Cumin (*Cuminum cyminum* L.): A Hidden Gem in Functional Food

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Abstract

Cuminum cyminum is an important food and spice that has been utilized by people globally. It can be utilized as a functional food for disease prevention. Cumin is an herbaceous plant that belongs to the family Apiaceae and has a significant nutritional and phytochemical composition, as well as its unique aroma and flavor. In this chapter, we explore the medicinal properties of cumin along with its traditional uses and health benefits. The seeds contain essential oils, flavonoids, phenolic compounds, and all the necessary nutrients like iron, calcium, magnesium, fiber, etc. Cumin possesses antioxidant, anti-inflammatory, and antimicrobial properties in addition to its digestive and diabetogenic properties, suggesting that it may be a promising choice for the diet in managing and preventing various chronic illnesses. These medicinal properties are due to the presence of various phytochemicals present in it. The chapter balances the use of cumin as a holistic food ingredient with consideration for its multiple health benefits, drawing on both historical and contemporary research.

Keywords: Cumin, Functional food, Medicinal plants, Phytochemicals, Anti-Inflammatory, Anti-diabetic, Antioxidant, Antimicrobial activity

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Introduction

Plants are necessary for life and provide the foundation for medical activities. Many significant medications that are used today are derived from ancient medicinal herbs (Aslam et al., 2016). *Cuminum cyminum*, often known as cumin, has been used for centuries as a spice and is profoundly ingrained in culinary traditions across many nations. It was used by ancient civilizations such as the Greeks, Romans, and Egyptians, who recognized its culinary and therapeutic benefits (Mishra & Shahi, 2023). It is an herbaceous annual plant that belongs to the family Apiaceae. It is widespread in North Africa and has expanded widely from South Asia to Central Asia. It is the oldest cultivated medical food herb in Asia, Africa, and Europe (Gohari & Saeidnia, 2011).

Functional foods are not supplementary food products, pharmaceuticals, or antibiotics; instead, they constitute a fundamental element of a standard. Fruits, vegetables, bread, dairy, cereals, and meat products are all functional foods. Functional foods boost human health and can considerably lower disease risk in the host body (Ghazanfar et al., 2022). Most of cumin's properties have been related to its bioactive ingredients, which include phenols, flavonoids, and terpenes (Mughal, 2022). Cumin is known for its antioxidant, anti-inflammatory, and antidiabetic characteristics, making it an important functional food with health benefits (Ghods et al., 2024).

Cumin seeds may contain a broad variety of phytochemicals, including alkaloids, coumarins, anthraquinones, flavonoids, proteins, glucosides, resins, saponins, steroids, and tannins. Linoleic acid, one of the unsaturated fatty acids abundant in umin oleoresin, has been linked to improved health. Cumin possesses various useful properties, such as antibacterial, antidiabetic, anticancer, analgesic, anti-inflammatory, insecticidal, antiplatelet aggregation, hypotensive, bronchodilator, immunological, antiamylodogenic, and anti-osteoporotic properties (Vinod et al., 2022).

This chapter explores the botanical characteristics, phytochemical constituents, and health benefits of cumin. Additionally, it addresses its application in functional foods, its role in disease prevention, and the prospective developments in cumin-based nutraceuticals.

Morphology and Geographical Distribution

Cumin is classified as an herbaceous species, with a branching stem and elongated, deeply divided green leaves. It reaches a height of 30-40 cm, and the inflorescence consists of very small flowers pale pinkish or white in color, in the shape of an umbel (Vinod et al., 2022). The seed is long and measures around 5mm with a light yellowish-brown color. Leaves of cumin contain 6-10 cm with bipinnate

and pinnate threadlike leaflets. It occurs horizontally, fusiform or ovoid achene, measuring around 4-5 mm in length and with one seed (Meena et al., 2024).

Cumin is grown commercially in Egypt and Tunisia, where it is the ingredient of the native diet (Akbar, 2020a). Cumin is among the most popular spices and medicines in India and Pakistan (Singh et al., 2021). It is largely grown in the Indian states of Punjab and Uttar Pradesh and Pakistan states of Punjab, KPK, Kashmir, and Balochistan. Countries in the east Mediterranean also grow cumin, with the optimal climatic condition for growth. Cumin has also been grown in China and Indonesia and on the increase globally (Akbar, 2020a).

