Int. J. Seed Spices 12(1), January 2022: 13-33 DOI : https://doi.org/10.56093/IJSS.v12i1.2

Reviewed By
Dr. Sarang Sapre, College of Agriculture, Junagadh Agricultural University, Amreli, Gujarat.
Email: sarangsapre27@jau.in

***Correspondence**
Kailashpati Tripathi
kailashpati92@gmail.com

Received: 19 January 2024
Revision: 21 February 2024
Accepted: 23 February 2024

Citation
Mahatma, M.K., Tripathi, K., Saxena, S.N. and Bhardwaj, V. 2022. Unveiling the nutraceutical potential of seed spices for multifaceted health effects. *Int J Seed Spices.*12 (1), 13-33

DOI
https://doi.org/10.56093/IJSS.v12i1.2

Affiliation
ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan, India

Unveiling the nutraceutical potential of seed spices for multifaceted health effects

M.K. Mahatma, Kailashpati Tripathi*, S.N. Saxena and Vinay Bhardwaj

Abstract

Seed spices, which are traditionally employed for flavor enhancement, coloration and food preservation, have long been recognized for their medicinal properties within the domain of traditional medicine systems. Recent advancements in seed spice technology, coupled with expanded knowledge of the chemical composition and pharmacological properties of these plants, have spurred comprehensive investigations into their potential health benefits. Pioneering experimental research, encompassing both animal studies and human trials, has revealed numerous health-promoting attributes associated with these commonplace culinary additives. These investigations have meticulously documented an array of health benefits attributed to seed spices, including their stimulatory effects on digestion, ability to lower lipid levels, influence on diabetes management, capacity to prevent stone formation, antioxidant properties, and anti-inflammatory characteristics, as well as their potential to inhibit mutagenesis and carcinogenesis. Notably, certain spices have garnered attention for their profound nutraceutical value due to their cholesterol-lowering and antidiabetic properties, suggesting far-reaching implications for health enhancement. These advantageous physiological effects not only signify potential nutraceutical applications but also suggest promising therapeutic interventions across various disease conditions. This review aims to provide a comprehensive overview of the experimental evidence underpinning the nutraceutical potential inherent in spices.

Keywords: Traditional medicine, health benefits, natural products, antidiabetic effect, antimutagenic effect, hypocholesterolemic effect.

Introduction

Seed spices are a group of tropical aromatic annual herbs whose dried seeds have been used as spices for thousands of years to enhance the sensory attributes of food, such as excellent aroma, color and flavor. The aromatic qualities of seed spices notably enhance the appeal of food, drawing increased attention to culinary experiences. Many seed spices are known for their medicinal properties, such as antioxidant, anticancer, antidiabetic, antimicrobial, hypolipidemic, insecticidal, and medicinal effects; are useful in treating menstrual disorders; can aid in digestion, the modulation of hypertension, and detoxification enzymes; can reduce inflammation; can modulate steroid metabolism; can stimulate the immune system; and can help improve several other human disorders, as listed in

Table 1. While these properties are primarily based on empirical observations, these unquestionably effective characteristics have led to their pharmacological utilization within indigenous medical systems, not only in India but also in various other countries.

The spice trade is likely the oldest trade in which humans have engaged. The wealth from the spice trade led to many historic voyages and the discovery of new lands. Approximately 7.25 lakh tons of cumin were produced in India from an area of 8.08 lakh ha during the year 2022-23. Of these, 1.86 lakh tons of cumin, worth L 4194 crores, were exported to various countries worldwide. Similarly, India produced approximately 1.37 lakh tons of fennels from an area of 0.82 lakh ha, out of which 0.37 lakh tons of fennel worth L 324 crore were exported. In the case of coriander, India produced approximately 8.47 lakh tons from an area of 6.38 lakh ha in 2022-23. However, in the case of fenugreek, the country produced approximately 2.26 lakh tons from an area of 1.46 lakh ha and exported approximately 0.35 lakh tons of fenugreek worth L 194 crores. Regarding ajwain, the nation cultivated around 0.36 million tons over an area of 42 thousand hectares. India witnessed a remarkable surge in the export of Ajwain by almost 158%, reaching USD 3.7 million during April-December 2021, contrasting with USD 1.5 million in the same period of 2013 (Source: State Agri/Hort. Departments/DASD Kozhikkode 2022-23).

Despite the astonishing advancements in medicine and combination drug development, the use of herbal plants for treating or preventing various diseases is enormously practiced due to their vast variety of nutraceutical properties and safety aspects. Seed spices are nutritious, functional, medicinal and nutraceutical in nature and are used in human diets. These are the golden mines for identifying beneficial bioactive compounds for use in pharmacology and other health-related issues. The Spice trade is known from permanence.

Table 1: The age-old medicinal benefits of seed spices

S.N.	Seed spices	Medicinal properties
1.	Fenugreek	Diuretic, emollient, cardiovascular diseases, sexual disorders, joint pain
2.	Coriander	Antidyspeptic, diuretic effect, menstrual disorder, sedative hypnotic activity, chronic ulcers, stimulants, sore throat, syphilis, muscle relaxant, relief from sunstroke
3.	Ajwain	Flatulence, abdominal pain due to gases, indigestion, loss of appetite, constipation
4.	Cumin	Diarrhea and dyspepsia, corneal opacities, ulcers, boils, styes , diuretic, cooling effect, galactagogue, chronic fever, antifertility ef fect, scorpion bite
5.	Nigella	Recovery from fatigue or dispiritedness, diabetes, antibacterial, re pellent
6.	Fennel	Diuretic, gonorrhea, kidney trouble, Cardiovascular diseases, antimicrobial, cough, cold, blood purification

Nutrient composition of the seed spices

Seed spices are used individually or in combination to suit various tastes and dishes. Although historically not considered to be significant contributors to human nutrition, these additives have been a part of human diets for centuries, enhancing flavor and making food more enjoyable. Interestingly, the protein content in the seed spices ranged from 9.38% in fennel seeds to 28.4% in nigella, while the fat content varied from 4.0% in fenugreek to 34.4% in nigella. The mineral content ranged from 3.0% in fenugreek and coriander to 12.97% in fennel seeds, indicating high mineral levels. Some seed spices contain notable amounts of vitamins, minerals, and dietary fiber. For instance, Coriander seeds boast the most dietary fiber at 36.0%, followed by fenugreek (33.5%), fennel (28.21%), and cumin (23.0%). However, due to their relatively low consumption levels, their overall impact on nutrient intake might not be as significant as that of other food ingredients. The "active principles" of spices not only define their quality attributes but also often contribute to their beneficial physiological effects (Table 2).

Table 2: Nutritional Value of Seed Spices

Constituents	Value per 100 gm					
	Coriander	Cumin	Fennel	Fenugreek	Ajwain	Nigella
Moisture (gm)	8.0-11.0	6.2-11.90	6.24	3.0-13.7	7.4	4-6.9
Protein (gm)	11.0-17.0	18.7-24.5	9.38	25-30	17.1	25.5-28.4
Fat/oleoresins (gm)	16.0-28.0	15.0-23.8	9.76	4-5.8	18.1	30.8-34.4
Minerals (gm)	3.0-5.3	5.8-10.5	13.40	3.0	7.9	4.3-4.8
Fiber (gm)	23.0-36.0	12.0	18.21	5-7.2	21.2	5.5-6.2
Carbohydrate (gm)	18.0-23.0	15.8-28.9	36.6	44.1-50.0	24.6	44-50.0
Energy (K cal)	298.0	356.0	344	333.0	363.0	375.0
Calcium (mg)	709.0	1080.0	580.6	160.0	1525	387-433.0
Iron (mg)	16.32.0	11.7	9.72	6.5	27.7	7.2-8.1
Magnesium (mg)	330.0	475.0	85.87	124.0	273.0	224-252.0
Manganese	1.90	1.02	211.35	1.03	6.86	1.99
Phosphorus (mg)	409.0	511.0	470.0	370.0	443.0	223.4
Potassium (mg)	1267.	980.0	852.45	530.0	1692.0	672-753.0
Sodium (mg)	35.0	126.0	16.21	19.0	56.0	14.5-16.3
Zinc (mg)	4.7	2.66	2.89	3.08	5.67	5.1-8.7
Vitamin C (mg)	21.0	8.0	21	0	1.2	7.7
Niacin (mg)	2.13	2.60	6.0	1.10	2.10	6.31
Thiamine (µg)	239.0	550.0	410.0	340.0	210.0	831.0
Riboflavin (µg)	290.0	360.0	350.0	290.0	280.0	63.0
Vitamin A (IU)	15.0	1270.0	135.0		5000	750.0
Total carotenoid (µg)	1010	522.0		96.0		
Folic acid free (µg)	32	10.0		14.5	51.79	160
Total Tocopherols (mg)	32.0	2.0	15-21.0	72.6-103.3		340.0

