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A Comprehensive Review on Coriander and its Medicinal properties

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ABSTRACT

Coriander is an ancient plant that is popularly known for its distinct flavor when added to food. The plant has been used from pre-historic time for its medicinal properties. Nowadays, there is great emphasis on integrating medicinal and aromatic plants with nutraceutical properties which pave way for the prevention of chronic diseases such as obesity, CVDs, diabetes e.t.c.One of such plants with such great potential is coriander. It is also known to be nutritionally endowed 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 up to 12 mg/100g. 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. This pre-historic herb is also know to for its antioxidant, anti-diabetic, anti-convulsant, anti-inflammatory, anti-mutagenic, anti-anxiety, antimicrobial activity, hepatoprotective activity amongst others along with hormone balancing effect and analgesic properties thus promoting its use in foods.The aim of this study was to buttress the health benefits of coriander and draw further attention to the herbal plant.

KEYWORDS: Coriander, Nutraceutical, Medicinal properties,Antioxidant, Antimicrobial, Anti-convulsant, Hepatoprotective,

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1.1 INTRODUCTION

Coriandrumsativum (Commonly used one) is a pre-historic herb that belongs to the parsley family, same as anise, caraway, dill and fennel. The plant Coriander is named after koris, the Greek word for bug, as the unripe fruits have a smell that has been compared to that of bedbugs. However when ripe, the seeds have a distinctive sweet citrus/mint/musty aroma that has been valued over the centuries [1]. The fruits and leaves of coriander possess very unique flavors and hence are used in different ways to flavor food.

Coriander is native to the Mediterranean and Western Asia regions though commercial supplies now come from Turkey, India, Bulgaria, Russia and Morocco.This plant is a very ancient herb. It is mentioned in ancient Egyptian, Sanskrit, Greek and Latin writings. The ancient records reveal that coriander was used for both culinary and medicinal purposes. It was one of the substances utilized by Hippocrates, and other Greek physicians, for medicinal purposes. The Romans made coriander a popular spice, and introduced it to Great Britain. It was later brought to America, and was one of the first spices grown in New England and grows wild in Palestine [2].

1.1.1 Coriander: an ancient spice.

Coriander is one of the oldest spices mentioned in recorded history, with evidence of its use more than 5000 years ago. Fifteen desiccated mericarps were found in the Pre-Pottery Neolithic B level of the NahalHemel Cave in Israel, which may be the oldest Archeological find of coriander. Coriander seems to have been cultivated in Greece since at least the second millennium B.C [3]. Egyptians called it the Herb of Happiness, found in the tombs of Tutankhamun and Ramses II. The Chinese incorporated Coriander into their medical practice as long ago as 207 B.C. and believed that Coriander could bestow immortality. In India, Coriander was a remedy for constipation and insomnia, as well as for easing the pain of child birth. Women consumed the seeds regularly to promote fertility.

During the Elizabethan era, candy coated coriander seeds were served as a sweet after meals and to guard against gas. Reported as an aphrodisiac of the Middle East, Egypt, and Palestine, Coriander was used as such in the classic tale, The Arabian Nights. Brought to Europe during the Crusades for use as a Love Potion, it flavored a popular drink of the Middle Ages called Hippocras (wine with Coriander and Fennel seeds) that was drunk at weddings to inspire love and sex. It was used as a spice in both Greek and Roman cultures; the latter using it to preserve meats and flavor breads. The early physicians, including Hippocrates, used coriander for its medicinal properties, including as an aromatic stimulant.

The Russian Federation, India, Morocco and Holland are among the countries that produce coriander seeds. Coriander Leaves (cilantro) are featured in the culinary traditions of Latin American, Indian and Chinese cuisine.

