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Cumin (*Cuminum cyminum* L.) an export-oriented Indian seed spice with inherent nutraceutical and therapeutic attributes: A review

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Abstract

Cumin seeds and value-added products are used in beverages, liquors, candy, nutraceuticals, therapeutics, toiletries, perfumery and lotions. In the Indian systems of medicine, cumin finds a vital role through its essential & total oil components and various aqueous and alcoholic extracts. Cumin seeds contain volatile oil (3–4%), the primary active principles of which are cumin aldehyde, terpenes (45–50%), phenols, unsaturated and saturated fatty acids, etc., those occur in varying fractions compensating each other, which act as a scavenger for free radicals and antioxidants. As a nutraceutical, cumin seeds contain plenty of iron, magnesium, calcium, manganese, and phosphorus. The vitamins present include thiamine, riboflavin, niacin, vitamin A, C, E, K, and vitamin B6. The seedspossess diuretic, carminative, stimulant, digestive, tonic, appetizer, stomachic and astringent properties. It is traditionally an essential critical remedial agent for digestion, diarrhoea, leucorrhoea, eczema, atonic, flatulence, dyspepsia and abdominal pains. Phytochemicals like alkaloid, coumarin, anthraquinone, flavonoid, protein, glycoside, resin, saponin, tannin and steroids are abundant in its seed. Cumin seed extracts bear various medicinal properties such as insecticidal, antimicrobial, anti-inflammatory, antioxidant, antidiabetic, anticancer, hypotensive, bronchodilator, immunological, contraceptive, aldose reductase, analgesic,alpha-glucosidase and tyrosinase inhibitory effects, etc. Thus use of cumin offers combined advantages, providing both nutraceutical and therapeutic properties simultaneously.

Keywords: Essential oil, flavorant, volatile oil, phytochemicals, scavenging activity

Introduction

Cumin (*Cuminum cyminum* L.) is an annual herb from the Apiaceae family, consisting of a somatic chromosome number of 2n=14. The seeds are valued for their taste enhancements and inherent therapeutic properties.Cumin is one of the earliest known spices used by humankind. The Latin name was Cuminum derived from the Greek word "Kuminon", which probably originated from the old Babylonian name for cumin-'ka-ma-nu'. Cumin, a native of Egypt, is now grown in most hot arid regions of the

world, comprising India, North Africa, China, America, etc. India is the largest producer of cumin in the world (Meena *et al*., 2022).In India, total cumin production was 7.95 lakh tons in 2020-21 from 10.87 lakhhectares grown area (Anonymous, 2022).Rajasthan and Gujarat are India's major cumin-producing states (Shivakumar *et al*., 2010, Zohary and Hopf 2002, Parashar *et al*. 2014). Cumin was known to the Egyptians five million years ago. Its seeds have been found in the old kingdom pyramids. The Romans and Greeks used it medicinally and cosmetically to induce a pallid complexion. After black pepper, cumin is one of the most extensively used seed spices worldwide. Optimum to good, fertile loamy soils are appropriate for its growth. The seed's flavour depends upon the proportion of cuminal terpenes, thus controlling the bitterness/pungency. The whole seeds have a better aroma which can be better retained through cryo-grinding and packaging in the powdered form. In the Indian medicine systems, cumin plays a significant role through its essential & total oil components and various aqueous and alcoholic extracts.

Shaath and Azzo 1993 and Dubey *et al.,* 2017 reported that Cumin seeds have about 3–4% volatile oil in them. The main components of this oil are cuminaldehyde and terpenes, making up around 45–50% of the volatile oil found in cumin seeds, besides these phenols, unsaturated and saturated fatty acids, α-pinene, γ-terpinene, p-mentha-1,3-dien-7-al, p-mentha-1,4-dien-7-al, and p-cymene, etc., occur in varying fraction compensating each other and possesses many health benefits. Borges and Pino, 1993 and Dubey *et al*., 2016 reported that cumin seeds contain a significant quantity of iron, manganese, magnesium, calcium, and phosphorus. Vitamins present in it include thiamine, riboflavin, niacin, vitamin A, C, E, K, and vitamin B6. A cumin seed possesses carminative, diuretic, stimulant, digestive, tonic, appetizer, stomachic and astringent properties and is traditionally used as an important key remedial agent for digestion, diarrhea, leucorrhoea, eczema, flatulence, atonic dyspepsia and abdominal pains. Phytochemical analysis of cumin showed that it contains various phytochemicals, *viz.* alkaloid, coumarin, anthraquinone, flavonoid, glycoside, protein, resin, saponin, tannin and steroid. Cumin seed extracts bear various medicinal properties such as antimicrobial, insecticidal, anti-inflammatory, analgesic, antioxidant, anticancer, antidiabetic, hypotensive, bronchodilator, immunological, contraceptive, aldose reductase, alpha-glucosidase and tyrosinase inhibitory effects etc. Hence, cumin is one of the major sources of medicinally active compounds and has various pharmacological effects, so, it is encouraging to find its new therapeutic uses. Value-added products from cumin seeds, *viz.* oleoresins and cumin oil are exported from India.