Nutraceutical properties of Seed Spices

Over the last two to three decades, numerous advantageous physiological effects of spices have been scientifically recorded (Table 3), indicating that these food additives offer more than just taste and flavor. Diseases such as diabetes, cardiovascular issues, inflammatory conditions such as arthritis, and cancer have been focal points of concern. Spices and their active components have recently undergone scrutiny as potential agents for alleviation or prevention. This review outlines the notable health benefits associated with common spices or their active components that have been documented thus far (Table 4-13).

Table 3: Experimentally documented beneficial health effects of seed spices

S.N.	Beneficial health effect	Seed spices observed to exert
1	Lowering of blood cholesterol	Fenugreek, Coriander, Cumin
2	Hypoglycemic potential	Fenugreek, Cumin, Coriander, Nigella
3	Antioxidant effect	Fenugreek, Coriander, Cumin
4	Anti-mutagenic/cancer preventive	Fenugreek, Nigella, Fennel
5	Digestive stimulant action	Cumin, Ajwain, Fennel, Coriander, Fenugreek
6	Antimicrobial	Nigella
7	Sexual disorder	Fennel, Fenugreek, Coriander
8	Anti-inflammatory effect	Coriander, Ajwain, Cumin, Fennel
9.	Anti-lithogenic effect	Ajwain,
10	Anti-hirsutism activity	Fennel

Table 4: Major flavor, taste and colour-contributing compounds found in seed spices

S.N.	Seed Spices	Major taste and flavor compounds
1	Coriander	Linalool, α,β-pinene, p-cymene, α-terpenene
2	Cumin	Cuminaldehyde, Cuminyl ester, L imonene, α -pinene, β-pinene, α-terpenene, p-cymene, P-mentha-1-3-dien-7-al and Borneol
3	Fennel	Anethole, Limonene, Fenchone, α-pinene, β-pinene Camphene
4	Fenugreek	Trigonellin, Diosgenin
5	Ajowain	Thymol, Carvacrol, p-cymene, γ-terpinene, α,β-pinene, Dipentene, Limonene
6	Dill	Carvone, α-pinene, Limonene, Phellandrene
7	Nigella	Nigellone
8	Anise	Anethole, Methyl Chaviciol, Anisaldehyde, Limonene
9	Celery	Limonene, Selenene, Sesquterpene Alcohol
10	Caraway	D-carvone, Limonene

(Rathore et al., 2017; Rathore et al., 2013; Saxena et al., 2016a)

Table 5: Nutritional/health impacts of fenugreek components

S.N.	Nutritional components	Health impacts
1	4- hydroxyisoleucine (amino acid)	Insulin stimulating activity
2	Fiber (solubl e dietary fiber, galactomannans nonstarch polysaccharides)	Binding of food toxins, protection of colon mucus membrane, promoting insulin secretion, water retention in the intestine, controlling glucose absorption
3	Phenolic acids	Antioxidant properties
4	Micronutrients (Vitamins and minerals)	Regulatory functions
5	Flavonoids	Antioxidant properties
6	Protodioscin	Inhibition of leukemic cells
7	Diosgenin	Hepatoprotective, anti-carcinogenic

(Saxena *et al.*, 2016b)

Table 6: Nutritional/health impacts of the various ajwain components

S.N.	Nutritional components	Health impacts
1	Carvacrol	Anti-diabetic effect
2	γ-terpinene	Antioxidant
3	Dipentene, p-cymene, α-phellandrene	Antimicrobial Activity
4	Limonene	anti-carcinogenic
5	Thymol, Limonene	Anti-inflammatory effect
6	α,β-pinene, Carvacrol, Limonene	Anti-aging effect

(Rathore *et al.*, 2015)

Table 7: Nutritional/health impacts of the various cumin components

S.N.	Health impacts	Cumin components	References
1	Digestive stimulant effects	Dietary 1.25% cumin for 8 weeks significantly enhanced the activities of pancreatic trypsin, chymotrypsin, and amylase on rodents	Platel and Srinivasan, 2000
2	Antidiabetic effect	Sprague– Dawley rats, Cuminaldehyde isolated from *C. cuminum* inhibited lens aldose reductase and α-glucosidase of rats	Lee, 2005
3	Antidiabetic effect	Human NIDDM subjects- Fasting and postprandial blood sugar was reduced when a formulation consisting cumin was orally administered for 24 weeks	Karnick, 1991
4	Cardio protective influence	Cumin in the diet (1.25% over 32 weeks) inhibited colon cancer caused by DMH	Samani and Farrokhi, 2014
5	Anticancer	Cumin in the diet (1.25% over 32 weeks) inhibited colon cancer caused by DMH	Nalini *et al.,* 2006

Table 8: Nutritional/health impacts of coriander components

Biological Effect	**Coriander Component (Extract)**	**Actions**	**References**
Prevent oxidative Damage (Rodents)	Seed (water and alcohol extracts, powder)	↓Liver, plasma TBAR; ↓ heart, liver MDA, peroxides; ↓hepatic damage; ↓kidney, liver oxidative damage; ↓brain oxidative stress, lipid peroxidation, seizures; ↑antioxidant enzymes	Pandey *et al.,* 2011; de almeida *et al.,* 2003; Anil *et al.,* 2010; Kansal *et al.,* 2011
	Seed (oil)	↑Liver oxidative damage, NE antioxidant enzymes	Samojlik *et al.,* 2010
	Linalool	↓Brain lipid peroxidation, restore lipids; ↑glutathione	Celic *et al.,* 2002; Mehri *et al.,* 2015
microbial growth (Human)	Seed (oil)	Skin fungal infection	Beikert *et al.,* 2013
Diabetes Management (Rodents)	Seed (alc. extract)	NE fasting blood glucose,	Sharaf *et al.,* 1963
	Seed (water and alc extr, powder)	↓Hyperglycemia, variable plasma insulin response; ↓pancreatic islet damage; ↑liver glycolysis, glycogenesis; ↓liver glycogenolysis, gluconeogenesis	Gray *et al.,* 1999; Deepa and Anuradha , 2011; Shrivastava *et al.,* 2010
Mood enhancement (Human)	Linalool	Inconsistent effect of inhalation on blood pressure, heart rate, stress task performance	Hoferl *et al.,* 2006
	High linalool essential oil	Inconsistent effect of inhalation on anxiety measures	Igarashi *et al.,* 2013; Muzzarelli *et al.,* 2006
	Linalool isomers	Contrasting effect of inhalation of isomers on mood, heart rate, electroencephalography	Kuroda *et al.,* 2005; Heuberger *et al.,* 2004

Table 9: Nutritional/health impacts of Fennel components

S.N.	Biological activities	Phytochemicals
1.	Estrogenic	Dianethole, Photoanethole
2.	Hepatoprotective	Myrcene, Limonene
3.	Human liver cytochrome P450-3A4 inhibitory	5-Methoxypsoralen
4.	5-Methoxypsoralen	3-Caffeoylquinic acid, quercetin-3-O-galactoside, kaempferol-3-O-glucoside, kaempferol-3-O-rutinoside, rosmarinic acid
5.	Antioxidant	*cis*-Miyabenol C
6.	Anticancer	Anethole
7.	Antibacterial	Dillapiol, Psoralen, Bergapten, Scopoletin, Imperatorin, Dillapional

(Bukhari, *et al.*, 2014)

