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Review Article

Coriandrum Sativum As A Potential Nephroprotective Agent: A Review of its Phytochemical and Pharmacological Properties

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ABSTRACT

Renal pathologies and nephrotoxic conditions constitute significant worldwide health challenges owing to their rising incidence and correlation with substantial morbidity and mortality rates. Primary contributors to renal damage and impairment include oxidative stress, inflammatory processes, programmed cell death, and contact with nephrotoxic substances including pharmaceuticals, heavy metals, and environmental contaminants. Recently, botanical medicines have attracted substantial scientific interest as prospective renal protective compounds due to their safety profile, economic accessibility, and varied pharmacological properties. Coriandrum sativum L., widely recognized as coriander or cilantro, is a fragrant plant from the Apiaceae family that has been conventionally employed across different traditional medicine systems for managing gastrointestinal, metabolic, inflammatory, and urogenital conditions. This botanical source contains abundant bioactive compounds such as linalool, quercetin, rutin, chlorogenic acid, caffeic acid, flavonoids, terpenoids, coumarins, vitamins, and essential minerals that underlie its therapeutic capabilities. This comprehensive review examines the phytochemical profile, pharmacological effects, and renal protective pathways of Coriandrum sativum.

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Laboratory investigations have revealed that coriander demonstrates notable antioxidant, anti-inflammatory, antidiabetic, antimicrobial, hepatoprotective, cardioprotective, immunomodulatory, and detoxification activities. These pharmacological characteristics provide protection for renal structures against oxidative injury, inflammatory cascades, apoptotic processes, and toxic exposure. Coriander preparations have additionally exhibited capacity to ameliorate renal biochemical parameters, strengthen intrinsic antioxidant protective mechanisms, and maintain normal kidney structural integrity across diverse nephrotoxicity experimental models. Collectively, current scientific evidence indicates that Coriandrum sativum demonstrates substantial promise as a natural renal protective compound. Nevertheless, additional clinical investigations and standardization protocols are required to confirm its safety profile, therapeutic effectiveness, and clinical utility in human kidney diseases.

INTRODUCTION

Renal organs represent vital components of human physiology, serving a pivotal function in sustaining homeostatic balance through blood filtration, electrolyte regulation, waste elimination, acid-base maintenance, and blood pressure modulation. Beyond their excretory roles, these organs participate in hormonal activities including erythropoietin synthesis, renin release, and vitamin D activation. Given their intensive metabolic demands and abundant vascular supply, renal structures exhibit heightened susceptibility to toxicological challenges, oxidative injury, inflammatory processes, and circulatory disruptions. Consequently, renal pathologies have become a significant worldwide health issue, substantially influencing disease burden, mortality rates, and medical expenditures globally. The rising occurrence of diabetes mellitus, hypertension, obesity, environmental contaminants, and inappropriate medication usage has further intensified the frequency of kidney-related ailments across both industrialized and emerging nations [1]. Renal pathologies comprise an extensive array of disease states spanning from AKI and CKD to nephrolithiasis, glomerulonephritis, diabetic nephropathy, and medication-induced kidney toxicity. Within this spectrum, nephrotoxicity has received substantial focus as it commonly manifests as an undesirable outcome of medical treatments utilizing antibiotics, anticancer medications, NSAIDs, contrast media, heavy metals, and environmental contaminants. Nephrotoxicity describes the decline in kidney function resulting from harmful substances that cause direct or indirect cellular damage, especially to tubular epithelial structures. The development of nephrotoxicity typically involves oxidative stress, inflammatory responses, mitochondrial impairment, programmed cell death, and compromised antioxidant protective systems. These pathological mechanisms eventually produce structural and functional kidney modifications, leading to diminished glomerular filtration, electrolyte disruption, waste accumulation, and potential renal failure in advanced stages [2]. Although significant progress has been achieved in renal medicine and drug development, existing therapeutic approaches for kidney conditions remain inadequately effective and frequently present considerable side effects. Standard medications employed in renal disease treatment may themselves cause kidney toxicity during extended use. Furthermore, dialysis and renal transplantation, regarded as ultimate treatments for terminal kidney disease, are costly, invasive, and unavailable to many individuals worldwide. Therefore, increasing focus has emerged on discovering safer, economical, and naturally sourced therapeutic compounds capable of preventing or reducing renal injury [3]. Within this framework, botanical medicines and plant-based preparations have garnered significant scientific interest owing to their extensive traditional usage history, broad therapeutic capabilities, and relatively reduced adverse reaction profiles. Herbal therapeutics has functioned as a fundamental element of

conventional medical practices including Ayurveda, Unani, Siddha, and Traditional Chinese Medicine throughout history. Many medicinal plants exhibit powerful antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and detoxification characteristics that may provide renal protection. Plant-derived bioactive compounds such as flavonoids, phenolic acids, alkaloids, tannins, terpenoids, and essential oils have shown capacity to scavenge reactive oxygen species, suppress inflammatory factors, stabilize cell membranes, and strengthen intrinsic antioxidant mechanisms. These therapeutic attributes position herbal treatments as encouraging options for kidney-protective intervention [4].

Chemical analyses have identified that *Coriandrum sativum* encompasses various bioactive components including linalool, geraniol, borneol, camphor, quercetin, rutin, caffeic acid, chlorogenic acid, coumarins, terpenoids, and polyphenolic substances. These components are responsible for its powerful antioxidant and reactive species neutralizing capabilities, which represent essential pathways in kidney protection. Oxidative damage serves as a fundamental element in nephrotoxic development, where excessive reactive oxygen species production results in membrane lipid degradation, genetic material harm, protein modification, and programmed cell death. The antioxidative molecules within *Coriandrum sativum* may oppose these harmful mechanisms through augmentation of intrinsic antioxidant enzymes including superoxide dismutase, catalase, and glutathione peroxidase. Beyond its antioxidative characteristics, *Coriandrum sativum* demonstrates considerable anti-inflammatory actions through regulation of inflammatory mediators and pathways implicated in kidney damage. Persistent inflammation plays a major role in kidney disease advancement by facilitating fibrotic changes, immune cell invasion, and structural deterioration. Laboratory investigations have shown that *Coriandrum sativum* preparations can inhibit inflammatory factors such as tumor necrosis factor-alpha (TNF-α), interleukins, cyclooxygenase enzymes, and nitric oxide synthesis. These mechanisms may contribute to decreased kidney inflammation and maintained renal structure during disease states.

An additional significant characteristic of *Coriandrum sativum* involves its detoxification and metal-binding capabilities [5]. Contact with heavy metals including lead, cadmium, arsenic, and mercury correlates strongly with kidney impairment through toxic metabolite accumulation in renal tissues. Multiple investigations have indicated that coriander demonstrates capacity to sequester and promote elimination of harmful metals from the organism, consequently decreasing oxidative injury and enhancing kidney health. Moreover, its diuretic characteristics may support increased urinary elimination of metabolic byproducts and toxins, promoting enhanced renal function. The glucose-lowering activity of *Coriandrum sativum* maintains specific importance in kidney protection since diabetes mellitus represents a primary cause of chronic kidney disease globally. Sustained elevated blood glucose triggers oxidative damage, advanced glycation end-product development, glomerular enlargement, and small vessel injury in kidneys. Scientific evidence suggests that coriander preparations may decrease glucose concentrations, enhance insulin responsiveness, and modulate fat metabolism. Through managing hyperglycemia and related metabolic abnormalities, *Coriandrum sativum* may indirectly inhibit diabetic kidney disease development [6].