1.1.2 Description

Coriander consists of dried ripe fruits and leaves of *Coriandrumsativum* Linn. (Fam. Apiaceae); a slender, soft, hairless, glabrous, branched, annual and a perennial herb growing to 50 centimeters (20in) tall.As shown in figure 1, the **stem** is feeble, smooth and light green in color. The **leaves** are compound, thin and alternate. Leaves are small herb having many branches and sub-branches [2] andnewleaves are oval but aerial leaves are elongated.**Fruits** are spherical about one centimeter in diameter with some longitudinal ridges. **Flowers** are white, having slightly brinjal like shape. Crop matures in 2-3 months after sowing; herb is pulled out with roots, after drying, fruits threshed out and dried in sun, winnowed, and stored in bags. The seeds/fruits have a lemony citrus flavor when crushed, due to terpenes linalool and pinene.

Figure 1: Fruit

Figure 2: Leaves

Figure 3: Flowers

Descriptive photograph of *Coriander sativum.*

1.1.3 Nutritional profile

The various nutrients present in coriander leaf and seeds are shown in Table 1. According to USDA [4], it contains no cholesterol content in its seeds. 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 µg/ 100 g (fresh

weight) (Iwatani et al., 2003). Among the various constituents, vitamin C content is present in ample amount (21 mg/100 g) (Table 1).

Table 1.Nutrient composition of coriander [4]

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

Coriander contains high amount of essential oils. 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 [5]. 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.

1.3 Phytochemical profile

The seeds of coriander contain up to 1.8% volatile oil [6]. The distilled oil (coriander oil BP) contains 65 to 70% of (+)-linalool (coriandrol), depending on the source. Therefore major active chemicals constituents of*Coriandrumsativum*are contained in its essential oils. It also contains significant amounts of fatty acids constituents [7]. The content of fatty acids varies between 9.9 and 27.7%. 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) [8].Coriander oil contains coriandrol, jireniol and vebriniol[9]. Other minor components of coriander includes;Monoterpene hydrocarbons viz α- pinene, β- pinene, limonene, γ-terpinene, ρ-lymene, borneol, citronwllol, Xmphoe, Geraniol and Geranylacetate; Hetero-cyclic compounds viz – pyrazine, pyridine, thiazole, furan, tetrahydrofuran derivatives; Isocoumacinvizcoriandrin, dihyrocoriandrin, coriandrones A-E, glazonoids; Phtha-lidesviz -neochidilide, Z-digustilide; Phenolic acids and sterols, flavonoids [10].

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 µg/100 g is present whereas total carotenoid content is 1010 µg/100 g [11]. Its foliage is used in various types of foods especially in diets of people facing vitamin A deficiency. Green foliage contains anthocyanin [12]. 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[13].

1.4 *Implication on health*

Coriander has been used in medicines for thousands of years. Various parts of this plant such as leaves, flower seed, and fruit possess antioxidant activity,diuretic, anti-diabetic, sedative, anti-microbial activity, anti-convulsantactivity, hypnotic activity,anti-helmintic activity and anti-mutagenic [714].

1.4.1 *Anti-microbial Properties*

*C. sativum*essential oil has been reported to inhibit a broad spectrum of micro-organisms [15]. The effective antibacterial activity of *C. sativum*essential oil against *Staphylococcus aureus*and Gram-negative bacterial strains including *Escherichia coli*, *Klebsiellapneumoniae*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa*and two clinical multidrug-resistant *Acinetobacterbaumannii*isolates has been shown. The primary mechanism of action of coriander oil is membrane damage, which leads to cell death [15]. The experiment also showed that 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.

Studies by [16]showed that 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.