Table 10: Nutritional/health impacts of Nigella components

S.N.	Health impacts	Nigella components	References
1	Anti-carcinogenic effect	Human: TQ exhibited an IC_{50} value of 10.7 μg/ml, inducing apoptosis in SiHa cells by downregulating the Bcl-2 protein and another study TQ's potential antitumor and anti-angiogenic effects might occur through the inhibition of NF-κB and its downstream molecules. In another study TQ reduced the movement and penetration of panc-1 cells in a dose-dependent manner by decreasing NF-kB and MMP-9 expression.	Ng *et al.,* 2011; Peng *et al.,* 2013; Wu *et al.,* 2011
2	Antidiabetic effect	Rodents: Nigella oil notably reduced blood sugar levels in rats with STZ-induced diabetes at 2, 4, and 6 weeks.	El-Dakhakhny *et al.,* 2002
3	Antidiabetic effect	Human: Nigella oil demonstrated positive effects on clinical and biochemical factors associated with insulin resistance syndrome and in another study when taking 2 g/day of Nigella, there were decreases observed in fasting blood glucose, postmeal levels, and glycosylated hemoglobin.	Najmi *et al.,* 2008; Bamosa *et al.,* 2010
4	Anti-inflammatory effect	Human: The anti-osteoporotic effects of Nigella and TQ were confirmed through the inhibition of inflammatory cytokines like interleukin-1 and 6, as well as the transcription factor NFκB.	Shuid *et al.,* 2012
5	Pulmonary protective effect	Human: Nigella administered at 15 ml/kg of a 0.1 % boiled extract for three months, notably eased asthma symptoms, chest wheezing, and improved pulmonary function test outcomes.	Boskabady *et al.,* 2007

Hypolipidemic/Hypocholesterolemic Effect

Eating a diet high in fats can affect the body in various ways. It often causes an increase in the cholesterol found in the bloodstream. When cholesterol increases along with higher levels of a substance called plasma fibrinogen, it can change how the body breaks down blood clots and how long it takes for blood to clot. This might increase the tendency for blood to clot, which increases the chance of developing atherosclerosis and heart problems. Many studies have shown that high cholesterol and certain types of fat in the blood can lead to these heart issues. Because of this, scientists are looking for ways to lower cholesterol levels, and they are interested in how food can help. The use of spices, which are common ingredients used in cooking, has been carefully studied to determine whether they might help lower cholesterol levels. These studies have been performed in different ways, including testing them on animals and people.

Research indicates that fenugreek seeds and leaves can lower serum cholesterol and triglyceride levels in people with both insulin-dependent and non-insulin-dependent diabetes. Additionally, studying germinated fenugreek seed powder in humans revealed notable changes in the soluble fiber content of the seeds due to germination. When individuals consumed these germinated seeds at a daily dose of 18.0 grams for one month, there was a marked decrease in total and LDL-C levels (Table 11). In the case of cumin, a randomized clinical trial, researchers investigated the effects of cumin powder on the lipid profiles of overweight and obese women. The authors randomly divided 88 women with obesity or overweight issues into two groups. One group consumed 3 grams of cumin powder mixed with yogurt twice a day for three months, while the other group consumed the same quantity of yogurt without cumin powder. The two groups received similar advice on nutritional status 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). Another study on how the addition of coriander seeds to the diet affects lipid metabolism in rats fed a high-fat diet supplemented with cholesterol was performed. The seeds notably reduced lipid levels. In the group of rats given coriander seeds, total cholesterol and triglyceride levels significantly increased. However, compared with those in the control group, the LDL + VLDL cholesterol levels decreased, and the HDL cholesterol level increased. It seems that the increased activity of plasma LCAT (an enzyme), improved breakdown of cholesterol into fecal bile acids, and neutral sterols play a role in reducing cholesterol levels (Dhanapakiam *et al.,* 2007). A further study aimed to explore how fenugreek seeds and a compound within them called trigonelline could address metabolic inflammation and excess very low-density lipoprotein (VLDL) production in insulin resistance. The mice were fed two groups of genetically modified mice, namely, a diet with 2% fenugreek seeds or a regular diet, for 7 weeks. Their findings showed that the fenugreek seed diet reduced the activation of hepatic SREBP-1c and subsequent production of new fats by increasing the expression of the insulin-inducible genes Insig-1 and Insig-2. This led to increased expression of genes involved in burning fat for energy, reducing fat buildup in the liver and VLDL secretion, and improving metabolic inflammation and insulin sensitivity. In laboratory tests using rat liver cells, treating them with trigonelline reproduced the effects observed in the mice. This study revealed a new way in which fenugreek seeds and trigonelline could counteract excess VLDL production and insulin resistance by boosting specific signaling pathways in the liver and reducing metabolic stress. Specifically, fenugreek seeds inhibited the generation of new fats in the liver and subsequent VLDL production by enhancing the activity of Insig-1 and Insig-2, two proteins that control SREBP activation. Furthermore, fenugreek seeds increased the breakdown of fatty acids in the mitochondria by activating PPAR alpha, which further decreased VLDL production and metabolic stress. In laboratory tests, trigonelline was shown to increase the activity of Insig-1 and Insig-2 in liver cells, reduce fat synthesis, lessen ER stress, and lower VLDL-triglyceride production (Khound *et al.,* 2018).

Table 11: Hypolipidemic effects of fenugreek venom in experimental and clinical studies

Human studies	Result demonstrated	Reference
NIDDM patients	Dietary fenugreek reduced blood cholesterol	Sharma, 1986
NIDDM patients	Dietary fenugreek lowered blood cholesterol and triglycerides 85	Sharma and Raghuram, 1990
IDDM patients	Dietary fenugreek lowered blood cholesterol and triglycerides 84	Sharma *et al.,* 1990
Normal subjects	Dietary germinated fenugreek reduced blood total and LDL-cholesterol 92	Sowmya and Rajyalakshmi, 1999

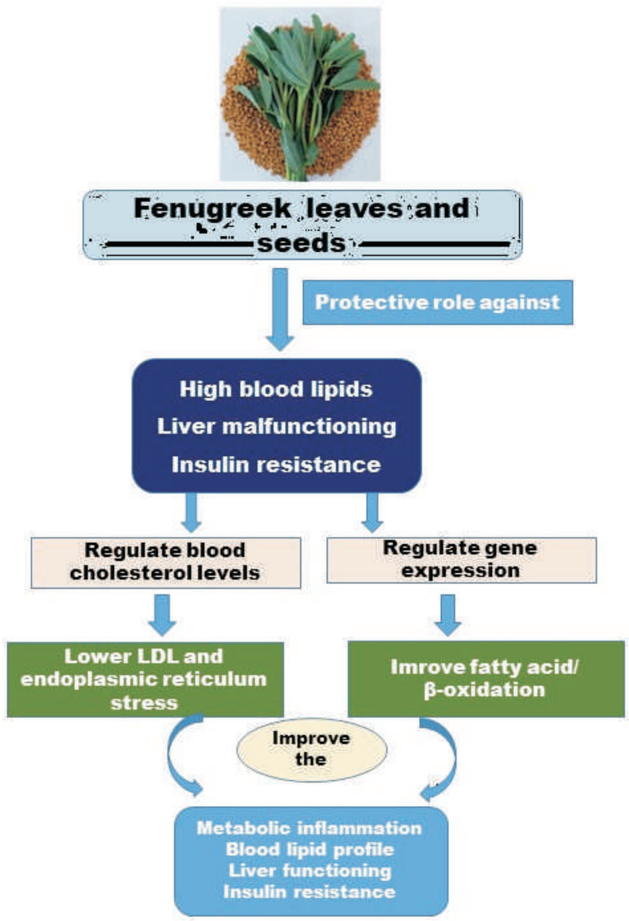

Figure 1. Role of fenugreek leaves and seeds in health (Khound *et al.*, 2018)