1.1. Overview of kidney disorders and nephrotoxicity

Renal pathologies encompass a broad spectrum of conditions that compromise kidney structure and physiological processes. Acute renal injury manifests as an abrupt deterioration in kidney function resulting from ischemic events, toxic exposures, infectious processes, or physical trauma, while chronic renal disease entails progressive and permanent deterioration of kidney function. Chronic renal disease impacts millions globally and correlates with elevated cardiovascular complications, metabolic disturbances, and diminished life quality. Diabetes mellitus and hypertension constitute the primary etiologies of CKD, succeeded by autoimmune conditions, genetic disorders, and nephrotoxic substances. Nephrotoxic injury represents a significant factor in renal dysfunction and frequently results from pharmaceutical agents, environmental contaminants, and industrial compounds [7]. Aminoglycoside antibiotics, cisplatin, cyclosporine, NSAIDs, and contrast media constitute recognized nephrotoxic substances. The kidneys demonstrate heightened vulnerability to toxic damage as they process approximately 25% of cardiac output while actively concentrating materials during filtration and elimination processes. Toxic exposures trigger oxidative damage, inflammatory responses, mitochondrial impairment, tubular cell death, and programmed cell death, consequently disrupting normal kidney function. Continued nephrotoxic exposure may advance to chronic renal insufficiency and terminal kidney disease [8].

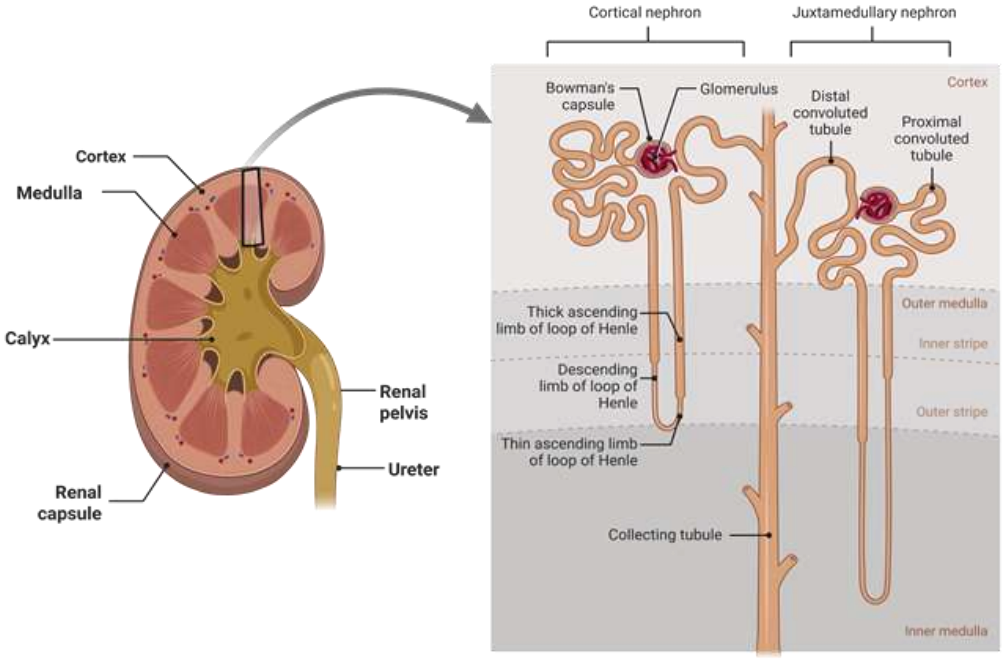


Fig.1: Anatomy of Kidney

1.2. Importance of herbal nephroprotective agents

The drawbacks and undesirable outcomes of standard therapeutic interventions have fostered increasing attention toward plant-based renal protective compounds. Botanical sources are regarded as important reservoirs of biologically active substances that can prevent kidney injury through various pathways. Plant-derived treatments frequently demonstrate complementary pharmacological actions attributed to their

complex mixture of natural constituents. Phytochemicals with antioxidant properties may neutralize free radicals, inhibit pro-inflammatory cascades, strengthen detoxification processes, and bolster cellular protective systems. Plant-based kidney protective substances are particularly appealing due to their availability, cost-effectiveness, and extensive historical application in traditional medicine. Various botanical species including Curcuma longa, Camellia sinensis, Allium sativum, Phyllanthus niruri, and *Coriandrum sativum* have shown substantial kidney protective activities in laboratory investigations. The combination of phytotherapy with contemporary medical treatments may provide enhanced safety profiles and improved therapeutic efficacy for renal disorder management while reducing medication-related kidney toxicity [9].

1.3. Introduction to *Coriandrum sativum*

Coriandrum sativum L. represents an annual fragrant herb classified within the Apiaceae family. This plant, frequently referred to as coriander or cilantro, demonstrates extensive utilization in gastronomic applications and conventional therapeutic practices throughout various cultural contexts. The foliage and seeds exhibit distinctive taste and scent profiles attributed to volatile compounds abundant in linalool and additional terpenoid constituents. Historically, this botanical specimen has served therapeutic purposes for gastrointestinal ailments, nervousness, sleeplessness, metabolic glucose disorders, pathogenic infections, and inflammatory pathologies. Research investigations have substantiated that *Coriandrum sativum* demonstrates diverse pharmacological properties encompassing antioxidative, antimicrobial, antidiabetic, anti-inflammatory, liver-protective, cardiac-protective, anxiety-reducing, and detoxification capabilities. This species harbors substantial quantities of flavonoids, phenolic constituents, vitamins, minerals, and essential compounds that enhance its therapeutic significance. Accumulating research indicates that coriander may additionally safeguard kidney structures from oxidative damage and harmful exposure, establishing its potential as a beneficial agent for renal protection therapy [10].

This comprehensive analysis endeavors to thoroughly assess the kidney-protective capabilities of *Coriandrum sativum* through examination of its phytochemical profile, pharmacological characteristics, and fundamental molecular pathways associated with renal safeguarding. The evaluation concentrates on synthesizing contemporary experimental data concerning antioxidative, anti-inflammatory, antidiabetic, detoxification, and kidney-protective attributes of coriander. Moreover, the manuscript addresses nephrotoxicity pathophysiology, renal damage mechanisms, and therapeutic significance of plant-derived bioactive molecules in kidney preservation. Additionally, this analysis seeks to emphasize current knowledge deficiencies, constraints of existing research, and future possibilities for clinical implementation of *Coriandrum sativum* in renal medicine. Through consolidation of accessible scientific data, this evaluation intends to establish a beneficial reference for investigators, pharmacologists, medical practitioners, and healthcare specialists pursuing herbal kidney-protective compounds and natural product-derived therapeutic approaches [11].

1.4. Botanical description and taxonomy of *Coriandrum sativum*

Coriandrum sativum L., recognized by various names including coriander, cilantro, or Chinese

parsley, represents a highly prevalent aromatic herb within the Apiaceae family. This plant has achieved significant prominence both as a culinary seasoning and flavoring component, as well as a therapeutic herb demonstrating various pharmacological characteristics. Throughout history, *Coriandrum sativum* has been integrated into conventional medical systems such as Ayurveda, Unani, Traditional Chinese Medicine, and Persian medicine for addressing gastrointestinal ailments, inflammatory disorders, anxiety, diabetes, and microbial infections. The medicinal value of coriander stems predominantly from its abundant phytochemical profile, which encompasses volatile oils, flavonoids, phenolic acids, alkaloids, coumarins, terpenoids, vitamins, and minerals. Growing scientific attention toward *Coriandrum sativum* has stimulated comprehensive investigations into its botanical characteristics, taxonomic classification, morphological features, agricultural techniques, and conventional therapeutic uses. Precise botanical identification remains crucial for appropriate recognition, verification, and standardization of medicinal plants, as differences in species, environmental factors, and agricultural approaches can substantially affect phytochemical content and biological efficacy. Additionally, comprehending the geographic spread and ethnomedicinal significance of coriander offers important perspectives on its historical value and healing potential across various cultural contexts [12].