The antimicrobial activity of Ethanol, Methanol, Acetone, Chloroform, Hexane and Petroleum ether extracts of *Coriandrumsativum*was investigated against infectious disease causing bacterial pathogens such as *E.Coli, Pseudomonas aeruginosa, Staphylococcus aureus*and *Klebsiella pneumonia*fungus like *Aspergillusniger, Candida albicans, Candida kefyr*and*Candidatropicalis*using the Agar Well diffusion method[17]. The Methanol extract of *Coriandrumsativum*showed more activity against *Staphylococcus aureus*zone of diameter 12.17±0.29 and *Klebsiella pneumonia* zone of diameter 12.17±0.15 and the Methanol extract of *Coriandrumsativum*showed more activity against *Candida albicans*zone of diameter 14.20±0.20 and *Aspergillusniger*of diameter 10.10±0.10 , when compared to other solvent extracts . In this study, both in bacteria and fungi methanol extract showed a varying degree of inhibition to the growth of tested organism than Ethanol, Acetone, Chloroform, Hexane and Petroleum ether. The results confirmed that presence of antibacterial and antifungal activity in the sundried extract of *Coriandrumsativum*against the human pathogenic organisms.

1.4.2*Antioxidative activity*

Polyphenolic compounds; caffeic acid, protocatechinic acid, and glycitin are present in high concentration (6.98, 6.43, and 3.27 µg/ml) in coriander aerial parts [18]. They 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 investigated. 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 (50µg/ml) increased the activities of antioxidant enzymes and glutathione content and reduced the levels of TBARS significantly. Other mechanism of actions includes DPPH free radical scavenging activity assay and ferric reducing antioxidant power (FRAP) [19 20]

[21] also investigated the anti-oxidative capacities of different parts of *C. sativum.*The method was based on inhibition of autoxidation of aldehyde to carboxylic (hexanoic) acid in the presence of compounds exhibiting antioxidant activity,diphenylpicrylhydrazyl (DPPH) radical-scavenging activity, Inhibition of 15-Lipoxygenase LO, Inhibition of Fe2+ 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. The study showed that scavenging activity of coriander seed essential oil is higher than coriander leaves essential oil. The antioxidant activity of coriander seed essential oil was might be due to presence of linalool in high concentration as compared to leaf essential oil. However, some essential fatty compounds such as linalool, a-pinene, limonene, and camphene had been reported to possess strong antioxidant activity.

[22] examined the antioxidant activity of the aqueous extract of umbelliferous fruit coriander (*Coriandrumsativum*) in comparison with the known antioxidant ascorbic acid in vitro studies. Time dependent & dose dependent antioxidant activities of fresh juice of *Coriandrumsativum* was evaluated by various methods in vivo.The spice reduced lipid peroxidation (by 300-600%) and increased the antioxidant enzyme activities (catalase by 55-75%, superoxide dismutase by 57-62% and glutathione

peroxidase by 80-83% reducing liver damage. Coriander seed extract could minimize the drug induced oxidative stress and protected the system against its toxicity.

1.4.3*Anti- diabetic activity*

- ***Insulin dependent diabetes***

Diabetes is a common problem in most developing countries and people prefer to take natural treatments than medicines. Various herbs are well reported to have anti-diabetic activities, among them are coriander leaves and seeds. Coriander leaves and seeds are well reported for their anti-diabetic activity by increased release of insulin from the pancreatic cells. It has been demonstrated that *C. sativum*extract was able to decrease hyperglycemia and increase glucose uptake and metabolism, and insulin secretion.

[23]investigated the effect of Sub-chronic oral administration of *C. sativum*extract (20 mg/kg) on obese-hyperglycemic and hyperlipidemic animal model. The result showed 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 cardio protective indices, its extract may have cardiovascular protective effect.

- ***Non-insulin dependent diabetes.***

Oxidative stress is increased in diabetic patients since persistent hyperglycemia causes an increased production of oxygen free radicals through autoxidation of glucose and non-enzymatic glycation of proteins. Increased levels of the products of oxidative damage to lipids and proteins have been detected in the serum of diabetic patients. [14] investigated the effect of administration of coriander seeds (5g/day) onNon- insulin dependent diabetes mellitus (NIDDM)patients for 60 days. Result showed that coriander seed countered oxidative stress as evidenced by significantly decreased lipid peroxidation, protein oxidation and decreased activity of erythrocyte catalase (CAT), increased serum carotene, vitamin A, E and C in diabetics treated with coriander seeds. Besides, the treatment increased the activity of erythrocyte antioxidant enzyme i.e. glutathione–S–transferase (GST) and reduced glutathione content (GSH) in the treated diabetics. The treatment with coriander seeds ameliorated oxidative stress in diabetics due to the synergistic action of antioxidant phytochemicals, carotenoids, flavonoids etc. present in the seeds.