Cumin seeds are a common dietary spice consumed in fairly large quantities in India. They are widely used in Ayurvedic medicine to treat dyspepsia, diarrhoea and jaundice. An aqueous extract of cumin seeds wasreported to prevent the accumulation of advanced glycation end-products due to fructose-mediated *in-vitro* glycation of eye lens soluble proteins (Lee 2005). Hypoglycaemic effects of cumin seeds were also observed in normal rabbits (Roman-Ramos *et al*., 1995). Dietary cumin showed marked hypoglycaemic responses in streptozotocin-diabetic rats by reducing blood and urinary glucose concentrations (Willatgamuwa *et al.,* 1998). An aqueous extract of cumin seeds lowered blood glucose and plasma and tissue lipid concentrations in alloxan-induced diabetic rats (Laland Meena 2018; Lee 2005; Dhandapani *et al.,* 2002). In Ayurveda, cumin is considered a warming spice, invaluable for digestion. It helps in burning toxins, thus enhancing the appetite.

Traditional uses

In addition to the volatile oil being used in cosmetics and perfumes, cumin seeds are utilized in cooking (Meena *et al.,* 2020). Soups, meats, cheese, pickles, and bread can all benefit from the use of cumin and cumin oil. The oil is used to standardise the volatile oil content of oleoresin in the food processing industries as well as to add fragrance to creams, lotions, and perfumes. Cumin is also used medicinally and aids in the treatment of numerous illnesses. It is an excellent source of iron. Cumin is regarded as a warming spice that is extremely beneficial for digestion in Ayurvedic medicine. Additionally, it is a cleansing spice that increases appetite and aids in toxin burning. Cumin has a long history of usage as an antispasmodic, diuretic, anti-inflammatory, and carminative.

It has also been used to treat dyspepsia, jaundice, diarrhea, flatulence, and indigestion. Cumin powder is used as a poultice, smoked in a pipe, and taken orally. Its essential oil contains magnesium, and sodium promotes digestion and relieves stomach aches when taken with hot water (Prajapati 2003; Parthasarathy 2008). In addition to being used as a flavouring in curry powders, soups, stews, sausages, cheeses, pickles, meats, and chutneys, cumin oil was also utilised in perfumery (Farrell 1985). Generally, oil extracted from cumin seeds is used for medicinal purposes (Joerg *et al.,* 2000).The

medication is used as an emmenagogue and an abortive in America, Africa, and India. It was utilized in Indonesia to treat headaches and bloody diarrhoea. Furthermore, it was administered orally for rheumatic conditions. Cumin was prescribed as an abortifacient in India for kidney and bladder stones (Joerg *et al.,* 2000). The seeds were also used as an emmenagogue, astringent, and carminative in the Unani system of medicine to treat corneal opacities, ulcers, boils, styes, and to ease cough and irritation (Shivakumar *et al.,* 2010).

Plant and Floral Morphology

Jeera is the most prominent name for cumin in India, however there are several more widely used regional names, such as Jiragam in Tamil and Jilakara in Telgu. The 3 to 6mm long seeds come as paired or single carpels. They are hairy, dark yellow to brownish in appearance, boat-shaped, tapering at either tip, and have tiny stalks attached. They have a striped pattern of seven to nine ridges with oil canals.

Crop Husbandry

The plants are multiplied from seeds by line sowing, eliminating thinning and makinginter-culture operations easier. For germination, 12 to 15 days are needed. Mature plants grow to a height of 0.5 to 0.75 metres with numerous branches on the stem. The leaves are finely dissected and green in colour during the vegetative stage. Flowers are pink in color and turn pale on maturity. The plants are harvested at ~125 days after maturity when the umbels wither and the seeds turn from pale brown to brown. Under adequate management and a favourable climate, the average yield ranges from 550 to 700 kg ha^{-1}.