Coriandrum sativum stands among the most ancient cultivated spices in human civilization. Archaeological findings demonstrate that coriander seeds were utilized in early societies including Egypt, Greece, and Rome millennia ago. The plant has appeared in numerous historical medical documents and religious texts owing to its culinary and therapeutic value. In contemporary periods, coriander remains extensively grown globally for its foliage and seeds, which find widespread application in food manufacturing, pharmaceutical preparations, cosmetic products, and herbal formulations. The plant's adaptability to various climatic environments and its commercial significance have facilitated its broad cultivation across tropical, subtropical, and temperate zones [13]. The botanical and therapeutic relevance of *Coriandrum sativum* extends beyond its nutritional benefits to encompass its versatile healing properties. Various plant components including foliage, fruits (typically called seeds), stems, and roots demonstrate distinctive phytochemical characteristics and pharmacological functions. The foliage contains abundant vitamins, chlorophyll, and antioxidants, while the seeds possess elevated concentrations of essential oils primarily composed of linalool and additional monoterpenes. This phytochemical variation accounts for the extensive range of biological activities linked to coriander, encompassing antioxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, cardioprotective, neuroprotective, and nephroprotective properties [14]. Comprehending the systematic classification and structural characteristics of *Coriandrum sativum* proves fundamental for differentiating it from closely related taxa within the Apiaceae family. This botanical family encompasses aromatic herbaceous plants distinguished by umbellate flower clusters and splitting fruit structures. Nevertheless, minor morphological differences occur across species, rendering precise taxonomic identification crucial for research endeavors and therapeutic applications. Furthermore, ecological variables including soil characteristics, watering regimens, thermal conditions, elevation, and collection methods affect plant development and bioactive compound synthesis. Consequently, comprehensive understanding of agricultural

practices and geographic occurrence remains vital for guaranteeing the efficacy and uniformity of coriander-based therapeutic preparations. The traditional medicinal application of coriander represents generations of experiential wisdom concerning its healing properties. Indigenous practitioners have utilized coriander formulations to treat digestive ailments, pyrexia, sleep disturbances, articular discomfort, urogenital conditions, and metabolic irregularities. Across numerous societies, coriander has additionally served as a purifying and cooling remedy owing to its diuretic and antioxidative characteristics. Contemporary scientific research has confirmed multiple traditional assertions, thus enhancing scientific interest in coriander as a promising phytotherapeutic option for persistent ailments, particularly kidney-related conditions [15].

1.5. Taxonomical classification

The systematic categorization of *Coriandrum sativum* establishes the scientific foundation for its recognition and orderly positioning within botanical hierarchies. Taxonomic frameworks serve an essential function in medicinal botany studies since precise classification guarantees appropriate verification, prevents contamination with inferior substances, and enables pharmacognostic uniformity. *Coriandrum sativum* is classified within the Apiaceae family, alternatively designated as Umbelliferae based on the distinctive umbrella-like flower clusters characteristic of species within this taxonomic group [16]. This family encompasses numerous commercially and therapeutically significant fragrant species including fennel, cumin, dill, celery, parsley, carrot, and anise. The taxonomical hierarchy of *Coriandrum sativum* is as follows:

- **Kingdom:** Plantae
- **Subkingdom:** Tracheobionta
- **Division:** Magnoliophyta
- **Class:** Magnoliopsida
- **Order:** Apiales
- **Family:** Apiaceae (Umbelliferae)
- **Genus:** *Coriandrum*
- **Species:** *Coriandrum sativum* L.

The genus Coriandrum encompasses a limited number of species, with *Coriandrum sativum* representing the most extensively recognized and commercially grown variety. The designation "L." following the scientific nomenclature indicates Carl Linnaeus, the Swedish taxonomist who provided the formal description of this species using binomial classification principles. The Apiaceae family exhibits characteristics including aromatic plants with hollow stem structures, complex leaf arrangements, and flower clusters organized in umbellate formations. Taxa within this family frequently possess substantial essential oil concentrations that account for their distinctive fragrance and therapeutic attributes. While *Coriandrum sativum* exhibits numerous taxonomic similarities with related Apiaceae species, it may be differentiated through its distinctive spherical seed structures and particular aromatic profile [17]. Accurate taxonomic determination holds significant importance since multiple Apiaceae plants may demonstrate morphological resemblance during specific developmental phases. Incorrect identification may jeopardize the therapeutic effectiveness and safety profiles of botanical formulations. Consequently, plant authentication utilizing morphological analysis, microscopic assessment, phytochemical characterization, and molecular methodologies is frequently implemented in medicinal plant investigations concerning

coriander. Contemporary developments in molecular systematics and DNA barcoding technologies have substantially improved the scientific categorization of therapeutic plants. Molecular indicators facilitate the detection of genetic variability among coriander cultivars and regional strains. These investigations provide significant value for comprehending phytochemical variation, plant breeding initiatives, and quality assurance protocols for medicinal botanical materials [18].

1.6. Morphological characteristics

Coriandrum sativum represents an annual herbaceous species characterized by distinctive morphological attributes that enable its recognition and agricultural management. This specimen presents as a tender, smooth, fragrant, and extensively branched organism, commonly achieving heights ranging from 30–70 cm based on environmental variables and genetic variety. Its structural characteristics demonstrate minor variations throughout successive growth phases, especially regarding foliar configuration and branching architecture [19].

Root system: The species develops a narrow primary root system accompanied by subsidiary lateral root networks penetrating the substrate. These root structures typically display light brown to cream pigmentation and serve crucial functions in moisture and mineral uptake. Within certain traditional therapeutic frameworks, coriander root tissues are employed for medicinal applications due to their content of essential oils and aromatic constituents.

Stem: The stem structure of *Coriandrum sativum* exhibits an upright, tubular, glabrous, and ramified architecture. Typically displaying a green coloration, it may develop slight reddish or purplish hues at the basal region under specific environmental circumstances. The stem possesses an internal cavity, representing a prevalent characteristic among numerous Apiaceae family members. Ramification predominantly manifests in the superior plant segments and provides structural support for the inflorescence arrangement.

Leaves: Coriander foliage demonstrates remarkable distinctiveness and experiences morphological transformations throughout plant development. Basal leaves present broad, lobate characteristics resembling parsley foliage, while superior leaves progressively develop into finely dissected narrow linear divisions. This heterophyllous nature constitutes a distinguishing plant attribute. Juvenile foliage appears delicate, succulent, and vibrant green with an agreeable fragrance. These leaves serve extensively as culinary herbs and decorative elements. The foliar tissue encompasses chlorophyll, vitamins A and C, flavonoids, and antioxidative compounds that enhance their nutritional and therapeutic properties.

Inflorescence: The flowering arrangement of *Coriandrum sativum* displays compound umbellate organization, representing a defining characteristic of Apiaceae members. Individual umbels encompass numerous minute flowers supported by delicate pedicels extending from a central junction. The blossoms typically exhibit white or light pink coloration and feature five petals. Anthesis commonly transpires within 45–60 days following seed germination, contingent upon environmental factors. The flowers demonstrate hermaphroditic characteristics and undergo entomophilous pollination, drawing bees and additional pollinators through their nectar production and fragrance. Successful pollination remains crucial for fruit development and reproductive success.

Fruits and Seeds: Coriander fruits are colloquially termed seeds, despite their botanical classification as schizocarps. These fruits display nearly globular morphology, exhibiting yellowish-brown coloration and measuring approximately 3–5 mm in diameter. Upon maturation, the fruit divides into two mericarps, each housing an individual seed. Coriander seeds demonstrate distinctive warm, aromatic properties resulting from essential oils abundant in linalool. These seeds function extensively as seasonings, flavoring components, and therapeutic materials. They encompass proteins, lipids, carbohydrates, minerals, and various bioactive phytochemical compounds [20].