Phytochemical Composition of Cumin

Cumin seeds have a high percentage of alkaloids, flavonoids, saponins, and tannins, which are responsible for conferring antioxidant and anti-inflammatory activities. *Cuminum cyminum* essential oil is endowed with phytochemical and antibacterial activity against gram-positive and gram-negative microbes (Vinod et al., 2022). Cumin oil contains active chemicals such as cuminal (35%), γ-terpinene (32%), α-terpinene-al (7%), γ-terpinene (4.4%), daucene (4.2%), and trans-caryophyllene (5.4%), as well as trace components such as myrcene (0.12%), 1-8 cineole, and γ-terpinene-7-al (Iram & Edwin, 2022). 31 bioactive compounds from *Cuminum cyminum* have been isolated, and these have demonstrated antioxidant activities (Abu Ahmed et al., 2022a). Cumin seeds have high contents of iron, magnesium, calcium, manganese, and phosphorus as shown in Figure1. Vitamins present they contain thiamine, riboflavin, niacin, vitamins A, C, E, K, and B6 (Meena et al., 2024).

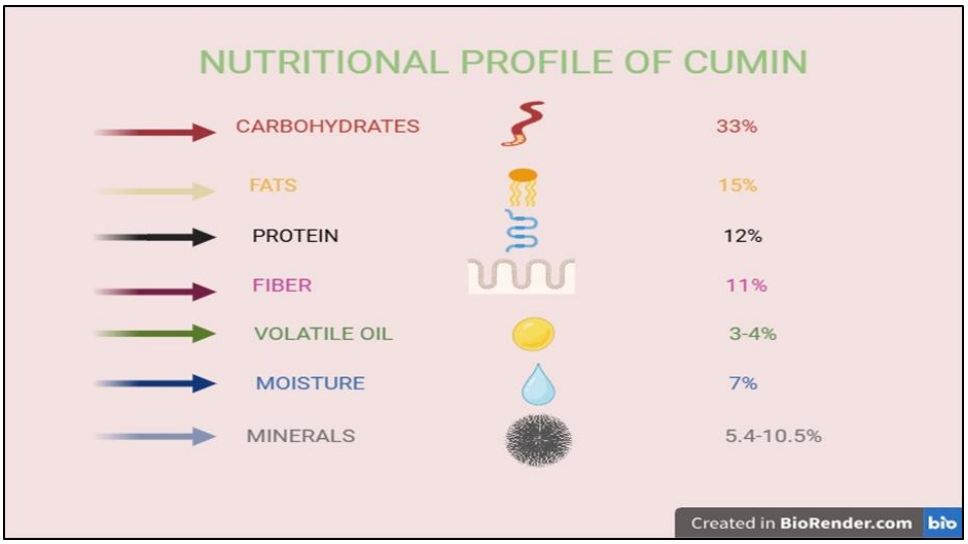

Fig. 1: Nutritional profile of *Cuminum cuminum*

Nutritional and Medicinal Properties

Nutritional Profile

Cumin seeds contain phytochemicals such as antioxidants and carminatives. The seeds contain fiber content that is also useful. Significant chemicals of cumin like cuminaldehyde, pyrazines, 2-methoxy-3-secbutylpyrazine, 2-ethoxy-3-isopropylpyrazine, and 2-methoxy-3 methylpyrazine have been used for different purposes. Active components of cumin have been reported to improve intestinal motility and promote digestion (Singh et al., 2017). Flavonoids and phenolic antioxidants abound in the seeds, as well. Some of them are vitamins such as E, B6, niacin, and riboflavin, as well. Flavonoid phenolic antioxidants also abound in cumin seeds in adequate quantities. Experimental studies have proven that the seeds possess muscle relaxant and anxiolytic activities. The ability to reduce locomotor activity was also determined (Jabeen et al., 2017). Cumin seeds are good source of carbohydrate (33%), fat (15%), protein (10%), starch (11%), fiber (20%), total ash (10%), moisture (7%), volatile oil (3-4%), and minerals (5.4-10.5%) (Singh et al. 2017). Cumin seeds comprise a wide range of essential oils, both saturated and unsaturated, such as essential oil compounds like omega-3, petroselinic acid, oleic acid, and other chemicals. The characteristic flavor of cumin seeds results from these essential oil constituents. Volatile compounds such as cuminaldehyde, p-cymene, cuminol, and -pinene are among the chemicals listed (Zaharan et al, 2021).