Physicochemical characteristics

Cumin has the following physicochemical characteristics: 8% moisture content, 7.3 pH, total ash of 7.5% of which 18% acid insoluble ash, 6.58% alcohol soluble extractive, 13.8% water soluble extractive, and 11.44 and 12.36 % ether soluble extractive in the wet and dry seeds, respectively (Rai *et al*., 2012). In the wet and dry seeds, there were crude proteins of 18.40 and 19.88%, crude fibres of 21.82 and 23.57 %, and total carbohydrates of 55.58 and 60.05%,respectively (Moawad *et al.,* 2015). Physical characteristics of cumin seed essential oil: Refractive index (20 ºC): 1.47-1.50, density (20 ºC): 0.90-0.94, extraction percentage: 2.3-5.7%, colourless or pale yellow, alcohol solubility (80% v/v): 1:1.3-1:2, aldehyde percentage (based on cuminaldehyde): 35-63%, acidity (based on cuminic acid): 0.36-1.8, alcohol percentage (based on cuminol): 3.5 carbonyl index: 9.32 and steric index: 19.24 (Gohari and Saeidnia, 2011).

Chemical constituents

Cumin contains alkaloids, anthraquinones, coumarin, flavonoid, glycoside, protein, resin, saponin, tannin and steroids (Rai *et al*., 2012). Cumin seeds are nutritionally rich and provide high amounts of fat (4 -22.3%), protein (15–18%), carbohydrates (29–44.24%), dietary fibre (10.5–17%) and minerals (6%). Cumin seeds (100 g) consist of vitamin A (1270IU), total carotenoids (522μg), thiamin (550μg), niacin (2.60 mg), vitamin C (8.0 mg), vitamin E (2.0 mg) and folate (10 μg). Besides, vitamins several dietary minerals are also found in cumin seeds in considerable amounts. The mineral profile of cumin seeds (mg 100^{-1} g) consists of calcium (1080), copper (0.71) 0.02, iron (11.7), magnesium (475), manganese (1.02), phosphorus (511), potassium (980), sodium (126) and 2.66 mg zinc (Azez 2008; Dubey *et al.,* 2016, Merah *et al*., 2020).The fatty acid profile of cumin revealed the presence of Cis-vaccenic acid (C18:1n7), a specific fatty acid of cumin seeds. Petroselinic acid (C18: 1n-12) was the predominant (55.9%) fatty acid at full maturity, followed by palmitic (23.82%), linoleic (12.40%) and pamitoleicacid (2.12%). A significant increase in polyunsaturated and monounsaturated fatty acids was observed during cumin seed ripening, whereas a decrease in saturated fatty acids. Organic acids (aspartic, citric, malic, tartaric, propionic, ascorbic, oxalic, maleic and fumaric acids) are also reported in cumin seeds (Hashum and Al-Hashemi 2014).

Significant oil constituents of cumin contain trans dihydrocarvone (31.11%), γ-terpinene (23.22%), p-cymene (15.8%), α- phellandrene (12.01%) and p-menth-2-en-7-ol (3.48%) and cumin aldehyde constituted only 0.58% (Chaudhary *et al*., 2014). In cumin oil samples from four German regions, beta-pinene, p-cymene, gamma-terpinene, terpenoids, cuminic aldehyde, and menthadiencarboxaldehydes were identified as the major compounds (Wanner *et al*., 2010).

