	0.00 µg
Vitamin A, IU	5850 IU	0 IU
Vitamin D (D2 + D3)	0.00 µg	0.0 µg
Vitamin D	0 IU	0 IU
Fatty acids, total saturated	0.115 g	0.990 g
Fatty acids, total monounsaturated	2.232 g	13.580 g
Fatty acids, total polyunsaturated	0.328 g	1.750 g
Cholesterol	0.00 mg	0 mg

species of oxygen can cause oxidative stress and consequently, the damage of tissues and biomolecules (Barros et al., 2012). Both leaves and seeds of coriander contain antioxidants but leaves contain more amounts of antioxidants than seeds (Wangensteen et al., 2004). Its Antioxidant content is attributed to its high content of pigments particularly carotenoids. The carotenoids of its extract were found to show higher hydroxyl radicals scavenging potential thereby protecting cells from oxidative damage (Peethambaran et al., 2012). Among secondary metabolites, phenolic compounds are considered as one of the most important and largest group. Phenolic groups may be categorized into four main groups depending upon number of phenol rings and structural elements that bind these rings. These groups include: flavonoids (anthocyanins, flavones and isoflavones) tannins, stilbenes and lignans (Balasundram et al., 2006).

In recent years, essential oils have been qualified as natural antioxidants. Coriander essential oils serve as potential antioxidants. Main components of its essential oil are: camphor (44.99%), cyclohexanol acetate (cis-2-

tert.butyl-) (14.45%), limonene (7.17%), α -pinene (6.37%). This essential oil at percentage of 0.05, 0.10 and 0.15 is very much effective in inhabiting primary and secondary oxidation products. It was found that at the proportion of 0.02%, its effects were almost equal to BHA (butylated hydroxyanisole) (Darughe et al., 2012).

One of the major problems in high lipid product in food industry is rancidity resulting in undesirable flavor changes and decline in nutrients (vitamins) leading to change in their texture and appearance. Lipid peroxidation causes oxidative stress, resulting in the development of rancidity, unpleasant taste and odors as well as changes in color and losses related to nutritional value. Use of antioxidants reduces oxidative rancidity (Bhanger et al., 2007). Addition of coriander essential oil may greatly serve the purpose. Darughe et al. (2012) studied the antioxidant effects of CEO (coriander essential oils) in cake. It was found that antioxidant effect of CEO may be due to the presence of terpenoid components (camphor, limonene, α -pinene and geraniol). This essential oil due to its radical scavenging activity can be used as natural antioxidant to enhance the shelf

stability of many foods (Ramadan et al., 2003).

ANTI-HYPERGLYCEMIC ACTIVITY

Its seed extract is used as a traditional medicine for diabetic patients. Incorporation of ground coriander seed extract in diet led to marked decline in blood glucose and rise in levels of insulin in diabetic rats. Besides peroxidative damage inhibition, addition of its seed extract reactivated antioxidant enzymes and antioxidant levels in diabetic rats (Deepa and Anuradha, 2011). Gray and Flatt (1999) studied insulin releasing and insulin like activity of coriander. It was observed that its aqueous consumption evoked 1.3-5.7 fold stimulation of insulin secretion from colon B- cell line. An aqueous extract of coriander (1 mg/ml) increased the 2-deoxyglucose transport by 1.6 folds, glucose oxidation by 1.4 folds and incorporation of glucose into glycogen of isolated murine abdominal muscle by 1.7 folds.

HYPOLIPIDEMIC EFFECT

Hyperlipidemia increases the risk for generation of lipid oxidation products, which accumulate in the subendothelial spaces of vasculature and bone. Atherogenic high-fat diets increase serum levels of oxidized lipids, which are known to attenuate osteogenesis in culture and to promote bone loss (Pirih et al., 2012). Lal et al. (2004) studied the hypolipidemic effect of coriander (*Coriandrum sativum* L.). Coriander was given at a dose of 1g/kg to triton induced hyperlipidemic rats. It was found that coriander decreases the uptake and enhances the breakdown of lipids. Results were compared with commercially available herbal drug for hyperlipidemia. From these findings it was assumed that coriander can be used as preventive and curative herbal against hyperlipidemia.