In another study by [24], 50 type- 2 diabetic patients consumed 2 capsules of the Coriander seed powder /day for a period of 6weeks. Blood samples were collected from the patients before and after the course of CSP consumption after 12 h of fasting.The plasma glucose, total cholesterol, triglyceride, LDL-C, HDL-C,urea and creatinine were measured before and after the CSP consumption for 6 weeks. Atherosclerotic and cardioprotective indices were calculated. The CSP consumption for 6 weeks in type 2 diabetic patients significantly reduced plasma glucose, total cholesterol, triglyceride, and LDL-C ($p< 0.001$), but HDL-C was not significantly changed ($p\geq 0.05$).But there was no significant effect on urea and creatinine concentrations. Atherosclerotic index decreased while cardio protective indices increased.Since the CSP consumption reduced several components of metabolic syndrome, decreased atherosclerotic and increased cardio protective indices, the CSP may have cardiovascular protective effect in type 2 diabetic patients.

1.4.4*Diuretic*

The aqueous extract of coriander seed possesses diuretic and saluretic activity, thus, validating the use of coriander as a diuretic plant in Moroccan pharmacopoeia [23] examined aqueous extract of coriander seed which was administered by continuous intravenous infusion (120 min) at two doses (40 and 100 mg/kg) to anesthetized Wistar rats. Furosemide (10 mg/kg), a standard diuretic was used as the reference drug. Excretion of water and electrolytes (sodium, potassium and chloride) in urine was measured, and glomerular filtration rate (equal to creatinine clearance) was determined. The crude aqueous extract of coriander seeds increased diuresis, excretion of electrolytes, and glomerular filtration rate in a dose-dependent way; furosemide was more potent as a diuretic and saluretic. The mechanism of action of the plant extract appears to be similar to that of furosemide which is a drug used in renal and hepatic failure, and for the treatment of hypertension. It acts at the luminal surface of the ascending limb of the loop of Henle by inhibiting the active reabsorption of chloride.

[25] also 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.

1.4.5*Gastric mucosal protective activity*

The effect of Coriander pretreatment on gastric mucosal injuries caused by NaCl, NaOH, ethanol, indomethacin and pylorus ligation accumulated gastric acid secretions was investigated in rats by [26].Pre-treatment at oral doses of 250 and 500 mg/kg, body weight was found to provide a dose-dependent protection against the

(i) Ulcerogenic effects of different necrotizing agents;

(ii) Ethanol-induced histopathological lesions;

(iii) Pylorus ligated accumulation of gastric acid secretions and ethanol related decrease of Non-protein Sulfhydryl groups (NP-SH).

Results obtained in the study of gastric mucus and indomethacin induced ulcers, demonstrated that the gastro protective activity of Coriander might not be mediated by gastric mucus and/or endogenous stimulation of prostaglandins. The protective effect against ethanol-induced damage of the gastric tissue might be related to the free-radical scavenging property of different antioxidant constituents (linalool, flavonoids, coumarins, catechins, terpenes and polyphenolic compounds) present in Coriander.The inhibition of ulcers might be due to the formation of a protective layer of either one or more than one of these compounds by hydrophobic interactions.

1.4.6 *Hepato-protective activity*

Hepatotoxicity is a common disease among peoples with long term consumption of alcohol amidst other causative hepatoxins. Among the plant leaves that are highly hepatoprotective, curry and coriander leaves are mostly dominant which in turns regulates many diseases including hyperlipidemia, diabetes and hepatotoxicity. The bioactive compounds that are highly protective are of alkaloids, flavonoids and phenolic compounds. Coriander leaves are rich in these compounds found to be highly hepato-protective.