Table 1: Gas chromatographic profile of cumin seed essential oils

S.No	Compounds	RT*	RI*	Identification	Content
Terpenic compounds					
1	α- Farnesene	5.062	1458	RI, MS, Co GC	0.16±0.03
2	α-Thujene	5.176	902	RI, MS	0.35±0.01
3	α-Pinene	5.291	948	RI, MS	0.76±0.03
4	α-Ocimene	5.749	805	RI, MS	0.04±0.01
5	β-Phellandrene	5.883	964	RI, MS, Co GC	0.37±0.02
6	Terpinene	5.902	1052	RI, MS, Co GC	0.85±0.03
7	β-Pinene	5.96	943	RI, MS	15.47±1.38
8	Myrecene	6.112	958	RI, MS	0.89±0.05
9	α-Phellandrene	6.361	969	RI, MS	0.55±0.07
10	β-Thujene	6.762	873	RI, MS	2.95±0.04
11	γ-terpinene	7.202	998	RI, MS, Co GC	33.79±3.42
12	Terpinolene	7.641	1052	RI, MS	0.06±0.02
13	Santolinatriene	9.265	894	RI, MS	5.00±0.15
14	α –terpinene	9.647	998	RI, MS	0.09±0.04
15	Isoterpinolene	10.29	1023	RI, MS	1.14±0.04
16	β- Farnesene	12.781	1440	RI, MS	0.14±0.04
17	Trans -α-Bergamotene	13.16	1430	RI, MS, Co GC	0.25±0.14
Alcohols/ phenols					
18	4-Allyl Anisole	9.284	1172	MS	0.07±0.05
19	p-cumenol	9.686	1149	RI, MS, Co GC	0.09±0.01
20	m-cumenol	9.666	1149	RI, MS, Co GC	0.10±0.01
21	Geraniol	9.991	1228	RI, MS, Co GC	2.39±3.47
22	p-thymol	10.53	1262	RI, MS	2.19±2.41
23	Anethole+Estyragol	10.60	1190	RI, MS, Co GC	9.15±4.03
24	Cumic alcohol	10.66	1284	RI, MS	14.40±1.7
25	Cymol	6.667	1042	RI, MS, Co GC	4.26±0.04
Aldehydes					
26	2-caren-10-al	9.303	1136	RI, MS	1.03±0.04
27	Cuminaldehyde	9.972	1230	RI, MS, Co GC	39.9±0.79
Esters					
28	Ethyl Mandelate	10.68	1421	RI, MS	0.24±0.22
29	Geranylacetate	11.85	1352	RI, MS, Co GC	0.19±0.12

Ms-Mass spectrum; CoGc -Co- injection with authentic compounds; -not detected; RT -retention index and RI- retention time.

Table 2: Name, Structure and IUPAC name of components of essential oil

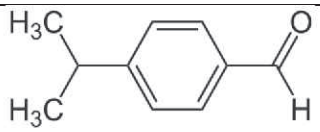
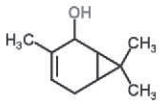
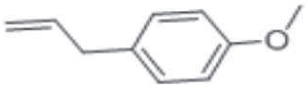
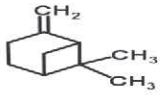
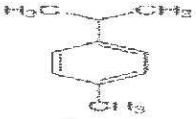
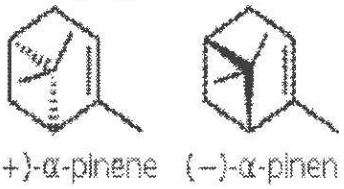
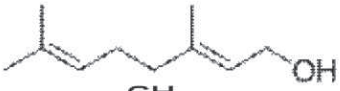
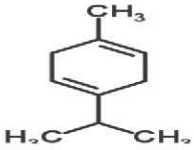
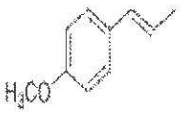
S. No.	Common name	IUPAC name	Structure
1	Cumin aldehyde	4-(1-Methylethyl)benzaldehyde , C10H12O	
2	Trans 3-caren-2-ol	3,7,7-Trim éthylbicyclo[4.1.0]hept-3-én-2-ol $C_{10}H_{16}O$	
3	4-allyl Anesole orEstyragol	1-allyl-4-methoxybenzene $C_{10}H_{12}O$	
4	β-pinene	6,6-Diméthyl-2-méthylènebicyclo[3.1.1]heptane $C_{10}H_{16}$	
5	Cymene	1-Methyl-4-(1-methylethyl)benzene $C_{10}H_{14}$	
6	α-pinene	(1S,5S)-2,6,6-Tri methylbicyclo[3.1.1]hept-2-ene (-)-α-Pinene) $C_{10}H_{16}$	 (+)-α-pinene (−)-α-pinen
7	Camphene	2,2-dimethyl-3-methylene-bicyclo[2.2.1]heptanes $C_{10}H_{16}$	
8	Myrecene	7-Methyl-3-methylene-1,6-octadiene $C_{10}H_{16}$	
9	Geraniol	(trans)-3,7-Dimethyl-2,6-octadien-1-ol $C_{10}H_{18}O$	
10	γ-terpinene	4-Methyl-1-(1-methylethyl)-1,4-cyclohexadiene $C_{10}H_{16}$	
11	Geranyl acetate	3,7-Dimethyl-2,6-octadien-1-yl acetate $C_{12}H_{20}O_2$	
12	Anethole	1-Methoxy-4-(1-propenyl)benzene $C_{10}H_{12}O$	