ANTI-ANTHELMINTIC ACTIVITY

In vitro anthelmintic activities of crude aqueous and hydro-alcoholic extracts of the seeds of Coriander were investigated on the egg and adult nematode parasite *Haemonchus contortus*. Its aqueous extract was also investigated for *in vivo* anthelmintic activity in sheep infected with *H. contortus*. Both extract types of coriander inhibited hatching of eggs completely at a concentration less than 0.5 mg/ml (Debella et al., 2007).

ANTI-ANXIETY EFFECT

An internal turmoil often accompanied by various diseases like stomach ache, nervous behavior. Anxiety

may be sometimes uncontrollable and irritating. Coriander has been used as folk medicine in Iran for treatment of insomnia. Mahendra and Bisht (2011) studied anti-anxiety activity of hydro alcoholic extract of coriander in mice using diazepam as standard. It was observed that the extract of 100 and 200 mg/kg produced anti-anxiety effects similar to diazepam. Its aqueous extract causes anxiolytic effect and was studied by using extract (10, 25, 50, 100 mg/kg) in male albino mice using elevated plus-maze as an animal model of anxiety. It was found that aqueous extract at 50, 100 and 500 mg/kg significantly reduced spontaneous activity and neuromuscular coordination, compared to control group. All these results led to conclusion that coriander extract can be used as potential sedative and muscle relaxant (Masoumeh et al., 2005). A chronological progression of different functional properties of coriander is depicted in Table 3.

DIURETIC ACTIVITY

Jabeen et al. (2009) studied the diuretic activity of the plant extracts on wistar rats of either sex (200 to 250 g). Negative and positive control group comprising of five animals, each received saline and standard diuretic drug: furosemide (10 mg/kg), while rest of the groups with similar number of animals, were given different doses of the plant extracts dissolved in saline (50 ml/kg). The results concluded that the diuretic effect of coriander was confirmed due to significant increase in urine output (diuresis) in rats, similar to furosemide, a standard diuretic. Therefore, diuretic is considered as one of the best choices for the treatment and management of uncomplicated hypertension.

METAL DETOXIFICATION

Coriander can be used as a natural cleansing agent as it has potential to remove toxic metals from body. Chemical compounds present in coriander attach to toxic metals and remove them from cells (Abidhusen, 2012). Arunasagar et al. (2005) observed that this plant is very effective to remove inorganic (Hg^{2+}) and methyl mercury (CH_3Hg^+) from aqueous solutions. This effect was due to the binding effect of carboxylic group to mercury. These results clearly showed that sorbent can be used to remove inorganic and methyl mercury from contaminated water. Kansal et al. (2011) found that coriander led to marked decline in oxidative stress caused by lead nitrate.

ANTI-BACTERIAL ACTIVITY

Aliphatic (2E)-alkenals and alkanals characterized from the fresh leaves of the coriander were found to possess

Table 3. Chronological progression of different functional properties of coriander

Functional activity	Compounds involved	Researcher
Inhibition of oxidative products	BHA	Darughe et al. (2012)
Antianxiety effect	Coriander extract	Mahendra (2011)
Antiglycemic activity	Aqueous seed extracts	Deepa and Anuradha (2011)
Antimicrobial activity	Coriander oil	Rattanachaiakunsopon and Phumkhachorn (2010)
Inhibition of oxidative products	Terpenoids	Bhanger et al. (2006)
Oxidative damage protection	Flavonoids (Anthocyanins, tannins, lignins)	Balasundarum et al. (2006)
Metal detoxification	Hydroxyl groups	Arunasagar et al. (2005)
Antioxidant activity	Phenolics	Wangenstein et al. (2004)
Hypolipidemic effect	Constituents present in it due to increase in lipid catabolism and excretion	Lal et al. (2004)

bactericidal activity against *Salmonella choleraesuis* spp. choleraesuis ATCC 35640. (2E)-Dodecenal was most effective against this food-borne bacterium with the minimum bactericidal concentration (MBC) of 6.25 µg/mL (34 µM), followed by (2E) - undecenal (C11) with an MBC of 12.5 µg/mL (74 µM).