[27]reported that *C. sativum*extract protects liver from oxidative stress induced by carbon-tetrachloride (CCl_4). Pre-treatment 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.

1.4.7*Anti-Convulsant activity*

The anti-convulsant effects of aqueous and ethanolic extracts of *Coriandumsativum* seeds were studied in order to evaluate the folkloric use of this plant. Two anti-convulsant evaluation tests, namely the pentylenetetrazole (PTZ) and the maximal electroshock test, were used for assessing anti-seizure effects of coriander extracts. The aqueous and ethanolic extracts- prolonged onset of clonic convulsions and anti-convulsant activity at a dose of 5mg/kg were similar to that of phenobarbital at a dose of 20mg/kg in the PTZ test. Both extracts in high doses decreased the duration of Tonic seizures and showed a statiscally significant anticonvulsant activity in the maximal electro shock test [28]. In the maximal electroshock seizures, the aqueous extracts of seeds (at a dose of 0.5 g/kg) and the ethanolic extract (at doses of 3.5 and 5 g/kg) decreased the duration of tonic seizures by 22.30%, 30.43% and 36.96%, respectively. The aqueous and ethanolic extracts of *C. sativum*seeds may have a beneficial effect in petit mal and grand seizures.

1.4.8 *Sedative Hypnotic Activity*

*Coriandrumsativum*has been recommended for relief of insomnia in Iranian traditional medicine. To determine sedative & hypnotic activity,aqueous and hydroalcoholic extract & essential oil wasadministered to rat. The results of experiment shows that aqueous extract prolonged pentobarbital induced sleeping time at 200, 400 and 600 mg/kg. Hydro-alcoholic extract at doses of 400 and 600 mg/kg increased pentobarbital-induced sleeping time compared to saline-treated group. The essential oil increased pentobarbital induced sleeping time only at 600 mg/kg. The extracts and essential oil of coriander seeds possess sedative-hypnotic activity [29].

1.4.9 *Anxiolytic effect*

*Coriandrumsativum*has also been recommended for relief of anxiety in Iranian folk medicine. The anxiolytic effect of aqueous extract (10, 25, 50, 100 mg/kg) was examined in male albino mice using elevated plus-maze as an animal model of anxiety by[30].The effects of the extract on spontaneous activity and neuromuscular coordination were assessed using Animex Activity Meter and rotarod, respectively. In the elevated plus-maze, aqueous extract at 100 mg/kg showed an anxiolytic effect by increasing the time spent on open arms and the percentage of open arm entries, compared to control group. Aqueous extract at 50, 100 and 500 mg/kg significantly reduced spontaneous activity and neuromuscular coordination, compared to control group. These results suggest that the aqueous extract of *Coriandrumsativum*seed has anxiolytic effect.

1.4.10*Anti-inflammatory*

*Coriandrumsativum*is traditionally used in the treatment of inflammation. [31]reported that ethanolic extracts of the aerial parts of *Coriandrumsativum*have a strong anti-inflammatory property which inhibits pro-inflammatory mediator expression by suppressing NF-kappaB activation and MAPK signal transduction pathway in LPS-induced macrophages. The study investigated the anti-inflammatory potency of coriander oil in the ultraviolet (UV) erythema test in vivo. Compared to placebo, the lipolotion with 0.5% coriander oil significantly reduced the UV-induced erythema, but it was not as effective as hydrocortisone. The skin tolerance of both coriander oil concentrations was excellent.