Aroma and essential oils: Among the most prominent morphological and sensory attributes of *Coriandrum sativum* is its distinctive fragrance. Fresh foliage generates an intense characteristic scent that certain individuals interpret as citrus-like while others characterize as sharp. This aroma results from aldehydes and volatile substances within leaf matrices. Conversely, seeds exhibit sweet and agreeable fragrances dominated by linalool and terpenoid constituents. Essential oils derived from coriander seeds receive extensive application across pharmaceutical, cosmetic, culinary, and fragrance industries.

1.7. Geographical distribution and cultivation

Coriandrum sativum L., frequently referred to as coriander or cilantro, represents an aromatic herbaceous annual species within the Apiaceae family. This plant experiences global cultivation owing to its significant culinary, therapeutic, and commercial applications. Recognized as among the most ancient cultivated spices, coriander has maintained its role in traditional healing practices and food preparation for numerous centuries. The species demonstrates remarkable environmental adaptability, facilitating its extensive geographic presence across tropical, subtropical, and temperate zones. The Mediterranean basin, Southern Europe, North Africa, and portions of Western Asia are considered the probable ancestral regions of *Coriandrum sativum*. Historical documentation confirms cultivation practices in ancient Egyptian, Greek, and Roman civilizations, where the plant held dual significance for gastronomic and therapeutic applications. Archaeological discoveries of coriander seeds within Egyptian burial sites underscore its cultural importance in early societies. Through commercial networks and agricultural dissemination, coriander subsequently expanded into Asian territories, Middle Eastern regions, and additional global locations. Contemporary cultivation occurs extensively across nations including India, China, Russia, Morocco, Egypt, Bangladesh, Pakistan, Turkey, Mexico, and various European countries. India maintains its position as the foremost global producer, consumer, and exporter of coriander seeds. Large-scale cultivation within Indian territories encompasses Rajasthan, Gujarat, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, and Karnataka states. Rajasthan provides a considerable portion of India's total coriander output through advantageous environmental and edaphic conditions. The extensive agricultural adoption of coriander stems primarily from its economic significance. Both foliage and seeds serve as spices, seasonings, flavoring compounds, and components in pharmaceutical and cosmetic formulations. Fresh leafy portions find application in salads, broths, curries, and decorative purposes, while dehydrated seeds contribute to spice mixtures and herbal preparations. Furthermore, coriander essential oil possesses commercial value through its aromatic and medicinal characteristics [21].

Coriandrum sativum demonstrates optimal performance under cool and arid environmental conditions. Cultivation typically occurs during winter seasons in tropical regions and spring or summer periods in temperate areas. The species requires moderate thermal conditions between 20°C and 30°C for ideal growth and maturation. Excessive heat may diminish vegetative development, reproductive processes, and essential oil production, whereas intense frost can harm young plants and compromise yields. Sufficient solar radiation proves essential for vigorous plant development and appropriate seed formation. The crop tolerates diverse soil classifications; nevertheless, well-draining loamy or sandy loam substrates enriched with organic components provide optimal cultivation conditions. Soil acidity levels between 6.2 and 7.8 generally support maximum development and productivity. Saturated or highly saline soils prove detrimental as they may restrict root formation and enhance disease susceptibility. Appropriate land preparation involving tillage, surface leveling, and organic amendment incorporation promotes soil nutrient status and enhances agricultural output [22]. The reproduction of coriander occurs predominantly via seed propagation. Prior to planting, the desiccated fruits are frequently subjected to gentle crushing to divide them into two segments, thereby enhancing germination rates. Seeds are typically planted directly into agricultural fields using broadcasting or row-planting techniques. Appropriate spacing between rows and individual plants is established to guarantee sufficient air circulation, solar radiation access, and nutrient distribution. Germination generally takes place within seven to fourteen days, contingent upon environmental factors including temperature and soil hydration levels. Sufficient water supply remains crucial throughout initial developmental phases and reproductive periods. Nevertheless, overwatering must be prevented as surplus moisture can encourage mycotic infections and root pathologies. Consistent moderate irrigation at regular intervals typically provides adequate support for optimal crop development. Fertilizing agents rich in nitrogen, phosphorus, and potassium are routinely utilized to enhance vegetative development, seed yield, and essential oil concentration. Organic cultivation methods are gaining preference for coriander production owing to increasing consumer demand for chemical-free botanical products [23-25]. Reproductive development in coriander typically commences 45–60 days following seed establishment. The species generates minute white or light pink blossoms organized in compound umbellate structures, representing typical characteristics of the Apiaceae family. Pollination predominantly occurs via insect vectors including bees and dipterans. Following fertilization, fruits emerge and progressively ripen into yellowish-brown globular seeds. Harvest timing varies according to the plant's intended application. For fresh foliage utilization, collection occurs during vegetative development, while seed harvesting takes place upon complete fruit maturation. Mature specimens are severed, dehydrated, and processed to extract seeds. Appropriate desiccation and preservation methods remain essential for maintaining aromatic properties, essential oil levels, and phytochemical integrity. Coriander cultivation possesses considerable commercial and therapeutic significance. Rising worldwide demand for botanical medicines, natural food supplements, and essential oils has strengthened the economic relevance of coriander agriculture. Furthermore, the species demonstrates relative ease of cultivation, exhibits brief developmental cycles, and delivers advantageous financial returns to agricultural producers. Contemporary farming methodologies and enhanced cultivars have

additionally improved productivity and quality standards of coriander harvests globally [26].

1.8. Traditional and ethnomedicinal uses

Coriandrum sativum L., widely recognized as coriander or cilantro, has demonstrated extensive application in traditional healing systems throughout history owing to its varied medicinal characteristics. This botanical species occupies a significant position within Ayurvedic practices, Unani medicine, Traditional Chinese Medicine, Persian therapeutic traditions, and numerous indigenous healing methodologies globally. Various plant components, encompassing foliage, seeds, roots, and volatile oils, have been conventionally employed for addressing multiple health conditions affecting digestive, urinary, metabolic, respiratory, and neurological systems. Within Ayurvedic practice, coriander is characterized as a cooling, digestive, carminative, and diuretic botanical that assists in moderating bodily heat and enhancing gastrointestinal functionality. Coriander seeds find frequent application in addressing dyspepsia, intestinal gas, loose stools, abdominal pain, nausea, emesis, and diminished appetite. Traditional preparations including decoctions and infusions derived from coriander seeds are customarily given to alleviate urinary system infections, painful urination, excessive thirst, and fluid accumulation through their diuretic and purifying characteristics. This herb is additionally valued for its capacity to reduce pyrexia and inflammatory states [27].

Within Traditional Chinese Medicine, coriander has served to enhance appetite, facilitate digestion, address gastric disturbances, and support circulation. It has been conventionally utilized for managing measles, fever, cough, and respiratory obstruction. Historical Persian and Middle Eastern therapeutic systems acknowledged coriander as a tranquilizing and comforting herb beneficial for anxiety, sleeplessness, cephalgia, and neurological disturbances. Coriander formulations were regularly recommended as gentle sedatives and digestive enhancers. Across various traditional healing practices, fresh coriander foliage and seed preparations are topically administered for dermatological irritation, articular pain, wounds, and inflammatory swelling through their antimicrobial and anti-inflammatory characteristics. Coriander has been conventionally applied in addressing metabolic conditions including diabetes and dyslipidemia. Traditional healers across numerous cultures advocated coriander seed preparations for regulating blood sugar concentrations and enhancing digestion in diabetic individuals. Furthermore, this plant has served as a natural therapeutic approach for hypertension and cardiovascular discomfort through its hypotensive and antioxidant mechanisms. Both seeds and leaves are extensively consumed as functional foods given their nutritional composition and health-enhancing properties [28-30].