ANTI-FUNGAL ACTIVITY

Moisture content and pH of the foodstuffs have been reported as the main biotic factors affecting the fungal deterioration especially in high moisture foods. Common moulds found in cakes and bakery products are *Penicillium expansum*, *Penicillium stoloniferum*, *Rhizopus stolonifer*, *Aspergillus niger*, *Monilia sitophila* and species of *Mucor* and *Geotrichum*. Among these moulds, *Penicillium expansum*, *Penicillium stoloniferum* and *Mucor* are mycotoxins producers. Darughe et al. (2012) studied the antifungal activity of coriander essential oil in cakes having moisture content and pH ranges between 13 to 15.5% and 6.64 to 7.81%, respectively. After 30 days, it was found that percentage of moulds in cakes containing coriander essential oil at 0.05% did not differ from cakes containing 0.01% BHA and both concentration were not able to control mould growth in cakes but increasing concentration of CEO up to 0.15%, antifungal activity of CEO showed better control on mould growth in cakes than control sample and BHA samples.

Despite of these important functional activities, coriander has several other functional properties that promote its use as a preventive and curative herb. Some of these important activities include: antifertility activity due to significant decline in serum progesterone (Al-said et al., 1987). It is used in the preparation of many household medicines to cure bed cold, seasonal fever, nausea, vomiting, stomach disorders and also used as a drug for indigestion, against worms, rheumatism and pain

in the joints. Many of its healing properties can be attributed to its exceptional phytonutrients and hence, it is often referred to as store house for bioactive compounds (Ullagaddi and Bondada, 2011). It also has preventive action on gastric mucosal membranes due to many reasons like free radical scavenging activity or due to formation of protective layer (Al-Mofleha, 2006). Its oil can also be used as anti microbial agent. This oil is effective against both gram positive as well as gram negative bacteria and also against pathogenic fungus. Coriander oil also exhibits bactericidal activity with the exception of *Bacillus cereus* and *Enterococcus faecalis* (Silva, 2011).

CONCLUSIONS

Herbs and spices are processed in foods from early times for seasoning as well as to increase shelf life of food and to restore health. Coriander is one of miraculous herb that functions as both, spice as well as herbal medicine. Although plant can be grown throughout the year, it is processed to increase its palatability, profitability and facilitate international trade. The leaves and fruits are highly fragrant and contain nutrients like fat, proteins, vitamins minerals etc. Its health benefits activities ranging from antibacterial to anticancer activities. Most important and well characterized property of coriander is its use as antioxidant. Due to its multifunctional uses and protective and preventive action against various chronic diseases, this herb is rightly called as "herb of happiness". Moreover, processing of fruits and leaves of coriander is the best way to preserve this herb.

REFERENCES

Abidhusen HM, Sawapnil SA, Amit VG (2012). *Coriandrum sativum*: Review of advances in psychopharmacology. Int. J. Res. Pharm. Sci.