1.4.11 *Anti-carcinogenic activity*

[32]Investigated the effect of powdered roots, leaves and stems of *C. sativum*whichwere extracted through sequential extraction using hexane, dichloromethane, ethyl acetate, methanol and water on carcinogenic cells. Anti-proliferative activity on the breast cancer cell line, MCF-7 (Michigan Cancer Foundation), was assayed using the MIT assay. Cell cycle progression was analysed using flow cytometry. Result obtained showed that the ethyl acetate extract of *C. sativum* roots had the highest anti-proliferative activity on MCF-7 cells (200.0 ± 2.6 µg/mL) and had the highest phenolic content, FRAP and DPPH scavenging activities among the extracts. *C. sativum* root inhibited DNA damage and prevented MCF-7 cell migration induced by H_2O_2, suggesting its potential in cancer prevention and inhibition of metastasis. The extract exhibited anticancer activity in MCF-7 cells by affecting

antioxidant enzymes possibly leading to H_2O_2 accumulation, cell cycle arrest at the G2/M phase and apoptotic cell death by the death receptor and mitochondrial apoptotic pathways.

[33]studied the biochemical effect of coriander seeds on lipid parameters in 1, 2-dimethyl hydrazine (DMH) induced colon cancer in rats. The study shows that the concentrations of cholesterol and cholesterol:phospholipid ratio decreased while the level of phospholipid increased significantly in the DMH control group compared to the spice administered group. Fecal dry weight, fecal neutral sterols and bile acids showed a sharp increase in the coriander-fed group compared with the DMH administered group. Thus, coriander plays a protective role against the deleterious effects in lipid metabolism in experimental coloncancer.

1.4.12*Anti-mutagenic activity*

Aromatic amines are metabolically activated into mutagenic compounds by both animal and plant systems. The 4- nitro-o-phenylenediamine (NOP) is a well-known direct-acting mutagen whose mutagenic potential can be enhanced by plant metabolism; m-phenylenediamine (m-PDA) is converted to mutagenic products detected by the Salmonella typhimurium TA98 strain, and 2-aminofluorene (2-AF) is the plant-activated pro-mutagen extensively studied. Plant cells activate both 2- AF and m-PDA into potent mutagens producing DNA frame shift mutations.

The anti-mutagenic activity of coriander juice against the mutagenic activity of 4-o-phenylenediamine, m-phenylenediamine and 2-aminofluorene was investigated by [34]using the Ames reversion mutagenicity assay with the *S. typhimurium* TA98 strain as indicator organism. The plant cell/microbe co-incubation assay was used as the activating system for aromatic transformation and plant extract interaction. Aqueous crude coriander juice significantly decreased the mutagenicity of metabolized aromatic amines (AA) in the following order: 2-AF (92.43%) > m PDA (87.14%) > NOP (83.21%). The chlorophyll content in vegetable juice was monitored and its concentration showed a positive correlation with the detected anti-mutagenic effect. Chlorophyll in coriander have been studied to show anti- mutagenic properties in response to the pro-mutagenic of amines and mutagenic amines. The deduction that chemical interaction takes place between the two molecules, leading to the inactivation of mutagenic moiety have been implicated as the mechanism of action.

1.4.13 *Anti-hypertensive Activity/Vasodilators*

Coriander crude extract (Cs.Cr) was evaluated through in vitro and in vivo techniques by [35]for anti-hypertensive activity. *C. sativum* (1-30 mg/ml) caused fall in arterial blood pressure of anesthetized animals, partially blocked by atropine and produced vasodilatation against phenylephrine induced contractions in rabbit aorta and cardio-depressant effect in guinea-pig . Coriander fruit exhibits anti-hypertensive effects mediating possibly through cholinergic, Ca (2+) antagonist or the combination of both mechanisms respectively.

1.4.14 *Cholesterol-lowering action*

Cardiovascular disease, the leading cause of death and illness in developed countries have become a pre-eminent health problem worldwide. Atherosclerosis is a progressive disease characterized by the accumulation of cholesterol; LDL-C and fibrous elements in the large arteries, would constitute most important contributor to this growing burden of cardiovascular disease.