Within traditional medicinal systems, *Coriandrum sativum* is regarded as a significant purifying agent with the capacity to eliminate toxins and detrimental substances from the organism. This plant has been utilized for heavy metal elimination and blood purification through its chelating and antioxidant activities. Traditional practitioners frequently recommended coriander water or seed preparations to support renal function, promote urinary flow, and reduce symptoms related to urinary and kidney disorders. These ethnomedicinal applications indicate potential renal protective properties, which receive growing validation through contemporary pharmacological research. In summary, the widespread traditional and ethnomedicinal utilization of *Coriandrum sativum* across diverse cultures emphasizes its therapeutic importance as a versatile medicinal

plant with extensive pharmacological possibilities [31].

2. Phytochemical composition of *Coriandrum sativum*

Coriandrum sativum L. stands as an exceptionally important medicinal and aromatic plant owing to its remarkably abundant and varied phytochemical content, which substantially enhances its nutritional, pharmacological, and therapeutic characteristics. This botanical species harbors an extensive array of primary and secondary metabolites dispersed across its foliage, seeds, stems, roots, and essential oils. These bioactive constituents encompass volatile oils, phenolic substances, flavonoids, alkaloids, terpenoids, coumarins, tannins, sterols, fatty acids, vitamins, minerals, proteins, carbohydrates, and dietary fibers. The collaborative effects among these compounds serve as the fundamental basis for the extensive biological activities exhibited by Coriandrum sativum, encompassing antioxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, cardioprotective, neuroprotective, and nephroprotective functions. The phytochemical composition of coriander exhibits variation based on environmental factors, geographical location, genetic diversity, agricultural methods, harvest timing, and extraction procedures; nevertheless, the plant reliably maintains elevated levels of bioactive substances with considerable medicinal significance. Within the principal phytochemical categories found in Coriandrum sativum, essential oils and volatile components represent the most distinctive and pharmacologically significant elements. Coriander essential oil undergoes extraction primarily from seeds via steam distillation and consists chiefly of monoterpenes and oxygenated terpenoids. Linalool serves as the dominant volatile component and may constitute roughly 60–80% of the complete essential oil profile [32]. Linalool demonstrates exceptional antioxidant, anti-inflammatory, antimicrobial, anxiolytic, and cytoprotective characteristics and represents a primary contributor to coriander's therapeutic efficacy. Beyond linalool, coriander essential oil encompasses various additional volatile substances including geraniol, borneol, camphor, limonene, α-pinene, γ-terpinene, p-cymene, citronellol, terpineol, carvone, camphene, and myrcene. These volatile components impart the characteristic fragrance and taste of coriander while demonstrating substantial free radical neutralizing capacity. Essential oils serve a vital function in safeguarding biological membranes from oxidative stress-mediated lipid peroxidation and cellular deterioration, thus promoting tissue preservation and organ functionality. The antioxidant characteristics of volatile oils hold particular significance in renal pathologies since oxidative stress represents a primary mechanism driving nephrotoxicity and chronic kidney damage. Research studies have demonstrated that linalool-enriched coriander preparations can diminish oxidative markers, enhance mitochondrial stability, and augment endogenous antioxidant enzyme function, including superoxide dismutase, catalase, and glutathione peroxidase. These mechanisms provide substantial contributions to coriander's nephroprotective effects [33].

Coriandrum sativum demonstrates exceptional nutritional significance due to its abundant content of vitamins, minerals, proteins, carbohydrates, dietary fiber, and fatty acids. The fresh foliage exhibits particularly high concentrations of vitamins A, C, E, and K, along with folate and various B-complex vitamins such as riboflavin, niacin, and thiamine. Ascorbic acid serves as a powerful hydrophilic antioxidant that shields cells from oxidative injury through neutralization of

reactive oxygen species and restoration of other antioxidant compounds. Tocopherol operates as a fat-soluble antioxidant that maintains membrane stability and prevents lipid peroxidation. Retinol contributes significantly to immune modulation, epithelial maintenance, and visual function, whereas phylloquinone remains crucial for hemostasis and skeletal metabolism. Both the foliage and seeds of coriander provide vital minerals including calcium, potassium, magnesium, phosphorus, sodium, iron, manganese, copper, selenium, and zinc. These elements are fundamental for sustaining electrolyte homeostasis, enzyme function, cellular processes, and antioxidant mechanisms [34]. Potassium and magnesium demonstrate particular significance for cardiac and renal wellness through regulation of blood pressure, muscular activity, and fluid equilibrium. Iron facilitates hemoglobin production and oxygen delivery, while zinc and selenium participate in antioxidant enzyme function and immunological responses. Coriander seeds additionally provide considerable amounts of proteins, carbohydrates, dietary fiber, and fixed oils enriched with beneficial fatty acids including petroselinic acid, linoleic acid, oleic acid, palmitic acid, and stearic acid. Petroselinic acid represents a distinctive fatty acid component of coriander and various Apiaceae species, demonstrating potential anti-inflammatory and metabolic advantages. The dietary fiber content in coriander promotes gastrointestinal wellness and may assist in regulating glucose and lipid homeostasis. The comprehensive nutritional profile of coriander enhances its pharmacological characteristics and validates its application as a functional food with therapeutic potential [35]. Within the extensive array of phytochemicals present in *Coriandrum sativum*, various bioactive constituents have been particularly linked to renoprotective functions. Linalool represents one of the most significant nephroprotective components owing to its robust antioxidant and anti-inflammatory properties. Linalool demonstrates the capacity to diminish reactive oxygen species production, suppress inflammatory cascade pathways, maintain mitochondrial membrane integrity, and safeguard renal structures from chemical-induced damage. Quercetin and rutin similarly contribute significantly to renal protection through enhancement of antioxidant enzyme function, suppression of pro-inflammatory mediators, and inhibition of apoptotic mechanisms associated with nephrotoxicity. Chlorogenic acid and caffeic acid provide nephroprotective benefits via their radical scavenging capabilities and potential to minimize oxidative tissue damage. β-Sitosterol may assist in reducing inflammatory responses and oxidative stress within renal structures, while terpenoids and coumarins enhance cellular protective mechanisms and circulation. Furthermore, the cooperative effects among vitamins, minerals, flavonoids, and essential oils amplify the renoprotective effectiveness of coriander. These constituents work collectively to maintain renal structure, preserve glomerular function, minimize tubular deterioration, and optimize biochemical markers including serum creatinine, blood urea nitrogen, and electrolyte homeostasis. The occurrence of these multifunctional phytochemicals substantially validates the therapeutic capacity of *Coriandrum sativum* as a natural renoprotective compound. In summary, the phytochemical profile of coriander demonstrates its extraordinary medicinal value and establishes a scientific foundation for its traditional application in preventing and treating oxidative stress-associated conditions, including renal pathologies and nephrotoxicity [36].