- 3(5):1233-1239.
- Ahmed J, Shivhare US, Singh G (2001). Drying characteristics and product quality of coriander leaves. *Food Bioprod. Process* 79:103-106.
- Ahmed J, Shivhare US, Singh P (2003). Colour kinetics and rheology of coriander leaf puree and Storage characteristics of paste. *Food Chem.* 84:605-611.
- Alibas I (2006). Characteristics of chard leaves during microwave, convective, and combined microwave convective drying. *Drying Technol.* 24(11):1425-1435.
- Alison MG, Peter RF (1999). Insulin releasing and insulin like activity of the traditional anti-diabetic plant *Coriander sativum* (coriander). *British J. Nutr.* 81(3):203-209.
- Al-Mofleha A, Al haider A, Mossa JS (2006). Protection of gastric mucosal damage by *Coriandrum sativum* L pretreatment in Wister albino rats. *J. Environ. Toxicol. Pharmacol.* 22:64-69.
- Al-Said MS, Al-Khamis KI, Islam MW, Parmar NS, Tariq M, Ageel AM (1987). Post-coital antifertility activity of the seeds of *Coriandrum sativum* in rats. *J. Ethnopharmacol.* 21(2):165-173.
- Apichart S, Danai B, Pichaya B (2012). Effect of vacuum cooling on physico-chemical properties of organic coriander. *As. J. Food Ag-Ind.* 5(02):96-103.
- Arunasagar D, Balarama KMV, Rao SV, Arunachalam J (2005). Removal and pre concentration of inorganic and methyl mercury from aqueous media using a sorbent prepared from plant coriander sativum. *J. Hazard Mat.* 118:133-39.
- Barros L, Duenas M, Dias MI, Sousa MJ, Santos-Buelga C (2012). Phenolic profile of in vivo and in vitro grown coriander sativum L. *Food Chem.* 132(2):841-848.
- Balasundram N, Sundram K, Samman S (2006). Phenolic compounds in plants and agri-industrial by-products Antioxidant activity, occurrence, and potential and uses. *Food Chem.* 99:191-203.
- Bhanger MI, Iqbal S, Anwar F, Imran M, Akhtar M, Zia-ul-Haq M (2007). Antioxidant potential of rice bran extracts and its effects on stabilization of cookies under ambient storage. *Int. J. Food Sci. Technol.* 43(5):779-786.
- Cortes-Eslava J, Gomez-Arroyo S, Villalobos-Pietrini R (2004). Antimutagenicity of coriander (*Coriandrum sativum*) juice on the mutagenesis produced by plant metabolites of aromatic amines. *J. Toxicol. Lett.* 153:283-292.
- Cristian D, Liliana G, Petru A, Stefan D (2013). Encapsulation of coriander essential oil in alginate and alginate/chitosan microspheres by emulsification of external gelation method. *Inside food symposium*, pp.9-12.
- Cruz-Zaragoza E, Ruiz-Gurrolab B, Wachter C, Flores Espinosac T, Barboza Flores M (2011). Gamma radiation effects in coriander (*Coriandrum sativum* L) for consumption in Mexico. *J. Revista Mexicana de Fisica S.* 57(1):80-86
- Darughe F, Barzegar M, Sahari MA (2012). Antioxidant and antifungal activity of Coriander (*Coriandrum sativum* L.) essential oil in cake. *Int. Food Res. J.* 19(3):1253-1260.
- Debella A, Feleke A, Makonnen E, Tilahun G, Eguale T (2007). In vitro and in vivo anthelmintic activity of crude extracts of *Coriandrum sativum* against *Haemonchus contortus*, *J. Ethnopharmacol.* 110:428-433.
- Deepa B, Anuradha CV (2011). Antioxidant potential of coriander sativum L seed extract. *J. Exp. Biol.* 49:30-38.
- Dhankar S, Kaur R, Ruhil S, Balhara M, Dhankhar S, Chhillar AK (2011). A review on *Justicia adhatoda* A potential source of natural medicine. *Afr. J. Plant Sci.* 5(11):620-627.
- Douglas M, Heyes J, Small field B (2005). Herbs, spices and essential oils post harvest operations in developing countries. *NZ Institute for Crop and Food Research Ltd., New Zealand.*
- Eidi M, Eidi A, Saeidi A, Molanaei S, Sadeghipour A, Bahar M, Bahar K (2012). Effect of coriander seed (*Coriandrum sativum* L) ethanol extract on insulin release from pancreatic beta cells in streptozotocin-induced diabetic rats. *J. Phytother. Res.* 23(3):404-406.
- Ertas ON, Guler IT, Ciftci Dalkilicand MB, Yilmaz O (2005). The Effect of a Dietary Supplement coriander seeds on the fatty acid composition of breast muscle in Japanese quail. *J. Revuede Med. Vet.* 156(10):514-518.