In a study by [36] coriander seeds were incorporated into diet and the effect of the administration of coriander seeds on the metabolism of lipids was examined in rats, fed with high fat diet and added cholesterol. The seeds had a significant hypolipidemic action. The level of low density lipoprotein (LDL) + very low density lipoprotein (VLDL) cholesterol decreased while that of high density lipoprotein (HDL) cholesterol increased in the experimental group compared to the control group. The increased activity of plasma LCAT, enhanced degradation of cholesterol to fecal bile acids and neutral sterols appeared to account for its hypo-cholesterolemic effect.

Hyperlipidemia increases the risk for generation of lipid oxidation products, which accumulate in the sub-endothelial 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 [37]. [38]studied the hypolipidemic effect of coriander (*Coriandrumsativum*). 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 hypolipidemia. From these findings it was assumed that coriander can be used as preventive and curative herbal against hyperlipidemia.

1.4.15 *Metal detoxification*

Coriander can be used as a natural cleansing agent as it has potential to remove toxic metals from the body. Chemical compounds present in coriander attach to toxic metals and remove them from cells. [39] observed that the plant is very effective in removing inorganic (Hg^{2+}) and methyl mercury (CH_3Hg+) from aqueous solutions. This effect was due to the binding effect of carboxylic group to mercury.

1.4.16 *Protective role against lead toxicity*

Studies by [40]investigated the Protective role of *C.sativum extracts* against Lead Toxicity. Oxidative stress was induced in mice by a daily dose of lead nitrate (40 mg/kg body weight by oral gavages) for seven days. From day eight, after lead nitrate treatment, experimental animals received an oral dose of coriander extracts (aqueous extract - 300 mg/kg body weight and 600 mg/kg body weight; ethanolic extract - 250 mg/kg body weight and 500 mg/kg body weight) daily. The effect of these treatments in influencing the lead induced changes on hepatic and renal oxidative stress and biochemical changes along with histo-pathological alterations in soft tissues was studied. The data showed significant increase in liver and kidney LPO levels in animals treated with lead nitrate while the effect was attenuated by the plant extracts. Also, lead caused a significant decrease in antioxidant enzyme activity and this effect was reversed in groups treated with plant extract. Treatment with coriander significantly reduced the adverse effects related to most of biochemical parameters altered in animals treated with lead, related to hepatic and renal oxidative stress.

Table 2: Summary of Work done

Functional Properties	Active Ingredients	Part of Plant		Disease	Test Animal	Mechanism of Action	Dose	Researh
Inhibition of Oxidation Products	Polyphenolic compounds Linalool	Coriander Arial Parts, leaves		Oxidative-stress induced diseases	Rats	Diphenylpicrylhydrazyl (DPPH)radical-scavenging activity. Inhibition of 15-Lipoxygenase LO Inhibition of Fe2+ induced porcine brain phospholipid	4.1-7.9 mg/ml) ,	21

						peroxidation.		
Anti-Diabetic	unidentified	Coriander Extracts		Insulin dependent diabetes	Obese hyperglycemic and hyperlipidemic animal model	Increased release of insulin from the pancreatic cells.	20mg/ kg	23
Anti-Diabetic	Carotenoids, flavonoids,	Coriander seeds		Non-Insulin Dependent Diabetes	NIDDM Patients For 60 days	Significantly decreased lipid peroxidation, protein oxidation Decreased activity of erythrocyte catalase (CAT)	5g/day	14
Gastric Mucosal Protective Activity	Linanool, flavonoids, coumarins, catechins, terpenes and polyphenolic compounds	Coriander extracts		Gastric Ulcers	Rats	Formation of a protective layer of either one or more than one of the active compounds by hydrophobic interactions.	205 & 500 mg/kg	25
Hepato-protective activity	Alkaloids, flavonoids and phenolic compounds	Coriander leaves		Liver Hepatoxicity	Rats	Significantly lowered serum glutamate oxaloacetate transaminase (SGOT), serum glutamate pyruvate transaminase (SGPT), and TBARS by inceasingHepatic	100 & 200 mg/kg	27