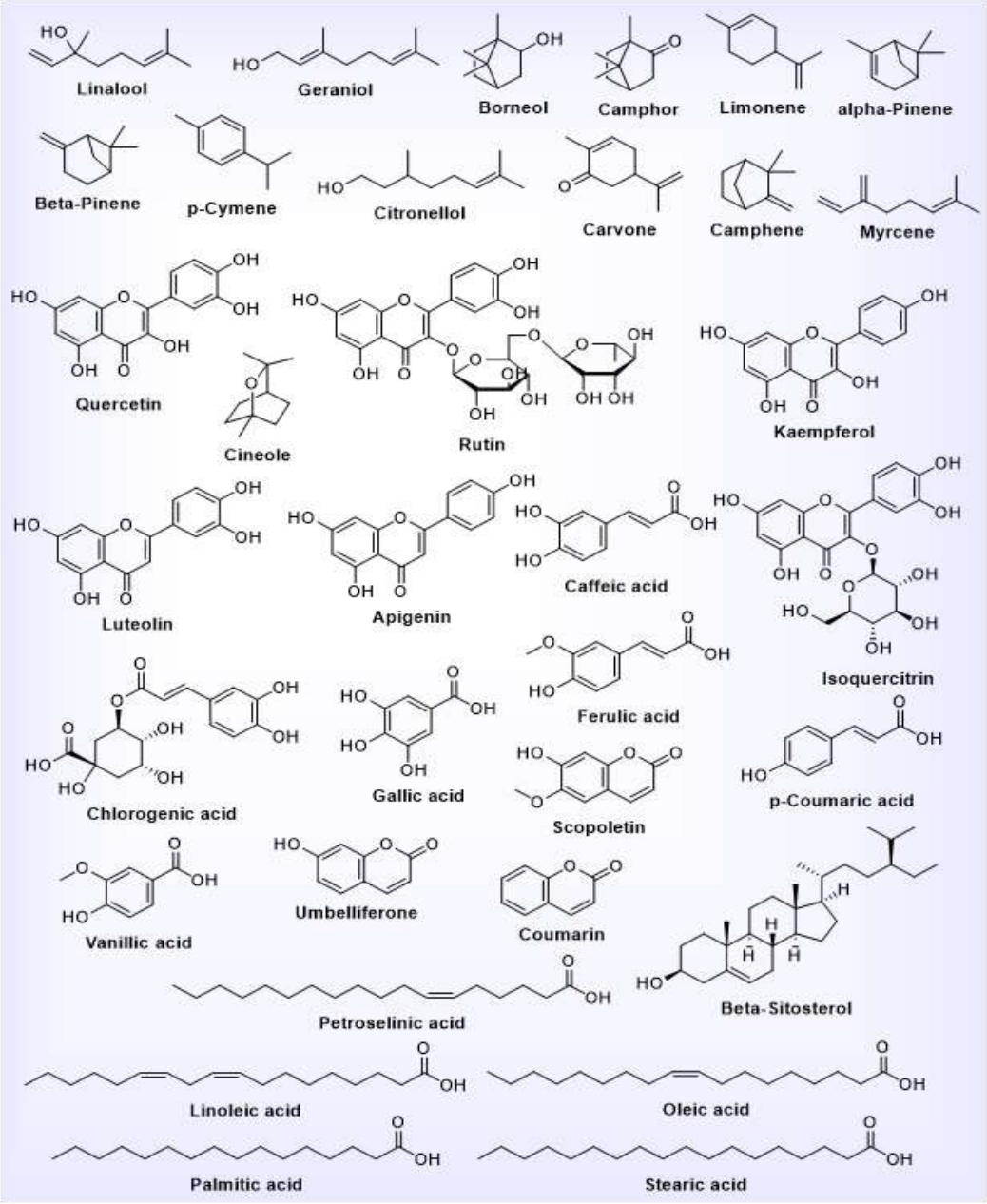


Fig.2: Phytochemistry of *Coriandrum sativum*

3. Pharmacological properties of *Coriandrum sativum*

Antioxidant activity

Coriandrum sativum demonstrates considerable antioxidative properties attributed to its constituent flavonoids, phenolic compounds, vitamins, and volatile oils including linalool, quercetin, rutin, caffeic acid, and chlorogenic acid. These phytochemically active substances efficiently neutralize reactive oxygen species (ROS), prevent lipid peroxidation processes, and safeguard cellular structures against oxidative harm. Research has revealed that coriander extracts promote the activity of intrinsic antioxidant enzymes such as superoxide dismutase, catalase, and glutathione peroxidase, thus preserving cellular oxidative equilibrium. The antioxidative capacity of coriander serves a crucial

function in mitigating oxidative stress-related pathologies including nephrotoxicity, diabetes mellitus, cardiovascular disorders, and hepatic damage [37].

Anti-inflammatory activity

The anti-inflammatory properties of *Coriandrum sativum* are primarily ascribed to its content of flavonoids, terpenoids, coumarins, and volatile oils. Extracts derived from coriander suppress the synthesis of inflammatory mediators including tumor necrosis factor-alpha (TNF-α), interleukins, cyclooxygenase enzymes, prostaglandins, and nitric oxide. Such mechanisms contribute to the mitigation of inflammation, tissue swelling, and cellular damage. Research investigations have established that coriander exhibits considerable protective benefits against persistent inflammatory disorders through the regulation of inflammatory signal transduction pathways and the attenuation of oxidative stress-induced inflammation [38].

Antidiabetic activity

Coriandrum sativum has exhibited encouraging antihyperglycemic effects across numerous experimental and clinical investigations. Extracts derived from coriander may contribute to the reduction of blood glucose concentrations through the promotion of insulin release, facilitation of glucose absorption, and enhancement of insulin responsiveness. The botanical species also modulates carbohydrate metabolic processes and mitigates oxidative damage linked to elevated glucose levels. Flavonoid and polyphenolic constituents found in coriander support the preservation of pancreatic β-cells and prevent glucose-mediated cellular injury. Furthermore, coriander may enhance lipid metabolism and minimize diabetic complications, such as diabetic nephropathy and cardiovascular impairment [39].

Antimicrobial activity

The volatile oils and bioactive compounds found in *Coriandrum sativum* demonstrate extensive antimicrobial efficacy against diverse bacterial, fungal, and microbial organisms. Linalool along with additional volatile constituents compromise microbial cellular membranes, suppress enzymatic functions in microorganisms, and disrupt pathogenic proliferation. Extracts derived from coriander have exhibited potency against numerous disease-causing microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, Salmonella species, and *Candida albicans*. These antimicrobial characteristics have led to the historical application of coriander in managing infections, digestive ailments, and food conservation practices [40].

Hepatoprotective activity

Coriandrum sativum demonstrates significant liver-protective properties through its ability to shield hepatic tissue from oxidative damage, chemical toxicity, and pharmaceutical-induced harm. The plant's antioxidant and anti-inflammatory bioactive compounds contribute to diminishing hepatic lipid peroxidation, maintaining membrane integrity, and enhancing liver enzyme profiles. Research investigations have demonstrated that coriander extracts can mitigate hepatic damage caused by toxic substances, ethanol, and medicinal compounds through the strengthening of antioxidant mechanisms and the inhibition of inflammatory pathways. The liver-protective characteristics of coriander may additionally provide secondary benefits to kidney function by decreasing overall oxidative burden and metabolic stress within the system [41].

Cardioprotective activity

The cardiac protective characteristics of *Coriandrum sativum* stem from its capacity to provide antioxidant, lipid-reducing, blood pressure-lowering, and anti-inflammatory benefits. Studies have demonstrated that coriander can decrease circulating cholesterol, triglyceride, and low-density lipoprotein concentrations while elevating high-density lipoprotein levels. The potassium content, flavonoid compounds, and volatile oils found in coriander may contribute to blood pressure modulation and enhanced vascular performance. Furthermore, coriander diminishes oxidative damage and inflammatory processes in cardiac tissues, consequently reducing atherosclerotic risk and heart muscle impairment. The cholesterol-reducing and vessel-relaxing mechanisms play a substantial role in promoting cardiovascular health protection [42].

Immunomodulatory and detoxifying effects

Coriandrum sativum demonstrates significant immune-regulating and purifying capabilities attributed to its abundant phytochemical constituents and antioxidant profile. The species strengthens immune responses through cytokine modulation and reinforcement of antioxidant protective systems. Additionally, coriander displays purifying actions by facilitating the removal of harmful substances and heavy metals from physiological systems. Research indicates that coriander may function as an endogenous chelating compound with the capacity to diminish toxic metal accumulation including lead, mercury, and cadmium. Its diuretic properties additionally contribute to purification processes by augmenting renal elimination of deleterious metabolites and toxic compounds. These immune-modulating and purifying characteristics prove especially valuable in mitigating oxidative stress-related tissue injury and preserving kidney function [43].