Medicinal Properties

Antibacterial properties

Cuminum cyminum essential oil (CcEO) is a plant-based antibacterial that is both a bacteriostatic and bactericidal agent. Sub-minimum inhibitory concentrations (sub-MIC) of CcEO have proven effective against major virulence factors such as quorum sensing (QS), polysaccharide intercellular adhesion (PIA), and the NorA efflux pump. All these facts highlight the oil as an antivirulence agent (Sharifi et al., 2021). In 2024, an experiment employing methanolic extracts of cumin exhibited antibacterial potential against *E. coli*, *Bacillus subtilis*, *Bacillus cereus*, and *Staphylococcus aureus* under different pH and temperature levels with maximum inhibition occurring at acidic pH and elevated temperatures (Singh et al., 2017).

Cumin oil includes 17 components, the most prominent of which are cumin aldehyde and γ-terpinene. It had excellent antibacterial activity as shown in Figure 2, particularly against germs from unsuccessful root canal operations. However, cumin oil outperformed co-trimoxazole in treating *E. faecalis*. All therapies completely inhibited bacterial growth within 24 hours. Overall, cumin oil is an effective and safe remedy for tooth diseases (Abbaszadegan et al., 2016).

In one of the cumin oil was tested against six bacterial strains, two gram-negative (*Escherichia coli* and *Salmonella typhi*) and four gram-positive (*Proteus vulgaris, Klebsiella pneumoniae, Enterococcus faecalis, and Staphylococcus aureus*). The findings showed that cumin oil exhibited antibacterial activity against both gram-positive and gram-negative bacteria, slowing the growth and activity of species such as *Streptococci* and *Salmonella*, so its use as a natural antimicrobial agent could be applicable in the pharmaceutical and food sectors (Belal et al., 2017). Alginate nanoparticles loaded with *Cuminum cyminum* essential oil exhibited potent antibacterial effects against *Escherichia coli, Pseudomonas aeruginosa,* and *Staphylococcus aureus*. The study emphasized the importance of cumin-based nanoparticles as a potential drug delivery mechanism (Osanloo et al., 2024).