Table 12: Documented pharmacological activities of Fennel

Activity	Concentration/ dosages- Dosage form/type of extract- Plant part used	Tested living system/organ/cell/type of study	Results	References
Antihirsutism	Fennel extract (seed)- Creams containing 1%, 2% of fennel extract and placebo	45 female patients aged 16 –53 years with mild to moderate forms of idiopathic hirsutism	Cream containing 2% fennel is better than the cream containing 1% fennel and these two were more potent than placebo	Javidnia *et al.,* 2003
Hypoglycemic	30 mg/kg - Essential oil (seed)	*invivo,* streptozotocin induced diabetic rats	Ingestion of essential oil to diabetic rats corrected the hyperglycemia and the activity of serum glutathione peroxidase and improved the pathological changes noticed in their kid ney and pancreas	Abou El - Soud *et al.,* 2011
Antitumor	25 to 200 µg/mL -Methanolic extract (Fruits)	B16F10 melanoma cell line	70% methanolic extract shows good antitumor activity at the concentration of 200µg/mL.	Pradhan *et al.,* 2008
Antioxidant	100µg of ethanol and water extract - Ethanol and water extract (seeds)	in vitro, not stated	77.5% and 99.1% inhibition of peroxidation in linoleic acid system, respectively.	Oktay *et al.,* 2003
Cytoprotective	200µg/mL - Methanolic extract (Fruits)	Normal human blood lymphocyte	Provides more cytoprotection for normal human lymphocytes as compared with standard sample, that is, doxorubicin	Pradhan *et al.,* 2008
Antiaging	Formulation containing 4% extract -Fennel extract (Seed)	Male volunteers with mean age of 48 years	Formulation showed significant effects on skin moisture and transepidermal water loss	Rasul *et al.,* 2012

Table 13: Documented pharmacological activities of Ajwain

Pharmaceutical benefits	Key points	Reference
Antibacterial effects	The effects of seed extract and essential oil on *Pseudomonas viridiflava*, *Pseudomonas syringae pv. syringae* and *Escherichia coli* have been reported.	Bahuguna *et al.,* 2020
Anticancer Effects	The chemopreventive potential of *Trachyspermum ammi* seeds against carcinogenesis for doses of 2%, 4% and 6% have been reported.	Kim *et al.,* 2016
Antioxidant activity	Its antioxidant activity may be mainly due to the presence of thymol and strong synergism between all monoterpenes and monoterpenoids components of essential oils	Khan and Jameel, 2018 and Wahab *et al.,* 2021
Anti-Inflammatory effects	*T. ammi* essential oil (TAEO) lowers lipo -polysaccharide induced nitric oxide synthesis in macrophages. *TAEO downregulates inducible nitric oxide synthase and hem oxygenase-1 expression.	Dutta *et al.,* 2020
Anti-fungal	Thymol and eugenol are the major contributors to the fumigant antifungal activities against the *Aspergillus ochraceus*, *A parasiticus* and *A. niger*	Aftab *et al.,* 1995

Antidiabetic Potential

A 3-year randomized, controlled, parallel study of the efficacy of fenugreek ($n = 66$) and matched controls ($n = 74$) was conducted on men and women aged 30–70 years with the criterion of prediabetes. Fenugreek powder, 5 g twice a day before meals, was given to the study subjects, and the progression of type 2 diabetes mellitus was monitored at baseline and every 3 months for the 3-year study. By the end of the intervention period, the cumulative incidence rate of diabetes was significantly lower in the Fenugreek group than in the control group. Significant reductions in fasting plasma glucose (FPG), postprandial plasma glucose (PPPG) and low-density lipoprotein cholesterol (LDLc) were observed, whereas the serum insulin concentration increased significantly in the fenugreek group. It was observed that the control group had a 4.2-fold greater likelihood of developing diabetes than did the Fenugreek group. The outcome of diabetes in the Fenugreek cohort was positively associated with the serum insulin concentration and negatively associated with insulin resistance (Gaddam *et al.,* 2015).

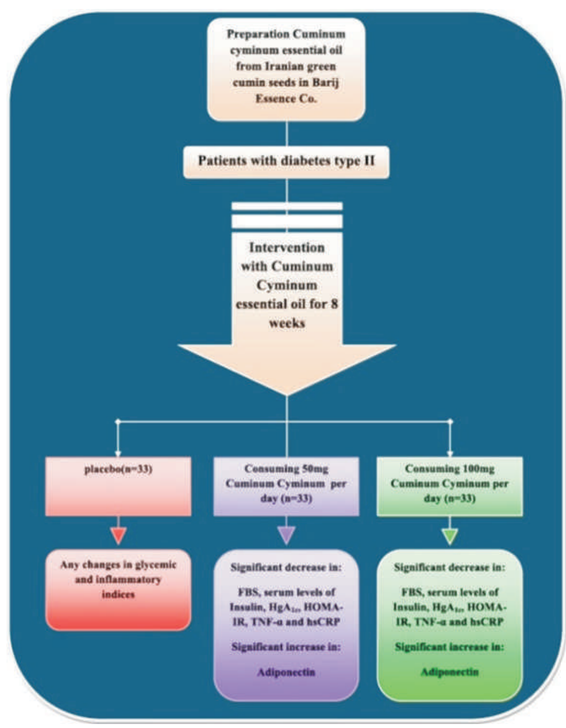

Figure 2. Effect of Cumin essential oil on glycemic indices, insulin resistance (Jafari *et al.*, 2017)

This research examined how a solution made from *Trigonella foenum-graecum* seeds affected the cholesterol levels of recently diagnosed type II diabetic patients. A total of 114 patients without significant diabetes complications were selected. These patients were split into two groups: one group (57 patients) drank 25 grams of *T. foenum-graecum* seed solution twice daily for a month, while the other group (also 57 patients) received metformin. At the end of the study period, the group treated with the seed solution had a notably lower total cholesterol level, approximately 13.6% lower than that of the control group receiving metformin (Geberemeskel *et al.,* 2019).

In the case of seeds, cumin hypoglycemic effects were also observed in normal rabbits (Roman-Ramos *et al.*, 1995). Dietary cumin markedly promoted hypoglycemic responses in streptozotocin-diabetic rats by reducing blood and urinary glucose concentrations. An aqueous extract of cumin seeds decreased blood glucose and plasma and tissue lipid concentrations in alloxan-induced diabetic rats (Willatgamuwa *et al.*, 1998). An herbal diabetes medication that contains cumin as one of its constituents has been successfully tested in human trials (Karnick 1991). The impact of cumin essential oil on different neurological disorders, such as the epileptic activity caused by pentylenetetrazol (PTZ), was also 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 the after polarization 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 suggest that the essential oil of *C. cyminum* might hinder PTZ-induced epileptic activity (Janahmadi *et al.*, 2006). Similarly, coriander is another seed spice whose flavonoids, terpenoids, and phenolic extracts have been proven to be antidiabetic agents. Seed extracts of the Coriander plant are customarily used as antidiabetic agents in some countries, such as southern Arabia and Morocco (Tahraoui *et al.,* 2007; Aissaoui *et al.,* 2011). The ethanolic extracts of seeds possess antidiabetic properties. In one study, mice were injected with a high dosage of glucose after the extract of the seeds (200-250 mg kg^{-1}) was given as a supplement (Gray and Flatt, 1999; Eidi *et al.,* 2009). A decrease in the serum glucose concentration and increase in the activity of beta-cells were detected (Thabrew *et al.,* 2003). Similarly, Samadi *et al.,* 2021 wanted to determine whether fennel or its active component, trans-anethole (TA), could shield rats from liver damage caused by a specific type of diabetes inducer, streptozotocin (STZ). The authors administered a dose of STZ to the rats to induce diabetes, after which the rats were treated with fennel (at doses of 200 and 400 mg kg^{-1}), TA (at 80 mg kg^{-1}), or metformin (at 300 mg kg^{-1}) for 35 days. The authors checked the rats' blood fat levels, liver enzymes, and signs of stress caused by oxygen. They also examined how much damage had occurred in the liver tissue. Both fennel and TA were found to decrease blood sugar levels and lower the activity of liver enzymes. The group also reduced how much food and water the rats consumed and prevented significant weight loss. Furthermore, these treatments decreased the levels of bad fats (triglycerides, total cholesterol, LDL cholesterol) while increasing good cholesterol (HDL cholesterol) levels. Moreover, fennel and TA significantly reduced markers of stress caused by oxygen while enhancing the liver's defense mechanisms against this stress. These compounds also decreased the degree of injury and scarring in the liver tissues of diabetic rats. These findings indicate that extracts from fennel seeds and their active component TA can guard the liver against damage caused by diabetes in rats. This protection likely occurs due to the ability of these bacteria to lower blood sugar levels and act as antioxidants.