Nephroprotective potential of *Coriandrum sativum*

Coriandrum sativum L., commonly referred to as coriander or cilantro, has garnered significant scientific interest owing to its potential renal protective characteristics. The kidneys demonstrate heightened vulnerability to oxidative damage, toxic exposure, inflammatory processes, and metabolic dysfunction due to their fundamental roles in filtration, detoxification, and waste elimination. Contact with nephrotoxic medications, heavy metals, environmental contaminants, and chronic conditions including diabetes mellitus and hypertension may result in gradual renal damage and compromised kidney performance. Recently, medicinal plants exhibiting antioxidant and anti-inflammatory characteristics have gained prominence as alternative therapeutic options for preventing and treating renal pathologies. Within this group of plants, *Coriandrum sativum* has distinguished itself as a valuable natural renal protective agent through its abundant phytochemical content and extensive pharmacological effects. The renal protective capacity of *Coriandrum sativum* stems primarily from bioactive constituents including linalool, quercetin, rutin, chlorogenic acid, caffeic acid, flavonoids, phenolic acids, terpenoids, vitamins, and essential minerals. These phytochemicals exhibit potent antioxidant, anti-inflammatory, detoxifying, and cytoprotective properties that assist in safeguarding renal tissues from oxidative damage and toxic harm [44]. Oxidative damage serves a pivotal function in nephrotoxicity development since excessive reactive oxygen species (ROS) production can harm lipids, proteins, DNA, and cellular membranes throughout kidney structures. Coriander preparations have exhibited remarkable free radical neutralizing capacity and the potential to strengthen endogenous antioxidant defense

mechanisms including superoxide dismutase, catalase, and glutathione peroxidase. Through diminishing oxidative damage and lipid peroxidation, coriander supports the preservation of renal cellular structural and functional integrity. Inflammation represents an additional significant element in renal damage and kidney disease advancement. Sustained inflammatory reactions facilitate tissue fibrosis, cellular invasion, and tubular deterioration, consequently resulting in compromised renal performance. Research has revealed that *Coriandrum sativum* demonstrates considerable anti-inflammatory properties through inhibiting pro-inflammatory mediator synthesis including tumor necrosis factor-alpha (TNF-α), interleukins, prostaglandins, cyclooxygenase enzymes, and nitric oxide. These mechanisms assist in diminishing renal inflammation and protecting kidney structures from inflammatory injury. The anti-inflammatory properties of coriander prove especially advantageous in preventing medication-induced nephrotoxicity and chronic renal damage linked to oxidative stress and metabolic disturbances. Experimental investigations utilizing animal models have furnished considerable evidence concerning the renal protective properties of Coriandrum sativum. Different preparations of coriander seeds and foliage have exhibited protective efficacy against chemically induced renal injury from nephrotoxic substances including gentamicin, cisplatin, carbon tetrachloride, lead, cadmium, and additional toxic materials. Coriander extract administration in experimental subjects has correlated with notable enhancement in biochemical indicators of kidney performance, encompassing decreases in serum creatinine, blood urea nitrogen, uric acid, and electrolyte disturbances. Histopathological analyses have additionally shown that coriander therapy can diminish tubular necrosis, glomerular deterioration, inflammatory infiltration, and oxidative tissue damage in renal structures. These observations suggest that coriander provides both functional and structural protective benefits for the kidneys [45]. A significant mechanism contributing to the renal protective effects of *Coriandrum sativum* involves its capacity to regulate oxidative stress-related signaling cascades. The flavonoid and phenolic constituents found in coriander prevent lipid peroxidation and preserve mitochondrial integrity, thus averting apoptotic processes and cellular impairment in kidney tissues. Quercetin and rutin, identified as principal flavonoids in coriander, have undergone comprehensive investigation regarding their kidney-protective properties. These bioactive molecules augment antioxidant enzymatic function, attenuate inflammatory cytokine production, and block apoptotic cascades associated with renal toxicity. Chlorogenic acid and caffeic acid similarly provide renal protection through free radical scavenging and reduction of oxidative tissue damage [46]. The detoxification and metal-binding capabilities of *Coriandrum sativum* additionally strengthen its renal protective capacity. Heavy metals including lead, mercury, cadmium, and arsenic are recognized for their accumulation in kidney tissues, causing substantial oxidative harm and renal impairment. Coriander demonstrates inherent chelating properties that enable binding of toxic metals and promote their removal from the organism. This detoxification mechanism assists in diminishing metal-induced oxidative stress while safeguarding renal tissues from harmful accumulation. Additionally, coriander displays modest diuretic properties that enhance urinary elimination of toxins and metabolic byproducts, thus supporting kidney function and detoxification mechanisms. The glucose-lowering activity of *Coriandrum sativum* provides indirect renal protection. Diabetes mellitus represents a primary etiology of chronic kidney disease and diabetic nephropathy globally. Sustained hyperglycemia triggers oxidative stress,

glomerular enlargement, inflammation, and microvascular injury in kidney tissues. Research demonstrates that coriander extracts reduce blood glucose concentrations, enhance insulin responsiveness, and modulate lipid metabolism. Through glycemic control and management of associated metabolic disorders, coriander may prevent or retard diabetic nephropathy progression and diabetes-related renal complications [47-50]. Moreover, the nutritional elements in coriander, encompassing vitamins A, C, and E, alongside essential minerals including potassium, magnesium, calcium, zinc, and selenium, provide supplementary support for renal health maintenance. Vitamin C and vitamin E function as powerful antioxidants protecting kidney tissues from oxidative injury, while minerals support electrolyte homeostasis, enzymatic function, and cellular metabolism. Potassium and magnesium hold particular significance for maintaining physiological blood pressure and fluid equilibrium, both crucial for optimal kidney performance. In summary, *Coriandrum sativum* exhibits exceptional renal protective potential through its antioxidant, anti-inflammatory, antidiabetic, detoxifying, and metal-chelating characteristics. The combined effects of its bioactive phytochemicals provide protection for renal tissues against oxidative stress, inflammation, toxic exposure, and metabolic dysfunction. Experimental investigations have repeatedly demonstrated enhancement in renal function indicators and histopathological improvements following coriander administration. These results underscore the therapeutic importance of *Coriandrum sativum* as a valuable herbal remedy for preventing and treating nephrotoxicity and kidney diseases. Future pharmacological and clinical investigations may further validate its utility in nephrology and natural product-derived therapeutics [51-53].

Molecular mechanisms underlying nephroprotection

The renal protective properties of *Coriandrum sativum* operate through diverse molecular pathways encompassing oxidative stress marker regulation, inflammatory cascade inhibition, apoptotic pathway modulation, and strengthening of kidney cellular protective mechanisms. Oxidative stress represents a fundamental driver of kidney damage and toxicity, as elevated reactive oxygen species production results in membrane lipid degradation, protein modification, mitochondrial impairment, genetic material harm, and tissue deterioration in kidney structures [54]. *Coriandrum sativum* possesses rich concentrations of antioxidant bioactive compounds including linalool, quercetin, rutin, chlorogenic acid, caffeic acid, flavonoids, and phenolic substances that are essential for controlling oxidative stress indicators and preserving cellular redox balance. Research investigations have shown that coriander preparations markedly decrease oxidative damage markers like malondialdehyde, nitric oxide, and free radicals while concurrently boosting intrinsic antioxidant protective enzymes such as superoxide dismutase, catalase, glutathione peroxidase, and reduced glutathione. These protective enzymes safeguard kidney cells through free radical scavenging and prevention of oxidative harm to cell membranes and mitochondrial components. The control of oxidative stress indicators through coriander significantly contributes to maintaining glomerular and tubular structural integrity and minimizing toxic kidney damage caused by pharmaceuticals, toxic metals, and metabolic disturbances [55]. Beyond its antioxidant properties, *Coriandrum sativum* demonstrates substantial anti-inflammatory action via cytokine regulation and inflammatory cascade modification associated with kidney damage. Inflammation constitutes a primary factor in kidney disease