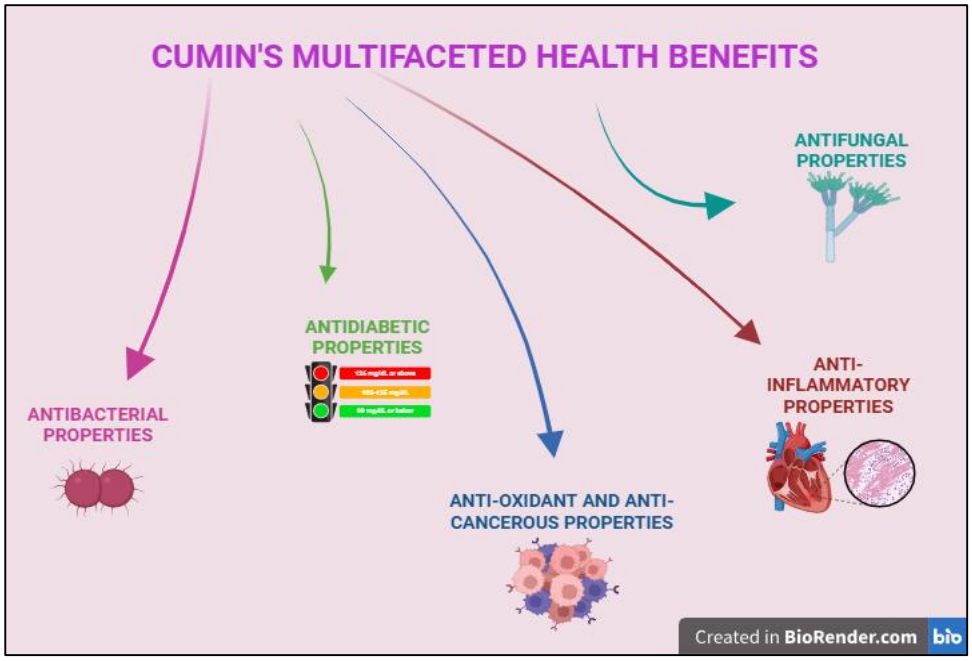

Fig. 2: Health benefits of *Cuminum cyminum*

Antifungal Properties

CcEO contains α-terpinene-7-al (33.48%), n-dodecane (25.54%), and cumin aldehyde (14.56%). Through the disc diffusion method, these components demonstrated significant antifungal activity as shown in Figure 2, against *Candida albicans,* suggesting their potential as natural antimicrobial agents (Ghafari et al., 2014). The antifungal activities of various compounds found in cumin's essential oil, including trans dihydrocarvone, terpinene, and p-cymene. On the other hand, extracts obtained through methanol, hydroalcoholic solutions, and aqueous methods demonstrated decreased effectiveness against fungi, suggesting their potential use in treating bacterial infections (Ali et al., 2014). The main components of CEO, such as cuminaldehyde (44.53%), p-cymene (12.14%), β-pinene (10.47%), and γ-terpinene (8.40%), had obvious in vitro antifungal activity against pathogenic fungi related to *P. notoginseng*. Additionally, cuminaldehyde and CcEO showed the ability to increase cell permeability and reduce cell membrane integrity (Huo et al., 2021).

Antioxidant Activity

The antioxidant compounds of cumin seeds exhibited superior properties with strong reducing capacity and short EC50 value (0.74 mg/mL). The basic component called cinnamaldehyde showed maximum antioxidant reactions (Einafshar et al., 2012). In one of the studies, it was demonstrated that the antioxidant potential of cumin is very high, as it is due to the existence of numerous antioxidant components in its essential oil. Moreover, the free radical scavenging activities of non-volatile cumin extracts are excellent. Notably, methanol extracts have higher antioxidant activity than n-hexane extracts. In addition, there is a positive correlation between antioxidant activity and phenolic content in nonvolatile extracts. These results suggest that cumin can be a potential source from which natural antioxidants and flavoring compounds for various food products can be derived (Nadeem & Riaz, 2012).

Another research indicated that cumin tincture-derived nanoemulsion exhibited enhanced antioxidant potential at 31.2 and 14.2 µg/mL. The strong free radical scavenging activity of the cumin-derived nanoemulsions had lowered oxidative stress. These kinds of nanoemulsions are suitable as natural biofunctional agents because of their strong antioxidant potential (Asgari et al., 2021). In the same manner, other research showed that the chloroform extract of cumin produced a strong antioxidant activity at different concentrations. This finding suggests that it might be used as a natural antioxidant agent. The results can be for possible utilization in the food, pharmaceutical, and dietary supplement industries (Abu Ahmed et al., 2022; Ghannay et al., 2022; Mohammed et al., 2024).

Anti-inflammatory Role

`In diabetic rats, crude alcohol extract of cumin essential oil reduced oxidative stress and swelling. The extract had many phenolic and flavonoid compounds. It had very powerful action against free radicals and increased blood fat concentration. This means cumin might act as a natural agent to lower blood sugar, boost insulin, and ease swelling linked to diabetes (Mohamed et al., 2018). Nitrogen-containing flavonoids

of cumin lower the production of nitric oxide and reduce key inflammation signals like inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2). Cumin's anti-inflammatory powers come from how it affects cell pathways NF-κB and MAPK that control inflammation (Kang et al., 2019). Polysaccharides from cumin can start immune responses by changing NF-κB and MAPK signalling pathways. These bioactive compounds may help control the immune system, causing both higher and lower levels of inflammation. This might boost usual treatments for swelling and inflammation (Tabarsa et al., 2020). Cumin seeds possess immunodulatory properties and may lower the inflammation within the body. One of the studies showed that cumin extract helps reduce swelling and oxidative stress in people with metabolic syndrome (Jannat, 2023).