Digestive Stimulant Action

In Ayurveda, cumin is considered a warming spice that is invaluable for digestion. It helps burn toxins, thus enhancing appetite. The traditional uses of cumin include anti-inflammatory, diuretic, carminative, and antispasmodic effects. It has also been used to treat dyspepsia, jaundice, diarrhea, flatulence, and indigestion. Cumin powder was used as a poultice, smoked in a pipe, and taken orally. Researchers have studied how water-based extracts from dried cumin fruit leaves could help with stomach ulcers caused by diclofenac sodium in rats by comparing their effects to those of omeprazole. They found that the cumin extract aided in healing ulcers. When they combined extracts of piper betel and cumin, they discovered that they were even more effective at promoting healing than was the use of the extracts alone. These extracts boosted the protection and regeneration of the stomach mucous lining (Pratyusha *et al.,* 2013). Additionally, another study investigated how the water-based extract of cumin seeds affects diarrhea in albino rats. The extract significantly reduced the frequency of diarrhea, delayed the duration of defecation, decreased intestinal fluid secretion, and slowed gut movement compared to those in the control group. The use of different doses of the extract showed that higher doses provided greater protection against diarrhea in a dose-dependent manner (Sahoo *et al.,* 2014). Further exploration of the effects of pretreatment with coriander on gastric mucosal injury in rats revealed that oral doses of 250 and 500 mg kg^{-1} body weight had dose-dependent protective effects on (i) the ulcers caused by various damaging agents; (ii) tissue damage caused by ethanol; and (iii) increased gastric acid secretion and decreased nonprotein sulfhydryl groups (NP-SHs) due to ethanol. The results highlighted Coriander's ability to protect the stomach. The protective effect against ethanol-induced gastric tissue damage could be linked to coriander's antioxidants, such as linanool, flavonoids, coumarins, catechins, terpenes, and polyphenolic compounds, which scavenge free radicals. This protection against ulcers might occur as these compounds form a protective layer through hydrophobic interactions (Al-Mofleh *et al.,* 2006).

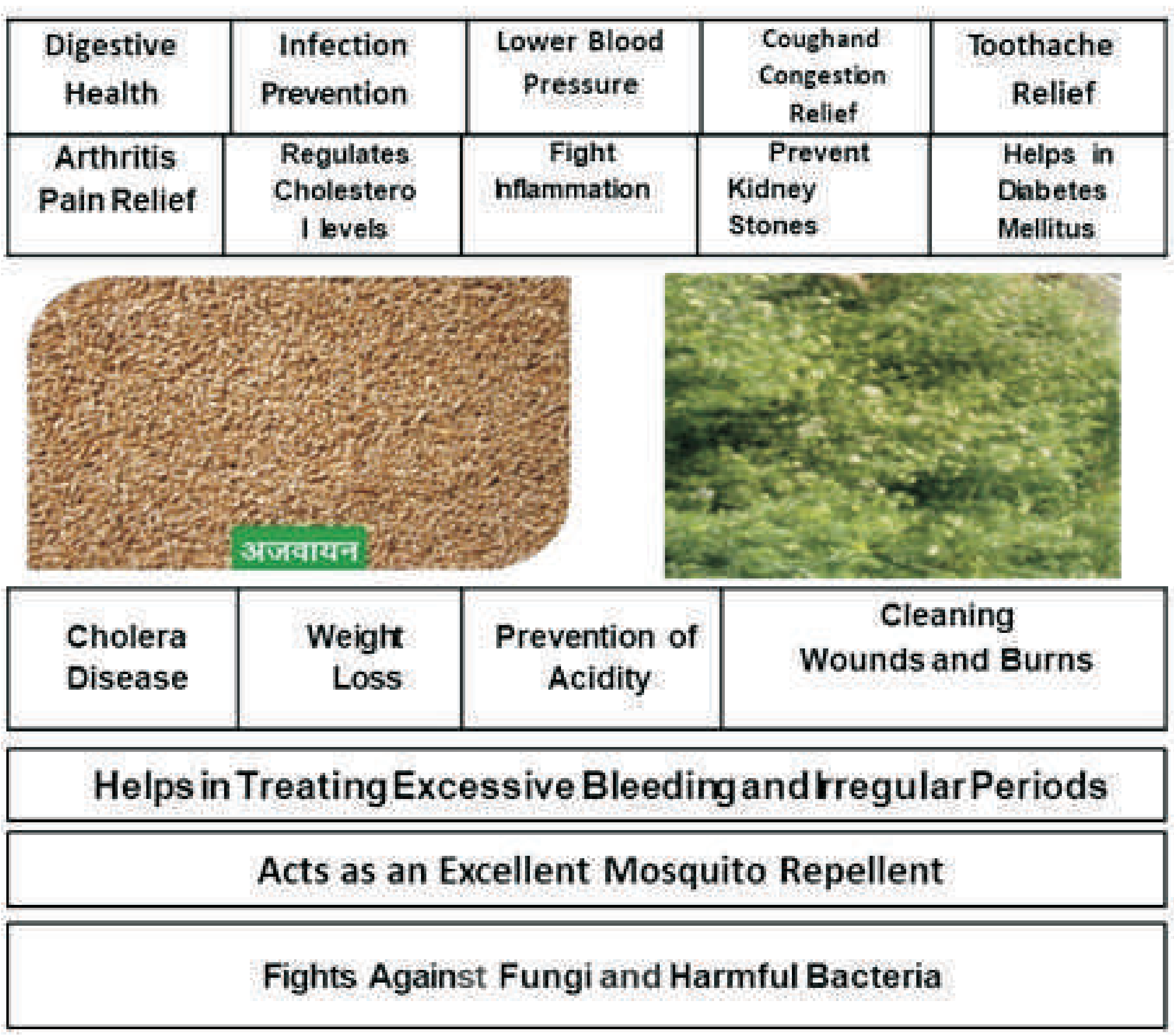

Figure 3. Pharmaceutical Benefits of Ajwain (Shahrajabian *et al.*, 2021)

Antioxidant Properties

Both the leaves and seeds of the coriander plant exhibit antioxidant properties, but the leaves of the plant exhibit greater antioxidant effects. Phenolic and carotenoid extracts of plants are more effective at protecting cells from oxidative damage, as they have greater hydroxyl radical scavenging potential (Lewis and Elvin-Lewis, 1977). This study aimed to explore the effects of the polyphenol fraction of Coriander seeds on diabetes incidence, inflammation, and oxidative stress. The diabetic mice received CS orally for 28 days at doses of 25 and 50 mg kg^{-1} b.w. Their glucose tolerance was tested, and their anti-inflammatory and antioxidant activities were evaluated using two tests (β-carotene discoloration and DPPH). Treating diabetic mice with CS for four weeks effectively alleviated their high blood sugar levels, improved their overall health and demonstrated impressive antihyperlipidemic effects. Oral glucose tolerance tests revealed potent antihyperglycemic effects followed by anti-inflammatory and antioxidant effects. The CS extract was found to contain nine polyphenolic compounds, including flavonoids such as vanillic acid, chlorogenic acid, catechin, epicatechin, oleuropein, epicatechin gallate, rutin, gallocatechin, and epigallocatechin, which contribute to its richness in flavonoids (Mechchate *et al.,* 2021).