advancement as inflammatory mediator activation facilitates cellular invasion, scarring, blood vessel dysfunction, and tissue breakdown [56]. Coriander bioactive compounds reduce the synthesis and secretion of pro-inflammatory cytokines including tumor necrosis factor-alpha, interleukin-1 beta, interleukin-6, and additional inflammatory factors linked to kidney toxicity. Additionally, coriander preparations block the activation of key inflammatory signaling cascades such as nuclear factor-kappa B, cyclooxygenase-2, inducible nitric oxide synthase, and mitogen-activated protein kinase networks. Suppression of these cascades diminishes inflammatory cell invasion, oxidative damage-related tissue injury, and scarring in kidney tissues. The anti-inflammatory properties of coriander prove especially valuable in progressive kidney disorders, diabetic kidney disease, and medication-induced kidney toxicity, where ongoing inflammation hastens kidney impairment and structural damage. Through inflammatory response reduction, coriander assists in maintaining kidney structure and operational effectiveness [57]. A significant molecular pathway through which *Coriandrum sativum* confers renal protection involves the modulation of cell death and survival mechanisms. Programmed cell death represents a pivotal pathological process in kidney damage triggered by oxidative stress, inflammatory responses, ischemic conditions, and nephrotoxic substances. Elevated reactive oxygen species generation and mitochondrial impairment initiate cell death signaling pathways that lead to tubular epithelial cell destruction and nephron depletion. Bioactive compounds from coriander have demonstrated the ability to inhibit programmed cell death through alteration of death and survival protein expression. Research findings indicate that coriander preparations reduce pro-death factors including Bax, caspase-3, and cytochrome c translocation while concurrently promoting survival proteins such as Bcl-2. This equilibrium between death and survival signaling maintains cellular viability and prevents kidney tissue deterioration. Flavonoid compounds including quercetin and rutin play crucial roles in preserving mitochondrial membrane stability, minimizing genetic material fragmentation, and blocking caspase-mediated death pathway activation. Via these processes, coriander shields kidney cells from oxidative damage-induced death and maintains physiological renal function [58].

Coriandrum sativum additionally provides kidney protection by regulating renal enzymatic activity and strengthening cellular protective mechanisms. Renal tissues possess multiple enzymatic and non-enzymatic protective systems responsible for detoxification processes and cellular equilibrium maintenance. Coriander bioactive constituents influence the function of kidney enzymes participating in oxidative processes, detoxification reactions, and mineral balance regulation. Research has demonstrated that coriander administration enhances kidney biochemical markers including serum creatinine, blood urea nitrogen, uric acid, and electrolyte concentrations by maintaining nephron integrity and filtration efficiency. Additionally, coriander may augment phase II detoxification enzymes and cellular antioxidant networks that shield kidney tissues from harmful metabolites and chemical damage. The volatile oils, phenolic substances, vitamins, and trace elements found in coriander facilitate membrane preservation, mitochondrial function, and energy production in kidney cells [59]. Coriander also demonstrates metal-binding and detoxification capabilities that enhance the removal of harmful heavy metals including lead, cadmium, and mercury, thus preventing their buildup and oxidative injury in renal tissues. Moreover, its gentle diuretic action encourages urinary elimination of toxins and waste materials,

supporting enhanced renal clearance and protection against kidney toxicity. Together, these molecular pathways illustrate that *Coriandrum sativum* provides kidney protection through a comprehensive strategy encompassing antioxidant protection, anti-inflammatory effects, cell death prevention, renal enzyme regulation, and cellular detoxification enhancement. These protective mechanisms establish a robust scientific foundation for coriander's therapeutic value in preventing and treating kidney diseases and nephrotoxic disorders [60].

FUTURE PERSPECTIVES

The accumulating research evidence concerning the kidney-protective properties of *Coriandrum sativum* underscores its potential significance in herbal medicine and renal care. While multiple experimental investigations have revealed notable antioxidant, anti-inflammatory, antidiabetic, detoxification, and kidney-protective properties of coriander, additional comprehensive research remains essential to determine its clinical utility and therapeutic value in human subjects. Subsequent studies should emphasize thorough pharmacological assessment of specific bioactive components including linalool, quercetin, rutin, chlorogenic acid, and additional phenolic compounds responsible for kidney protection. Elucidating the exact molecular mechanisms and cellular pathways underlying kidney protection could create opportunities for developing innovative plant-derived therapeutic compounds. A primary future direction involves implementing extensive clinical investigations to assess the safety profile, effectiveness, dose optimization, and sustained therapeutic advantages of *Coriandrum sativum* in individuals with both acute and chronic renal conditions. The majority of existing research remains confined to laboratory studies and animal experiments; consequently, human clinical validation becomes crucial prior to incorporating coriander into evidence-supported kidney-protective treatment protocols. Establishing uniform extraction procedures, phytochemical characterization, and formulation design is equally necessary to guarantee consistency, quality assurance, and reliable therapeutic results. Additionally, future studies may investigate potential synergistic interactions between coriander and established kidney-protective medications to minimize adverse effects and enhance treatment effectiveness. Nanotechnology-enhanced herbal preparations, bioavailability improvement strategies, and precision delivery systems utilizing coriander-derived phytochemicals constitute encouraging research domains. Moreover, the metal-binding and detoxification capabilities of coriander warrant exploration for treating heavy metal-induced kidney damage and environmental toxin exposure. In summary, *Coriandrum sativum* demonstrates considerable promise as a safe, cost-effective, and versatile herbal therapeutic for kidney protection, and ongoing scientific investigation may enable its incorporation into contemporary treatment approaches for renal diseases.

CONCLUSION

Coriandrum sativum L., widely recognized as coriander, represents a therapeutically valuable botanical species exhibiting extensive pharmacological and medicinal characteristics. This comprehensive analysis emphasizes the notable renal protective capabilities of *Coriandrum sativum* and its applicability in preventing and treating kidney-related pathologies. The species contains abundant diverse bioactive chemical constituents such as linalool, quercetin, rutin, chlorogenic acid, caffeic acid, flavonoids, terpenoids, coumarins, vitamins,

and vital minerals, which synergistically facilitate its antioxidant, anti-inflammatory, antidiabetic, antimicrobial, hepatoprotective, cardioprotective, immunomodulatory, and detoxification functions. These therapeutic characteristics are instrumental in safeguarding renal structures from oxidative damage, inflammatory responses, programmed cell death, and harmful effects caused by pharmaceuticals, toxic metals, and metabolic disturbances. Research investigations have established that coriander preparations markedly enhance kidney biochemical indicators, diminish lipid oxidation, strengthen intrinsic antioxidant protective mechanisms, and maintain physiological renal tissue organization. The capacity of *Coriandrum sativum* to control oxidative stress indicators, inhibit pro-inflammatory mediators, influence cell death pathways, and reinforce cellular protection systems establishes a robust scientific foundation for its kidney-protective effects. Furthermore, its purification and metal-binding characteristics amplify its therapeutic importance in preventing kidney toxicity and sustaining renal function. Although encouraging laboratory results exist, additional investigation is needed to develop standardized preparations, treatment protocols, absorption and distribution patterns, and therapeutic effectiveness in human populations. Extensive clinical studies and sophisticated molecular research are essential to confirm its healing potential and guarantee safety for prolonged administration. Nonetheless, current scientific data substantially validates the conventional medicinal application of *Coriandrum sativum* and suggests its potential as a secure, cost-effective, and efficient natural kidney-protective compound. Ongoing investigation of coriander and its active components may substantially advance the creation of innovative botanical treatments for renal diseases and kidney toxicity.

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