Antidiabetic role

Cumin shows strong benefits for people with diabetes. It lowers blood sugar, helps with high sugar levels, and boosts metabolism in diabetic cases. These good effects might come from stopping the work of certain enzymes called aldose reductase and alpha-glucosidase (Kumar et al., 2017). Cumin helps lower blood sugar and boosts insulin use. This shows cumin might serve as a remedy for regulating blood glucose levels. The strength of the evidence supporting its benefits varies, with moderate support for certain biomarkers and weaker support for others, indicating that cumin may serve as a beneficial adjunct in the treatment of diabetes (Tavakoli-Rouzbehani et al., 2021). Cumin seeds were studied using different methods like HPLC, UV-Vis, FTIR, NMR, and ESI MS. Seven useful compounds were found: α-pinene, β-pinene, Δ3-carene, ρ-cymene, α-terpineol, cuminaldehyde, and linalool. Docking models showed their role in controlling key enzymes of sugar that are used in the body. These results offer proof for using cumin in managing diabetes and related issues (Lakshmanan et al., 2023).

Cumin helps lower blood sugar. It supports cognitive improvement in individuals with diabetes. A higher dose lowered AChE in the brain, which helped make thinking better. The study says cumin might help slow down the brain functions caused by diabetes due to its blood sugar control and anti-aging powers. Still, more studies are needed to fully understand its healing benefits (Kumar et al., 2024). Cumin helps with diabetes by making cells more responsive to insulin. It also lowers blood sugar levels. When cumin is taken with black seed (NS-CC), it reduces HbA1C and fasting blood sugar a lot more than a fake pill (placebo) (Ghods et al., 2024).

Anti-cancerous Properties

A diet with cumin seeds cuts down the number of stomach and cervical tumors. Cumin is able to control detox enzymes in two phases. It also boosts antioxidant defenses, like superoxide dismutase, catalase, and glutathione levels, and lessens lipid peroxidation. These results show cumin fights cancer by influencing how the body handles foreign compounds, boosting antioxidants, and reducing damage from oxidation. Therefore, cumin is a promising natural way to prevent cancer (Gagandeep et al., 2003). Cumin seed extract works as a natural stabilizer and reducer in making silver nanoparticles (AgNPs). Tests like UV-Vis, XRD, EDS, SEM, and FTIR showed the efficient production of bio-made AgNPs. These Bio-AgNPs exhibited intense anticancer activity against two human breast cancer cell lines (MCF-7 and AU565), with metastatic AU565 cells being the most potent. In addition, bio-AgNPs were less toxic than chemically synthesized AgNPs, thus a safer option. This indicates the potential of cumin-based green nanotechnology to achieve safe and efficient anti-cancer medications (Dinparvar et al., 2020).

Cumin seed extracts, and particularly the hexane extract, exhibit significant anticancer activities, such as induction of apoptosis, inhibition of the cell cycle in the S phase, and inhibition of colony formation and cell migration in MG63 cells. The extract also shows high bactericidal activity against drug-resistant bacteria. Gas chromatography has been employed in a study to isolate major bioactive compounds that induce such activities and show the potential of cumin as a natural anticancer drug (Gagandeep et al., 2003).

Gastro-protective Role

The bioactive compounds and essential oils found in cumin, including terpenes and flavonoids, are thought to be particularly important in conveying the gastro-protective action of cumin by reducing oxidative stress and inflammation within the gastrointestinal tract (Akbar, 2020). Haque and Ansari (2018) conducted a clinical trial on Wistar rats and administered cumin and its major constituents to the rats after they were fed a high-fat diet (HFD) to cause obesity. Body weight, liver weight, lipid status, glucose, insulin, leptin, weight of visceral fat pad, alanine aminotransferase, and aspartate aminotransferase levels all decreased significantly after cumin supplement intake, indicating that it can potentially have anti-obesity effects. Historically, cumin was applied in the treatment of inflammatory and neurological disorders and gastrointestinal disorders like gastritis, diarrhea, and dyspepsia. It has also been connected to preventing cancer. Additionally, it is used to treat diabetes and toothaches (Singh et al., 2017).