						enzymes like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx)		
Anti-Convulsant Activity	-	Aqueous and ethanolic extracts of *C. sativum*seeds		Seizures and convulsions	Rats	Decrease duration of Tonic and Clonic Seizures	5mg/kg	28
Sedative and Hypnotic Activity	-	Aqueous Extract Hydro-alcoholic extract and essential oil		Insomnia	Rats	Prolonged pentobarbital-induced sleeping time compared to saline-treated group.	400 &600 mg/kg	29
Anxiolytic Effect	.	Aqueous Extracts		Anxiety	Albino Male Mice	Reduced spontaneous activity and and enhanced neuromuscular coordination.	100mg /kg	30
Anti-Inflammatory	Sequiterpenes	Corriander Oil + Ethanolic extracts		Skin Inflammation	Human	Inhibits pro-inflammatory mediator expression by suppressing NF-kappaB activation and MAPK signal transduction pathway in LPS-induced macrophages.	0.5% 0il	31

Anti-carcinogenic activity	Poliphenolic Compounds	Powdered roots, stems and leaves.		Breast Cancer	Human	FRAP and DPPH scavenging activities among the extracts. Inhibited DNA damage and prevented MCF-7 cell migration induced by H_2O_2.	200.0 ± 2.6 µg/mL	32
Anti-Mutagenic Activity	Chlorophyll	Coriander Juice		Genetic Mutation	Rats	Chlorophyll in coriander showed anti- mutagenic properties in response to the pro-mutagenic of amines and mutagenic amines. A deduction that a chemical interaction takes place between the two molecules, leading to the inactivation of mutagenic moiety have been implicated as the mechanism of action.	50-1000 µl/coin cubation flask	34
Anti-hypertensive Activity	-	Coriander crude extract		Hypertension	Rabbits	Anti-hypertensive effects mediating possibly through cholinergic, Ca (2+) antagonist or the combination of both mechanisms respectively.	1-30 mg/ml	35

Cholesterol-lowering Action	-	Coriander seeds		Hypocholesteremia	Rats	Increased activity of plasma LCAT, enhanced degradation of cholesterol to fecal bile acids and neutral sterols appeared to account for its hypo-cholesterolemic	8 %	36
Metal Detoxification	Hydroxyls groups	Coriander extracts		Lead Nitrate Toxicity causing hepatic and renal oxidative stress	Mice (Daily dose for seven days)	Binding effect of carboxylic group to metals	250-600 mg/kg	40

1.6 Safety, Toxicity and adverse effects; study cases

The major component of the essential oil, linalool is non-mutagenic. Coriander oil is irritating to rabbits, but not to humans. Based on the history of consumption of coriander oil without reported adverse effects, due to 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.

A human clinical study was conducted to investigate potential effects ofcoriander[41]. In this controlled randomized double-blind study in healthy Caucasian women aged between 18 and 50 years, one group received the test product coriander seed oil (600 mg/day) and the other group received the placebo, paraffin oil, for six months. Blood samples were collected at baseline (day 1), day 20-28, day 76-84 and day 160-168 (termination of study) and analyzed for hematological parameters, triglycerides, cholesterol, urea, creatinine and glucose concentrations. No significant difference between the placebo group and the coriander seed oil group was observed for any of the blood parameters. The coriander seed oil was well tolerated and no adverse effects related to treatment with coriander seed oil were

observed. The deduction was made that no treatment-related adverse effects were observed in healthy women consuming the coriander at a dose of 600 mg/day for six months

1.7 CONCLUSION

Herbs and spices are processed in foods from early times for unique flavor when added to food.. Coriander is one of miraculous herb that functions as both, spice as well as herbal medicine. Although the 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 anti-microbial, anti-oxidant, anti-diabetic,anticancer activities amongst others. Most important and well characterized property of coriander is its use as antioxidant. Due to its multi-functional uses and protective and preventive action against various chronic diseases, this herb is rightly called as "herb of happiness".

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