- Gray AM, Flatt PR (1999). Insulin-releasing and insulin-like activity of the traditional anti-diabetic plant *Coriandrum sativum* (coriander). *J. Nutr.* 81(3):203-209.
- Girenko MM (1982). Initial material and basic trends in breeding of some uncommon species of vegetables. *J. Bull. VIR im. Vavilova*, 120:33-37.
- Illes V, Daood HG, Perneczki S, Szokonya L, Then M (2000). Extraction of coriander seed oil by CO₂ and propane at super- and subcritical conditions. *J. Supercritical Fluids* 17:177-186.
- Iwatani Y, Arcot J, Shreshtha AK (2003). Determination of folate contents in some Australian vegetables. *J. Food Compos. Anal.* 16:37-48.
- Jabeen Q, Bashir S, Lyoussi B, Gilani A (2009). Coriander fruit exhibits gut modulatory, blood pressure lowering and diuretic activities. *J. Ethno. Pharmacol.* 122(1):123-130.
- Kaiser A, Kammerer DR, Carle R (2013). Impact of blanching on polyphenol stability and antioxidant capacity of innovative coriander (*Coriandrum sativum* L.) pastes. *Food Chem.* 140(1-2):332-339.
- Kandlakunta B, Rajendran A, Thingnganing L (2008). Carotene content of some common (cereals, pulses, vegetables, spices and condiments) and unconventional sources of plant origin. *Food Chem.* 106:85-89.
- Kansal L, Sharma V, Sharma A, Lodi S, Sharma H (2011). Protective role of *Coriandrum sativum* (coriander) extracts against lead nitrate induced oxidative stress and tissue damage in the liver and kidney in male mice. *Int. J. Appl. Pharmaceut. Technol.* 2(3):65-83.
- Lal AA, Kumar T, Murthy PB, Pillai KS (2004). Hypolipidemic effect of *Coriandrum sativum* in triton-induced hyperlipidemic rats. *J. Exp. Biol.* 42(9):909-912.
- Mahendra P, Bisht S (2011). Anti-anxiety activity of *Coriandrum sativum* assessed using different experimental anxiety models. *J. Pharmacol.* 43(5):574-577.
- Masoumeh E, Mohammad K, Maryam FA (2005). *Coriandrum sativum* evaluation of its anxiolytic effect in the elevated plus-maze. *J. Ethnopharmacol.* 96(3):365-337.
- Mhemdi H, Rodier E, Kechaou N, Fages J (2011). A supercritical tuneable process for the selective extraction of fats and essential oil from coriander seeds. *J. Food Engg.* 105(4):609-616.
- Nadeem M, Anjum FM, Khan MI, Tehseen S, El-Ghorab A, Sultan JI (2013). Nutritional and medicinal aspects of coriander (*Coriandrum sativum* L.) A review. *Brit. Food J.* 115(5):743-755.
- Nadia G, Hala K (2012). Influence of cobalt nutrition on coriander (*Coriandrum sativum* L.) Herbs yield quantity and quality. *J Appl. Sci Res.* 8(10):5184-5189.
- Omidbaigi R (2005). Production and processing of medicinal plants. Vol 2, Tehran. Astan Quds Publication, Tehran, pp.397.
- Parthasarathy VA, Chempakam B, Zachariah TJ (2008). Coriander: Chemistry of Spices, CAB International, 190-206. doi:10.1079/9781845934057.0190 13
- Peethambaran D, Bijesh P, Bhagyalakshmi N (2012). Carotenoid content, its stability during drying and the antioxidant activity of commercial coriander (*Coriandrum sativum* L.) varieties. *Int. J. Food Res.* 45(1):342-350.
- Pirih F, Lu J, Ye F, Bezouglia O, Atti E, Ascenzi MG, Tetradis S, Demer L, Aghaloo T, Tintut Y (2012). Adverse effects of hyperlipidemia on bone regeneration and strength. *J. Bone Miner. Res.* 27(2):309-318.
- Politeo O, Jukic M, Milos M (2007). Chemical composition and antioxidant capacity of free volatile aglycones from basil (*Ocimum basilicum* L.) compared with its essential oil. *Food Chem.* 101:379-385.
- Rahimi AR, Babaei S, Kambiz M, Asad R, Sheno A (2013). Anthocyanin content of coriander leaves as affected by salicylic acid and nutrients application. *Int. J. Biosci.* 3(2):141-145.
- Ramadan MF, Kroh LW, Mo Rsel JT (2003). Radical scavenging activity of black cumin (*Nigella sativa* L.), coriander (*Coriandrum sativum* L.), and niger (*Guizotia abyssinica* Cass.) crude seed oils and oil fractions. *J. Agric. Food Chem.* 51:6961-6969.
- Rao AS, Ahmed MF, Ibrahim M (2012). Hepatoprotective activity of *Melia azed* arach leaf extract against simvastatin induced Hepatotoxicity in rats. *J Appl. Pharm. Sci.* 02 (07):144-148.
- Rattanachaiakunsopon P, Phumkhachorn P (2010). Potential of