Anti-Inflammatory Properties

Cumin extracts in both aqueous and ethanolic forms significantly reduce pain and exhibit strong anti-inflammatory effects on carrageenan-induced paw edema and cotton-pellet granulomas, respectively (Bhat *et al*., 2014). Similarly, cumin essential oil demonstrated a strong dose-dependent analgesic effect on both chronic and inflammatory pain at doses ranging from 0.0125 to 0.20 ml kg^{-1}. However, essential oils do not have anti-inflammatory properties (Sayyah *et al.,* 2002). Compared to those in the control group, the dose-dependent reduction in paw edema in the volatile cumin oil treatment group was dose-dependent at a dose of 0.1 ml kg^{-1}. Its effectiveness was comparable to that of the common medication diclofenac sodium (Shivakumar *et al*., 2010). An additional study on the inhibition of lipoxygenase activity by the methanolic extract of cuminaldehyde revealed that this compound is a 15-LOX inhibitor through activity-guided screening of crude extracts. This aldehyde is a competitive inhibitor of free radicals (Tomy *et al*., 2014).

A traditional formulation from Sri Lanka, Maharasnadhi Quather (MRQ), which contains coriander seeds as the main component, has been reported to have anti-inflammatory and analgesic effects (Jagtap *et al.,* 2004) both in human and animal models. An effective result is obtained when MRQ is supplemented to patients suffering from rheumatoid arthritis, inflammation, liver function and gastrointestinal activity (Reuter *et al.,* 2008). In addition, 40 humans were tested for the anti-inflammatory effect of a combination of 0.5% and 1% coriander oil. Lipolotion effectively reduces UV-induced erythema (Aga *et al.,* 2001)

In another study on ajwain, the anti-inflammatory properties of these two extracts, rat models were tested; one induced acute inflammation (carrageenan-induced rat paw swelling), and the other caused subacute inflammation (cotton pellet-induced granuloma). Aspirin (ASA) and phenylbutazone (PBZ) were used as standard drugs for comparison. At a dose of 100 mg kg^{-1}, both total alcoholic extract (TAE) and total aqueous extract (TAQ) had significant anti-inflammatory effects on both models. In the rat paw swelling test induced by carrageenan, ASA and PBZ inhibited 45.23% and 43.83%, respectively. Comparatively, the TAE and TAQ extracts exhibited 38.32% and 41.11% inhibition, respectively. In the cotton pellet-induced granuloma studies, the TAE and TAQ extracts inhibited the pellet weight by 38.05% and 43.87%, respectively. Moreover, ASA and PBZ inhibited 44.69% and 42.04%, respectively (Thangam *et al.,* 2003).

Antimutagenic and Anticarcinogenic Properties

The study compared how different parts of fenugreek, such as its seeds and sprouts, as well as specific substances found in them, affect the growth and behavior of MCF-7 breast cancer cells. They identified certain chemicals in these fenugreek parts using LCMS. Various flavones and isoflavones were found in the fenugreek extracts. When they tested these extracts on cancer cells using the MTT assay, they noticed that the cells' response depended on the dosage and duration of exposure to the fenugreek extracts. Treating cancer cells with these extracts resulted in changes in cell viability and mitochondrial DNA damage and reduced the spread and growth of cancer cells. This research highlights the potential of fenugreek seeds and sprouts to fight cancer and suggests that fenugreek sprouts, in particular, may contain valuable compounds with health benefits (Khoja *et al.,* 2022). This study investigated the chemopreventive effects of chemically induced Cumin on stomach and uterine cervix tumors. A study of murine models revealed that Cumin has chemopreventive effects on stomach and uterine cervix tumors (Gagandeep *et al.,* 2003).

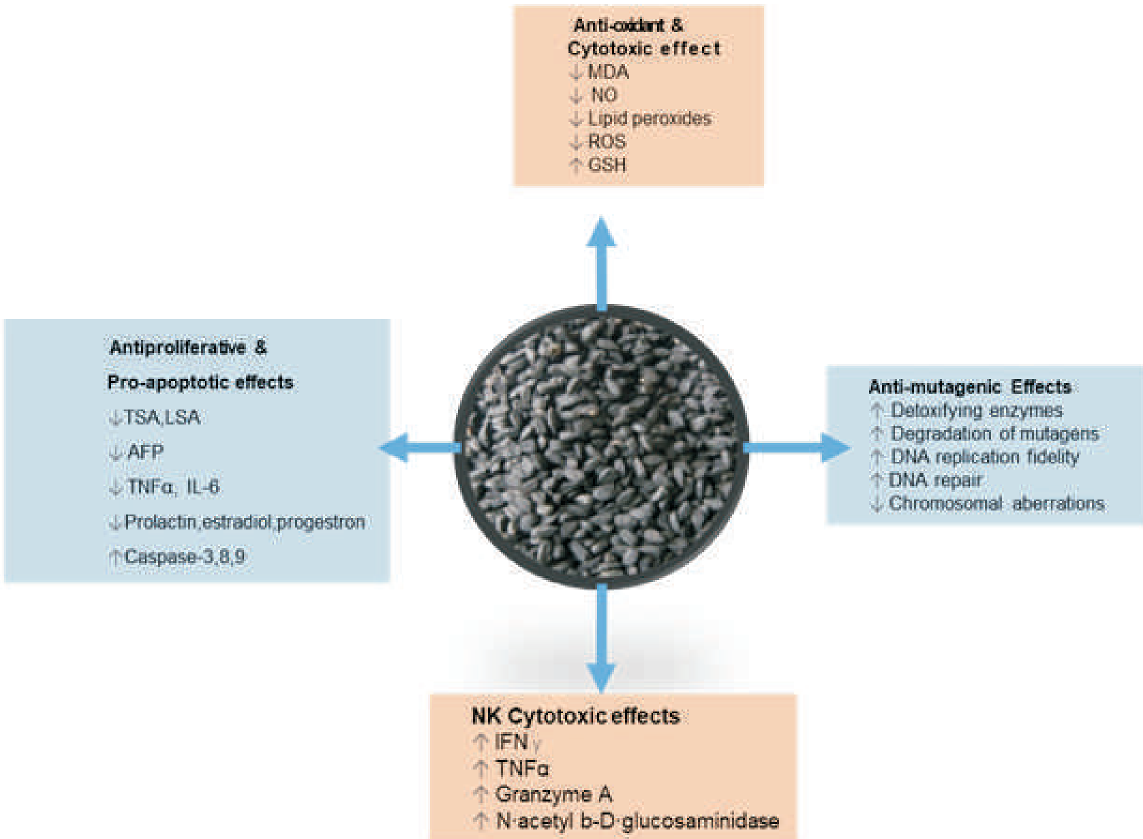

Figure 4. Nigella species have various effects (Majdalawieh and Fayyad, 2016)

(TSA: total sialic acid, LSA: lipid-bound sialic acid, AFP: α-fetoprotein, TNFα: tumor necrosis factor α, IL-6: interleukin-6, MDA: malondialdehyde, NO: nitric oxide, ROS: reactive oxygen species, GSH: glutathione, t-PA: tissue-type plasminogen activator, u-PA: urokinase-type plasminogen activator, PAI-1: plasminogen activator inhibitor type 1, IFNγ: interferon γ). Where : ↑ increase, ↓ decrease

Antimicrobial activity

In the medical field, the essential oil and alcoholic extract of cumin are used as antiseptic and disinfectant agents, respectively (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).

Various studies have been performed on the essential oils of coriander plants because of their different properties, such as antibacterial, antifungal, and cell reinforcement properties (Elgayyar *et al.,* 2001). Analytical examination (GC-MS) has shown a high degree of inhibition against microorganisms (Tolkunova, 2002). Various studies have been performed on the essential oils of coriander plants because of their different properties, such as antibacterial, antifungal, and cell reinforcement properties. Analytical examination (GC-MS) revealed a high degree of inhibition of the microorganisms. Coriander oils also influence the microbiological status of meat products (Delaquis *et al.*, 2002). The antibacterial compound present in the coriander is a protector against Salmonella (Kubo *et al.,* 2004 and Rajeshwari *et al.,* 2011). A reported study was performed to determine the antifungal property of Coriander against *Candida sp.* It was found that the essential oil extracted from coriander leaves possesses antifungal properties (Freires *et al.,* 2014).