Cumin contains a substance called thymol, which promotes the stomach and digestive tracts to produce the proteins, bile, and acids needed for food processing. Because of its carminative qualities, cumin stimulates appetite and digestion while lowering gas. Its high content of salt, magnesium, and essential oils facilitates digestion and eases gastrointestinal distress (Mishra & Shahi, 2023). Cumin is also composed of advantageous compounds, including thymoquinone and cuminaldehyde, which contribute to digestive health. The consumption of cumin has been shown to mitigate gastrointestinal symptoms, such as bloating and flatulence, in individuals experiencing dyspepsia (Ahmed, 2024).

Nephroprotective Role

It was found that cumin possesses uroprotective properties by suppressing the CYP-induced interstitial cystitis by cutting down the oxidative stress, downregulating the expression of inflammatory cytokines, and inhibiting the bladder overactivity (Singh et al., 2017). Through the interaction of proteins 2I3Y and 1TNF with a variety of ligands, their antioxidant and anti-inflammatory properties were identified. Any hydrogen bonds, the electrostatic forces, as well as hydrophobic interactions between the seeds imply that they have substantial antioxidant and anti-inflammatory potential, making them an excellent resource for a multitude of applications (Anjum et al., 2023).

The extract from the seeds of cumin was synthesized through the maceration method, which is an old method used to treat urolithiasis. For *in vitro* anti-urolithiatic efficacy evaluation, the titrimetric method was used, and Cystone was taken as a benchmark pharmaceutical agent. It showed a much greater extraction rate of calcium oxalate stones than Cystone. It showed efficacy in nucleation at a concentration of 10

mg/ml, with a maximum inhibition of 41.5 %, which increased to 400 µg/mg. This investigation provides preliminary evidence indicating that cumin possesses anti-urolithiatic properties (Farooqui & Kudsi, 2024).