Table 3: Proximate composition of cumin seed analysed for the cumin from various growing regions of Rajasthan and Gujarat (India) are presented below

District	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	N (ppm)	P (ppm)	K (ppm)	Carbo hydrate (%)	Protein (%)
Jodhpur	16.2	486.8	425.0	48.9	1.34	3.26	0.10	3.50	0.37	1.77	15.86	21.89
Jaisalmer	16.2	448.2	612.5	54.0	1.05	3.28	0.13	3.08	0.29	1.72	19.94	19.26
Barmer	14.9	428.9	312.5	46.3	1.86	1.74	0.10	3.09	0.47	1.78	17.16	19.33
Nagaur	16.2	438.6	287.5	46.3	1.58	1.42	0.14	3.09	0.39	1.59	16.35	19.30
Jalore	16.8	455.4	525.0	77.2	1.53	2.27	0.12	3.15	0.40	2.50	28.88	19.71
Pali	22.4	448.2	337.5	38.6	1.40	3.20	0.16	3.13	0.55	2.65	26.47	19.58
Ajmer	19.9	472.3	437.5	46.3	1.24	2.83	0.15	2.96	0.59	2.26	24.15	18.52
Banaskantha	13.7	443.4	275.0	84.9	1.27	2.87	0.11	3.37	0.47	2.14	19.59	21.08
Surendranagar	13.1	455.4	337.5	57.9	1.45	3.15	0.13	3.32	0.29	2.01	20.80	20.75
Amreli	14.9	469.9	337.5	99.3	1.18	3.42	0.11	3.49	0.46	2.53	19.33	21.80
Kuchchh	14.9	433.7	375.0	73.3	1.29	3.61	0.14	3.11	0.48	2.22	23.63	19.42
Radhanpur	11.2	419.3	487.5	69.4	1.08	1.72	0.15	3.09	0.52	2.60	23.38	19.32
Mean	15.9	450.0	395.8	61.9	1.36	2.73	0.13	3.20	0.44	2.15	21.30	20.00
Range	11.2-22.4	419-486	275-612	38-99	1.05-1.86	1.42-3.61	0.10-0.15	2.96-3.49	0.29-0.59	1.59-2.70	15.86-28.88	19.30-21.89

Medicinal and Pharmacological Properties

***Antioxidant Activity*:** Cumin seeds contain apigenin and luteolin flavonoids with antioxidant activity. The ether soluble fraction of cumin has also been reported to have antioxidant activity (Leung 1980). It has been shown that cuminaldehyde scavenges superoxide anion (Krishnakantha and Lokesh 1993).The daily use of cumin is widespread in India. The present study has revealed that the aqueous extract of cumin exhibits strong antioxidant activity superior to known antioxidant ascorbic acid and indicates that the intake is beneficial as a food additive (Satyanarayana *et al*., 2004).

***Blood Platelet Aggregation*:** A dose-dependent inhibition of arachidonate-induced platelet aggregation by cumin extract in ether was observed in human platelets (Srivastava 1989). Samabaiah and Srinivasan (1991)demonstrated that cumin has a hyper-cholesterolemic effect in rats.

Antidiabetic: Lower blood urea levels and decreased excretions of urea and creatinine by diabetic mice showed that dietary cumin prevented other metabolic changes (Willatgamuwa *et al*. 1998). Dietary cumin considerably reduced (about 50%) the increased plasma urea level of diabetic rats. Glucosuria and hyperglycemia were significantly reduced when cumin powder (1.25%) was used. A herbal diabetes medication that contains cumin as one of its constituents has been shown successfully in human trials (Karnick 1991).