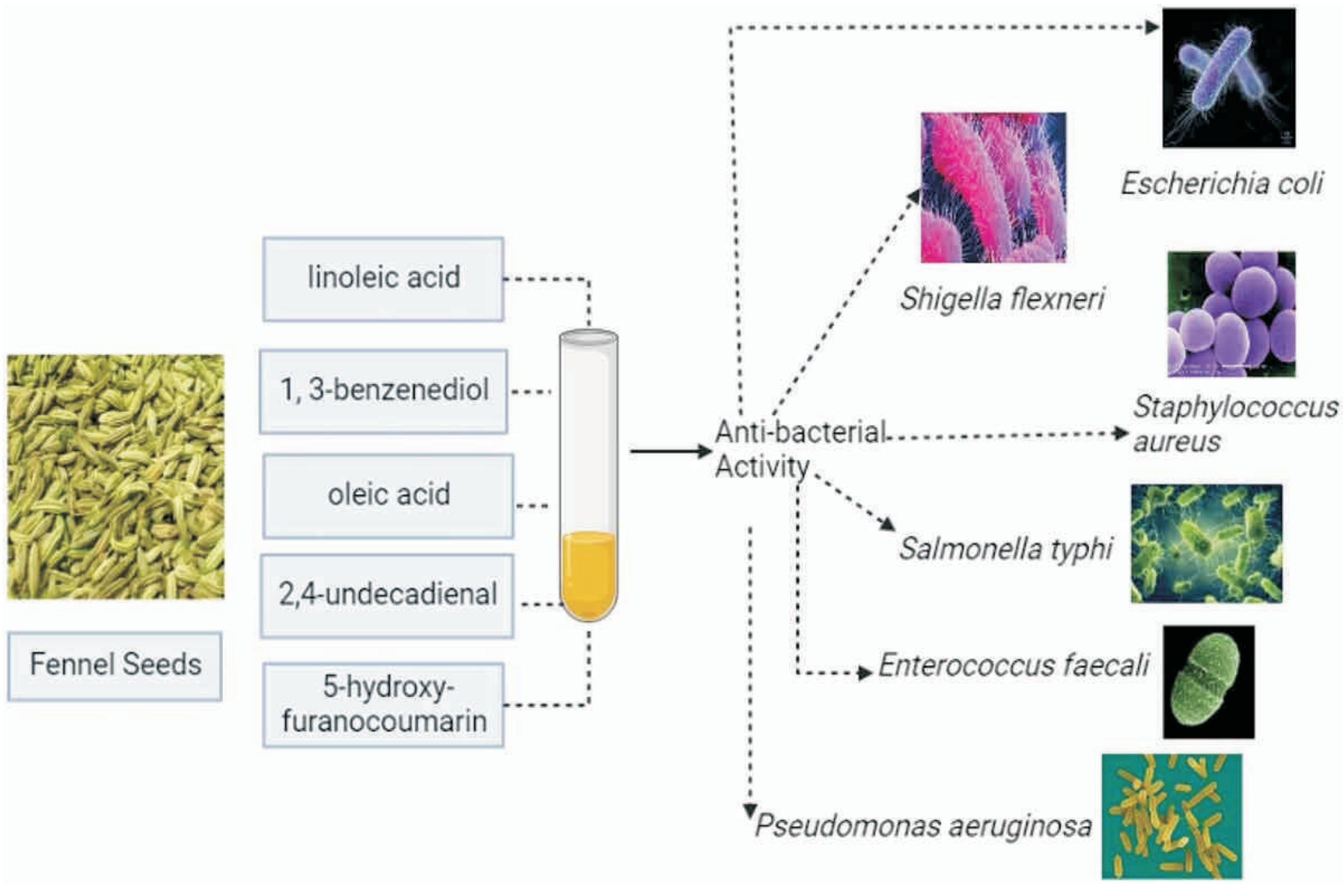

Figure 5. Antibacterial activity of fennel seed extracts (Noreen *et al.*, 2023).

Other Beneficial Physiological Effects

Egyptian women traditionally use fenugreek to increase milk flow and supplementation. The study investigated how adding fenugreek to the diet of new mothers affected the amount of breast milk they produced and the levels of a hormone called prolactin. The authors divided the participating mothers into two groups: one group included 30 mothers who drank fenugreek tea three times a day and whose breasts were pumped eight times daily, while the other group included 30 mothers of similar ages who only pumped their breasts eight times a day without drinking fenugreek tea. On the third day, the fenugreek group produced significantly more breast milk than the control group did (approximately 274.60 ± 46.97 ml compared to 246.37 ± 46.62 ml). However, by the fifth day, there was no significant difference in milk production between the fenugreek group, which produced approximately 485.27 ± 58.84 ml, and the control group, which produced approximately 474.83 ± 59.11 ml (Abdou & Fathey, 2018). Another exploration of the aqueous extract of cumin seeds revealed that this extract prevents the accumulation of advanced glycation end products due to fructose-mediated in vitro glycation of soluble proteins in the eye lens (Lee, 2005). Similarly, the methanolic extract of coriander seeds had an anti-diuretic effect on anesthetized rats, and the results were similar to those obtained with the standard drug furosemide. The seeds of the coriander plant also exert anti-diuretic effects on conscious rats and are recommended for the relief of insomnia in Iranian traditional medicine. In another study on the antihirsutism activity of Fennel, excessive male-pattern hair growth was shown in women with regular ovulation and normal serum androgen levels. In this study, three groups were formed: Group 1 received a cream with 1% fennel extract, Group 2 had a cream with 2% fennel extract, and Group 3 was given a placebo cream without the extract. After 12 weeks, patients applied the creams twice daily on their faces. The results showed mean hair diameter reductions of 7.8%, 18.3%, and -0.5% for the 1%, 2%, and 0% (placebo) groups, respectively (Javidnia *et al.*, 2003).

Conclusion

The exploration of seed spices has transcended their conventional roles as culinary enhancements, delving into their nutraceutical potential and multifaceted health effects. Seed spices, which are traditionally valued for their medicinal properties in traditional medicine systems, have undergone thorough investigation, benefitting from advancements in technology and expanded knowledge of their chemical composition. Pioneering experimental research, comprising both animal studies and human trials, has revealed a myriad of health-promoting attributes associated with these commonplace culinary additives.

The documented health benefits of seed spices include their ability to stimulate digestion and lipid-lowering activities; impact on diabetes management; prevent stone formation; and have antioxidant properties, anti-inflammatory characteristics, and the potential to inhibit mutagenesis and carcinogenesis. Notably, certain spices have emerged as potent nutraceutical agents, particularly for cholesterol reduction and antidiabetic effects, suggesting profound implications for health enhancement. These physiological effects not only underscore the potential nutraceutical applications of seed spices but also suggest promising therapeutic interventions for various disease conditions.

This review paper serves as a comprehensive compilation of experimental evidence highlighting the nutraceutical potential inherent in seed spices. The multifaceted health effects revealed through rigorous scientific investigation pave the way for a deeper understanding of the therapeutic implications of seed spices, positioning them as valuable contributors to health and well-being.

Conflicts of Interest : The authors declare no conflicts of interest.

References

Abdou, R.M. and Fathey, M. 2018. Evaluation of early postpartum fenugreek supplementation on expressed breast milk volume and prolactin levels variation. *Gaz Egypt Paediatr Assoc.*, 66(3):57-60.

Abou El-Soud, N., El-Laithy, N., El-Saeed, G., Wahby, M., Khalil, M., Morsy, F. and Shaffie, N. 2011. Antidiabetic activities of *Foeniculum vulgare* essential oil in streptozotocin-induced diabetic rats. *Macedonian J Med Sci.*, *4*(2):139-146.

Aftab, K. and Usmanghani, K. 1995. Blood pressure lowering action of active principle from *Trachyspermum ammi* (L.) Sprague. *Phytomed, 2*(1):35-40.

Aga, M., Iwaki, K., Ueda, Y., Ushio, S., Masaki, N., Fukuda, S., Kimoto, T., Ikeda, M. and Kurimoto, M. 2001. Preventive effect of *Coriandrum sativum* on localized lead deposition in ICR mice. *J Ethnopharmacol*, *77*(2-3):203-208.

Aissaoui, A., Zizi, S., Israili, Z.H. and Lyoussi, B. 2011. Hypoglycemic and hypolipidemic effects of *Coriandrum sativum* L. in Meriones shawi rats. *J Ethnopharmacol,* 137(1):652-661.