- coriander (*Coriandrum sativum*) oil as a natural antimicrobial compound in controlling *Campylobacter jejuni* in raw meat. *J. Biosci. Biotechnol. Biochem.* 74(1):31-35.
- Ravi R, Prakash M, Bhat KK (2007). Aroma characterization of coriander (*Coriandrum Sativum* L) oil samples. *Eur. J. Food Res. Technol.* 225(3-4):367-374.
- Rohit RP, Kavindra RJ, Chintan KM (2011). Image morphological operation based quality analysis of coriander Seed (*Coriandrum sativum* L.) Emerging Trends in Networks and Computer Communications (ETNCC), International Conference on 22-24 Aprilpp.482-486.
- Shaw M, Meda V, Ttabil JR, Opoku A (2007). Drying and color characteristics of coriander foliage using convective thin layer and microwave drying. *J. Microw. Power Electromagn. Energy* 41(2):59-68.
- Sahib NG, Anwar F, Gilani AH, Hamid AA, Saari A, Alkharfy KM (2012). Coriander (*Coriandrum sativum* L.): A potential source of high-value components for functional foods and nutraceuticals- A Review. *J. Phytother. Res.* 27(9), doi10.1002/ptr.4897.
- Silva F, Ferreira S, Queiroz JA, Fernanda CD (2011). Coriander (*Coriandrum sativum* L.) essential oils antibacterial activity and mode of action evaluated by flow cytometry. *J. Med. Microbiol.* 60:1479-1486.
- Sunil C, Agastian P, Kumarappan C, Ignacimuthu S (2012). *In vitro* antioxidant, antidiabetic and antilipidemic activities of *Symplocos cochinchinensis* (Lour.) S. Moore bark. *J. Food Chem. Toxicol.* 50(5):1547-1553.
- Ullagaddi R, Bondada A (2011). Medicinal benefits of coriander (*Coriandrum sativum* L). *J Spatula* DD1(1):51-58.
- USDA National Nutrient Database for Standard Reference Release 26 Full Report (All Nutrients) Nutrient data for 2013, Spices, coriander seed.
- Verma A, Pandeya SN, Sanjay KY, Styawan S (2011). A Review on *Coriandrum sativum* (Linn.) An Ayurvedic Medicinal Herb of Happiness. *J. Adv. Pharm. Healthcare Res.* 1(3):28-48.
- Wangensteen H, Samuelsen AB, Malterud KE (2004). Antioxidant activity in extracts from coriander. *Food Chem.* 88:293-297.
- Wallis TE (2005). *Textbook of Pharmacognosy*; 5th edn, S. K. Jain for CBS publishers and distributors; New Delhi (India). pp. 125-126, 246-248.