***Antimicrobial Activity*:** Alcoholic extract of cumin and its essential oil has proven antibacterial action against the ceftazidime-resistant strain of Klebsiella pneumonia ATCC 13883. Strong larvicidal and antibacterial action has been observed for cuminaldehyde. In the medical field, cumin's essential oil and alcoholic extract are used as antiseptic and disinfectant (Derakhshan *et al*., 2007). Cumin oil inhibits the *in-vitro* growth of *Lactobacillus Plantarum* at doses of 300 or 600 ppm (Kivanc *et al*., 1991). *In-vitro* tests using cumin oil showed antibacterial efficacy against gram-negative and gram-positive plant pathogens and against common human diseases (Iacobellis *et al*., 2005). In general, and with some dermatophytes, cumin extract demonstrated anti-fungal activity. At a 5µl dose, *Trichophytonrubrum*was the most noticeably suppressed fungus. It was less effective against phytopathogens (Romagnol *et al*., 2010)

***Anticancer Effects*:** It has been demonstrated that cumin seeds inhibit the induction of gastric squamous cell carcinomas (Gagandeep *et al.,* 2003). A protective effect against induced colonic cancer was observed in rats fed with cumin. The reverse mutation Salmonella typhimurium (TA100) test of cumin seeds was non-carcinogenic, but the oxidative mutation test with strain TA102 was weak (Al-Batania *et al*., 1995).

***Anti-inflammatory and analgesic effects*:** Cumin extracts in both aqueous and ethanolic forms significantly reduce pain and exhibit strong anti-

inflammatory effects in carrageenan-induced paw oedema and cotton-pellet granuloma, respectively (Bhat *et al.*, 2014). Cumin essential oil demonstrated a strong and dose-dependent analgesic effect in both chronic and inflammatory pain at dosages ranging from 0.0125 to 0.20 mlkg^{-1}. However, essential oils did not have anti-inflammatory properties (Sayyah *et al.,* 2002). Compared to the control group, the volatile cumin oil showed a dosage-dependent reduction of rat paw oedema at a dose of 0.1ml kg^{-1}. The effectiveness was comparable to that of the common medication, diclofenac sodium (Shivakumar *et al.*, 2010). Themethanolic extract of cumin inhibited lipoxygenase activity. Cuminaldehyde was identified as a 15-LOX inhibitor through activity-guided screening of cumin crude extracts. Cuminaldehydea component of essential oil, is a competitive inhibitor of free radicals (Tomy *et al.*,2014).

***Effect on nervous system*:** The impact of Cumin fruit essential oil on epileptic activity caused by pentylenetetrazol (PTZ) was studied using intracellular techniques. The findings revealed that applying the essential oil of Cumin at 1% and 3% levels externally substantially reduced the frequency of spontaneous activity triggered by PTZ. This reduction occurred in a time-dependent and concentration-dependent manner. Additionally, the oil demonstrated protective effects against PTZ-induced epileptic activity by altering various aspects of nerve cell behavior. It increased the duration and reduced the intensity of after hyperpolarization potential (AHP) after the nerve cell's action, decreased the peak of the action potential, and inhibited the rate of nerve cell firing. These effects on the nerve cell membrane hint at how the essential oil of Cumin might hinder PTZ-induced epileptic activity. (Janahmadi *et al.*, 2006).

Antistress activity:

Antistress capacity in rats was assessed by forcing them to swim, and their urine levels of vanillylmandelic acid (VMA) and ascorbic acid were measured as biomarkers. Daily intake of cumin at doses of 100, 200, and 300 mgkg^{-1} body weight decreased the stress-induced urine biochemical alterations in a dose-dependent manner one hour before the induction of stress without changing the levels in the normal control groups (Koppula and Choi, 2011). Only at a dose of 2% cumin FEO considerably slow the emergence of morphine tolerance and dependence. It was significantly beneficial in a dose-dependent (0.5, 1 and 2%)way on the expression of morphine dependence and tolerance (1 and 2%) (Haghparast *et al.*, 2008). Cuminaldehyde does not disaggregate the produced fibrils but inhibits α-SN fibrillation in the presence of seeds. Because of its interaction with amine groups as a Schiff base reaction, cuminaldehyde inhibits the assembly of proteins into β-structural fibrils, as demonstrated by structural investigations. The FITC labelling efficiency assay validated this hypothesis (Morshedi *et al.*, 2015).

***Hypotesiveeffect*:** In hypertensive rats, cumin seeds were given orally (200 mg kg^{-1}bw) for 9 weeks; this enhanced plasma nitric oxide levels and reduced systolic blood pressure. Additionally, it increased the gene expression of eNOS, Bcl-2, TRX1, and TRXR1 while decreasing the expression of Bax, TNF-, and IL-6. According to the research, cumin seeds help endothelial functioning and reduce inflammation and oxidative stress in hypertensive rats (Kalaivani *et al.*, 2013).