Table 1: Mechanism of action and potential health benefits of cumin

Medicinal properties	Bioactive compounds	Mechanism of action	Potential health benefits	References
Anti-bacterial	cuminic aldehyde, α, β-dihydroxyethylbenzene, 2-caren-10-al, γ-terpinene, and β-pinene, α-pinene	The cumin EO can penetrate into the cytoplasmic membrane, pore formation and voltage-gated channels are activated, leakage of essential cellular components and cell death happen	Bacteriostatic and bactericidal properties of the cumin EO were evaluated against *S. aureus* bacteria, microbial flora of the teeth, antiseptic, analgesic, anti-inflammatory, and anti-bactericidal	(Belal et al., 2017; Sharifi et al., 2021; Osanloo et al., 2024; Zubair et al., 2024)
Anti-fungal	γ-terpinene, γ-terpinene-7-al, 9-epi-caryophyllene,	Destroying the cell walls and proteins, interfering with membrane enzymes and affecting DNA and RNA replication. Example is *Fusarium oxysporum*	High antimicrobial activity against *Candida albicans* and *Escherchia coli*. Strong inhibitory effect on fungal growth.	(Ali et al., 2014; Ghafari et al., 2014; Huo et al., 2021)
Antioxidant	Cumin aldehyde, α-terpinene-7-al, p-cymene, limonene (4.40%), trans-dihydrocarvone, terpinene	Capable of scavenging hydroxyl, peroxy, and DPPH free radicals and thus inhibits radical-mediated lipid peroxidation	Good inhibition properties against the free radicals, lowering oxidative stress	Einafshar et al., 2012; Nadeem & Riaz, 2012; Asgari et al., 2021)
Anti -inflammatory	P-cymene, α-phellandrene, p-menth-2-en-7-ol, cuminaldehyde, p-cymene, β-pinene, and γ-terpinene.	The modulation of nuclear factor kappa B (NF-κB) and mitogen-activated protein kinase (MAPK) signaling pathways	Reduce inflammation and reduce symptoms of conditions such as irritable bowel syndrome (IBS), diabetes, cardiovascular disease, and Alzheimer's disease.	(Mohamed et al., 2018; Kang et al., 2019; Jannat, 2023)
Anti-diabetic	α-pinene, β-pinene, ρ-cymene, α-terpineol, cuminaldehyde, and linalool	Inhibition of aldose reductase and alpha-glucosidase enzymes, and modulation of carbohydrate metabolism enzymes.	Lowers blood glucose levels, enhances insulin sensitivity	(Kumar et al., 2017; Tavakoli-Rouzbehani et al., 2021; Lakshmanan et al., 2023; Kumar et al., 2024).
Anti-cancerous	Cumin aldehyde, terpenes, flavonoids, and phenolic acids	Induces apoptosis, arrests cell cycle in S phase, regulates phase one and two detoxifying enzymes	Inhibits cell proliferation, decreases oxidative damage	(Dinparvar et al., 2020; Chandrasekaran et al., 2023).
Gastroprotective	Cinnamaldehyde, thymol, thymoquinone, terpenes, flavonoids, magnesium, sodium	Stimulates saliva, bile, and digestive enzyme secretion	Relieves indigestion, bloating, and gas; helps manage obesity	(Ansari, 2018; Mishra & Shahi, 2023; Ahmed, 2024).
Cardio-protective	Cuminaldehyde	Inhibits HMG-CoA reductase, stimulates reverse cholesterol transport, reduces phospholipase activity,	Lowers cholesterol, LDL, and triglycerides; improves lipid profile and dyslipidemia – induces cardiovascular diseases	(Chouhan & Purohit, 2018; Chouhan et al., 2021).
Nephron protective	-	Various ligands (interacting with proteins 2I3Y and 1TNF), inhibit calcium oxalate stone formation and enhance stone dissolution	Protects against urolithiasis; reduces bladder dysfunction; supports kidney health	(Anjum et al., 2023; Farooqui & kudsi, 2024).
Hepato protective	Flavonoids, polyphenols, and cumin oil	Restores liver enzymes (ALT, AST)	Protects the liver from acetaminophen, dibutyl phthalate, high-fat diets, and diabetes-related damage	(Ebada, 2018; Miah et al., 2021; Alfahdawi et al., 2023; Mozaffarinia et al., 2023).
Neuroprotective	Cuminaldehyde	Inhibits α-synuclein fibrillation, prevents protein aggregation, reduces neuroinflammation, enhances cognitive functions	Protects against Parkinson's, improves memory and learning, and prevents age-related cognitive decline	Morshedi et al., 2015; Omari et al., 2021.

Neuroprotective role of Cumin

Another active ingredient of cumin (*Cuminum cyminum*) is cumin aldehyde, which is neuroprotective with strong inhibition of α-synuclein (α-SN) fibrillation, a crucial mechanism relating to neurodegeneration conditions like Parkinson's. It stops elongation and switches the structure of monomeric proteins so that it reduces the amount of amine groups available to aggregate by fibril elongation. Additionally, cuminaldehyde did not induce any toxicity on PC12 cells pre-incubated with α-SN. Appropriately, baicalein only suppressed fibrillation on a short term basis, while cuminaldehyde showed long term inhibition, making it a possible neuroprotective drug for the treatment of protein aggregation based illnesses. Lastly, these results are consistent with importance of cumin essential oil in neuroprotection and cognitive wellness (Morshedi et al., 2015; Omari et al., 2021). Some of the other properties with their mode of action are given in Table 1.

Conclusion

Cuminum cyminum is an important food and spice that has been utilized by people globally. Cumin possesses antioxidant, anti-inflammatory, and antimicrobial properties in addition to its digestive and diabetogenic properties, suggesting that it may be a promising choice for the diet in managing and preventing various chronic illnesses. These medicinal properties are due to the presence of various phytochemicals present in it. Most of cumin properties have been related to its bioactive ingredients, which include phenols, flavonoids and terpenes. Polysaccharides from cumin can start immune responses by changing NF-κB and MAPK signalling pathways. These bioactive compounds may help control the immune system, causing both higher and lower levels of inflammation.

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