***Hypolipidemic and weight reduction effects*:** Hypocholesterolemic effect of methanolic extract of cumin seed and estradiol, protected OVX rats against increased cholesterol levels due to ovariectomy. However, methanolic extract of cumin seed was better than estradiol (Shirke and Jagtap, 2009). In a randomized clinical trial, researchers investigated the effects of cumin powder on the lipid profiles of overweight and obese women. They divided 88 women with obesity or overweight issues into two groups randomly. One group consumed 3 grams of cumin powder mixed with yogurt twice a day for three months, while the other group had the same quantity of yogurt without cumin powder. Both groups received similar advice on nutrition for weight loss. Before and after the intervention, the researchers measured various biochemical and physical parameters. They found that the fasting blood levels of cholesterol, triglycerides, and LDL decreased, whereas HDL levels increased in the group that consumed cumin powder. Additionally, there were significant reductions in weight, BMI, waist size, and fat mass. However, the intervention did not affect fasting blood sugar levels or fat-free mass (Zare *et al.*, 2014).

***Gastrointestinal effect*:** The antiulcer activity of the aqueous extracts of leaves of dried fruits of cumin against the diclofenac sodium-induced stomach ulceration has been studied in rats compared with omeprazole. Cumin extract helped in curing ulcers. The healing activity of the aqueous extracts of a combination of piper betel and cumin was found to be better than the healing activity of aqueous extracts of cumin and piper betel alone. The aqueous extract enhances gastric much in protection and regeneration (Pratyusha *et al.*,

2013).The effect of aqueous extract of Cumin seeds was studied against diarrhoea in albino rats. Extract showed significant ($p< 0.001$) inhibition in the frequency of diarrhoea, defecation time delay, secretion of intestinal fluid and propulsion compared to the control. The graded doses of the tested extract showed dose-dependent protection against diarrhoea (Sahoo *et al*., 2014).

***Protective effects*:** The effect of Cumin on kidneys exposed to profenofos was evaluated in female swiss albino mice. The results showed that cumin effectively normalised uric acid and creatinine levels (Kumar *et al*., 2011).

***Depression effect*:** Depression in growth, hepatotoxicity and nephrotoxicity was observed in rats that had been given paracetamol at 500 $mgkg^{-1}$ orally for 4 weeks. These findings were accompanied by leucopenia, macrocytic normochromic anemia and alterations of serum aspartate aminotransferase, alanine aminotransferase and alkaline phosphatase activities and concentrations of cholesterol, urea and other serum constituents. Serum bilirubin did not change. In rats, the mixture of paracetamol 500 mg kg^{-1} plus 6% cumin seeds for four weeks, the reduction in paracetamol hepatotoxicity resulted in increased body weight, absence of hepatocellular fatty vacuolation and significant improvement of biochemical and haematological parameters (Elhabib *et al*., 2007).

Significant improvement in the sperm count, motility and viability, and standard architecture in most seminiferous tubules with organized epithelium was observed in cumin treated group, as compared to the copper group (Sakhaee *et al*., 2015).

***Bronchodilatory effects*:** Macerated and aqueous extracts of cumin show relaxant effects of tracheal chains of guinea pigs compared with saline and theophylline (Boskabady *et al*., 2005). Immunological effect: Cuminshowshealth-modulating effects and immunomodulatory properties in normal and immune-suppressed animals (Chauhan *et al*., 2010).

***Contraceptive effect*:** The contraceptive efficacy of cumin-isolated fractions (*Cifr*) was investigated in male albino rats. The oral dose of *Cifr* 50 mg/rat/day for 60 days revealed no significant changes in body weight, while marked abnormalities in spermatogenesis were observed with decreased counts ($P \leq 0.001$) in round spermatids, preleptotene spermatocytes and secondary spermatocytes. Thus results revealed that *Cifr* inhibited spermatogenesis in rats and can act as herbal male contraceptive (Saxena *et al*., 2015).

***Anti-amyloidogeniceffect*:** The active anti-amyloidogeniccompoundin cumin oil was studied. GC-MS analysis of this fraction indicated the presence of eight compounds. Molecular local docking analysis suggested a site of interaction forterpinolene in the flexible cleft of the protein. This interaction site was close to tryptophan-62 and -63 and two other hydrophobic residues in the hot spot regions of the protein (Morshedi *et al*., 2014).

***Anti-osteoporotic effect*:** The anti-osteoporotic activity of cumin extracts was studied in rats using scanning electron microscopic analysis, that showed greater bone and ash densities and improved micro-architecture of bones. Contradictory to estradiol, it did not affect body weight gain and weight of atrophic uterus in OVX animals. Methanolic cumin extracts prevented ovariectomy-induced bone loss in rats with no anabolic effect on the atrophic uterus (Shirke *et al*.,2008).

***Aldose reductase and alpha-glucosidase inhibitory effects*:** Quercetin, an aldose reductase inhibitor, and acarbose, an alpha-glucosidase inhibitor, were used to compare the inhibitory efficacy of the cumin seed oil component against lens aldose reductase and alpha-glucosidase isolated from Sprague-Dawley male rats. Cuminaldehyde has been identified as the biologically active component of cumin seed oil using a number of spectral analyses. Cuminaldehyde has an IC_{50} value of 0.00085 $mgml^{-1}$ against aldose reductase and 0.5 mg ml^{-1} against alpha-glucosidase It was found that cumulativedehyde showed less inhibitory activity than quercitin and acarbose by 1.8 and 1.6 times, respectively (Lee, 2005).

***Tyrosinase inhibitory effect*:** Cuminaldehyde was identified as a potent mushroom tyrosinasemonophenol monooxygenase inhibitor. It inhibited the oxidation of L-3,4-dihydroxyphenylalanine (L-DOPA) by mushroom tyrosinase with an ID_{50} of 7.7 g/ml (0.05 mM). Its oxidized analogue, cumic acid (p-isopropylbenzoic acid), also inhibited this oxidation with an ID_{50} of 43 g/ml (0.26 mM). These two inhibitors affected mushroom tyrosinase activity differently (Kubo and Kinst-Hori, 1998).

***Effect on erythrocyte hemolysis*:** The effect of methanolic and acetonic seed extracts of Cumin was studied on human erythrocyte hemolysis in comparison with caraway. Both seed extracts were able to protect erythrocytes from hemolysis. Methanolic cumin extract showed higher percentage of protection than caraway (Atrooz, 2013).

Conclusion

Cumin is a commercially important seed spice and is one of the ingredients in many spice mixes consumed in our daily diet. Value-added products from cumin, *viz.,* cumin powder, oil, and oleoresin, also form commercially viable products and find application in food processing industries. Research towards developing improved methods to process and extract cumin extracts with higher retention of bioactive compounds would be welcome. As evidenced by the literature, the different forms of cumin possess many remarkable health benefits, *viz.*, inhibition of blood platelet aggregation, antidiabetic, antimicrobial, antiseptic, and antioxidant. The flavanoidsapigenin, luteolin, and their glycosides present in cumin are reported to be responsible for many of the biological activities of cumin. Cuminaldehyde, the principal constituent of volatile oil, is responsible for its antimicrobial and antimutagenic properties. Cumin residue, after extraction, has the potential to be new source of dietary fibrethat can be utilized for incorporation into many food formulations. Cumin could be considered a health-promoting food additive as it contains significant monounsaturated fatty acids (MUFA) compared to spices like ginger, chilli, and pepper. But as a spice, cumin is consumed in low quantities, which may not be sufficient to provide the health effects. With the increasing awareness and demand for functional foods, the consumption of cumin in different forms (e.g., as an ingredient in a ready-to-drink beverage, as a mouth freshener, or as a tabletop shake-on for salad dressings) can be popularized.

Challenges to be addressed

As a seed spice, cumin contains higher amounts of fatty oil (around 15%) which causes problems for large-scale grinding and requires newer methods of extraction of volatile oil without flavor loss.

Storage of oleoresin for a longer time is problematic due to the unsaturated fatty acids (oleic acid is the major fatty acid present around 60%) which lead to rancidity formation in the product. Methods to stabilize the oleoresin and products containing oleoresin must be worked out. In contrast to onion and garlic, cumin does not have a strong odor, so its usage will likely increase. However, it is important to determine the ideal dosage for individuals to obtain maximum health benefits.

Future perspectives

Future studies should focus on consolidating good agricultural practices to obtain higher essential oil yields, total oil, and oleoresin production. This improvement aims to enhance concentrate uses and further strengthen the medicinal applications of cumin. Additionally, further research should delve into the specific targets of various constituents found in cumin. This review aims to be informative for those interested in tapping into the herb's potential for pharmaceutical and nutraceutical applications.

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