Al-Mofleh, I.A., Alhaider, A.A., Mossa, J.S., Al-Sohaibani, M.O., Rafatullah, S. and Qureshi, S. 2006. Protection of gastric mucosal damage by *Coriandrum sativum* L. pretreatment in Wistar albino rats. *Environ Toxicol Pharmacol,* 22(1):64-69.

Anilakumar, K.R., Khanum, F. and Bawa, A.S. 2010. Effect of coriander seed powder (CSP) on 1,2-dimethyl hydrazine-induced changes in antioxidant enzyme system and lipid peroxide formation in rats. *J Diet Suppl.,* 7(1):9-20.

Bahuguna, A., Ramalingam, S., Arumugam, A., Natarajan, D. and Kim, M. 2020. Molecular and in silico evidence explain the anti-inflammatory effect of *Trachyspermum ammi* essential oil in lipopolysaccharide induced macrophages. *Process Biochem,* 96:138-145.

Bamosa, A.O., Kaatabi, H., Lebdaa, F.M., Elq, A.M. and Al-Sultanb, A. 2010. Effect of Nigella seeds on the glycemic control of patients with type 2 diabetes mellitus. *Indian J Physiol Pharmacol*, 54(4):44-54.

Beikert, F.C., Anastasiadou, Z., Fritzen, B., Frank, U. and Augustin, M. 2013. Topical treatment of tinea pedis using 6% coriander oil in *unguentum leniens*: a randomized, controlled, comparative pilot study. *Dermato,* 226(1):47-51.

Bhat, S.P., Rizvi, W. and Kumar, A., 2014. Effect of *Cuminum cyminum* L. seed extracts on pain and inflammation. *J Nat Remedies*, *14*(2):186-192.

Boskabady, M.H., Javan, H., Sajady, M. and Rakhshandeh, H., 2007. The possible prophylactic effect of *Nigella sativa* seed extract in asthmatic patients. *Fundam Clin Pharmacol,* 21(5):559-566.

Bukhari, H., Shehzad, A. and Saeed, K. 2014. Compositional profiling of fennel seed. *Pak J Food Sci.,* 24:132–136.

Çelik, S. and Ozkaya, A. 2002. Effects of intraperitoneally administered lipoic acid, vitamin E, and linalool on the level of total lipid and fatty acids in guinea pig brain with oxidative stress induced by H_2O_2. *BMB Repo.,* 35(6):547-552.

De Almeida Melo, E., Bion, F.M., Filho, J.M. and Guerra, N.B. 2003. In vivo antioxidant effect of aqueous and etheric coriander extracts. *Eur. J. Lipid Sci. Technol.,* 105(9):483-487.

Deepa, B. and Anuradha, C.V. 2011. Antioxidant potential of *Coriandrum sativum* L. seed extract. *Indian J Exp Biol.*, 49:30-38

Delaquis, P.J., Stanich, K., Girard, B. and Mazza, G. 2002. Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and eucalyptus essential oils. *Inter J Food microb.,* 74(1-2):101-109.

Derakhshan, S., Sattari, M. and Bigdeli, M. 2007. P2081 Evaluation of antibacterial activity and biofilm formation in *Klebsiella pneumoniae* in contact with essential oil and alcoholic extract of cumin seed. *Inter J Antimicrob Agents.*, 29:601.

Dhanapakiam, P., Joseph, J.M., Ramaswamy, V.K., Moorthi, M. and Kumar, A.S. 2007. The cholesterol lowering property of coriander seeds: mechanism of action. *J Environ Biol.*, 29(1):53.

Dutta, S., Kundu, A., Saha, S., Prabhakaran, P. and Mandal, A. 2020. Characterization, antifungal properties and in silico modeling perspectives of *Trachyspermum ammi* essential oil. *Lwt.*, 131:109786.

Eidi, M., Eidi, A., Saeidi, A., Molanaei, S., Sadeghipour, A., Bahar, M. and Bahar, K. 2009. Effect of coriander seed ethanol extract on insulin release from pancreatic beta cells in streptozotocin-induced diabetic rats. *Phytother Res.,* 23(3):404-406.

El-Dakhakhny, M., Mady, N., Lembert, N. and Ammon, H.P.T. 2002. The hypoglycemic effect of *Nigella sativa* oil is mediated by extrapancreatic actions. *Planta medica*, 68(05):465-466.

Elgayyar, M., Draughon, F.A., Golden, D.A. and Mount, J.R. 2001. Antimicrobial activity of essential oils from plants against selected pathogenic and saprophytic microorganisms. *J Food Protect.,* 64(7):1019-1024.

Freires, I.D.A., Murata, R.M., Furletti, V.F., Sartoratto, A., Alencar, S.M.D., Figueira, G.M., de Oliveira Rodrigues, J.A., Duarte, M.C.T. and Rosalen, P.L. 2014. Coriander essential oil: antifungal activity and mode of action on Candida spp., and molecular targets affected in human whole-genome expression. *PLoS One*, 9(6):99086.

Gaddam, A., Galla, C., Thummisetti, S., Marikanty, R.K., Palanisamy, U.D. and Rao, P.V. 2015. Role of Fenugreek in the prevention of type 2 diabetes mellitus in prediabetes. *J Diabetes Met Dis.,* 14:1-10.

Gagandeep, Dhanalakshmi, S., Mendiz, E., Rao, A. R., & Kale, R. K. 2003. Chemopreventive effects of *Cuminum cyminum* in chemically induced forestomach and uterine cervix tumors in murine model systems. *Nutri cancer.*, *47*(2):171-180.

Geberemeskel, G.A., Debebe, Y.G. and Nguse, N.A. 2019. Antidiabetic effect of fenugreek seed powder solution on hyperlipidemia in diabetic patients. *J Diabetes Res.*, 8507453

Gray, A.M. and Flatt, P.R. 1999. Insulin-releasing and insulin-like activity of the traditional anti-diabetic plant Coriander. *Br J Nutr.,* 81(3):203-209.

Heuberger, E., Redhammer, S. and Buchbauer, G. 2004. Transdermal absorption of linalool induces autonomic deactivation but has no impact on ratings of well-being in humans. *Neuropsychopharmaco,* 29(10):1925-1932.

Höferl, M., Krist, S. and Buchbauer, G. 2006. Chirality influences the effects of linalool on physiological parameters of stress. *Planta Medica*,72(13):1188-1192.

Iacobellis, N.S., Lo Cantore, P., Capasso, F. and Senatore, F., 2005. Antibacterial activity of *Cuminum cyminum* L. and *Carum carvi* L. essential oils. *J Agric Food Chem.,* 53(1):57-61.

Igarashi, T. 2013. Physical and psychologic effects of aromatherapy inhalation on pregnant women: a randomized controlled trial. *J Alternat Complement Med., 19*(10):805-810.

Jafari, S., Sattari, R. and Ghavamzadeh, S.I. 2017. Evaluation the effect of 50 and 100 mg doses of *Cuminum cyminum* essential oil on glycemic indices, insulin resistance and serum inflammatory factors on patients with diabetes type II: A double-blind randomized placebo-controlled clinical trial. *J Tradit Complement Med.,* 7(3):332-338.

Jagtap, A.G., Shirke, S.S. and Phadke, A.S., 2004. Effect of polyherbal formulation on experimental models of inflammatory bowel diseases. *J Ethnopharmacol,* 90:195-204.

Janahmadi, M., Niazi, F., Danyali, S. and Kamalinejad, M. 2006. Effects of the fruit essential oil of

Cuminum cyminum on pentylenetetrazol-induced epileptiform activity in F1 neurones of Helix aspersa. *J Ethnopharmacol,* 104:278-282.

Javidnia, K., Dastgheib, L., Samani, S.M. and Nasiri, A. 2003. Antihirsutism activity of fennel extract–a double-blind placebo controlled study. *Phytomed.,* 10:455-458.

Kansal, L., Sharma, V., Sharma, A., Lodi, S. and Sharma, S.H. 2011. Protective role of coriander extracts against lead nitrate induced oxidative stress and tissue damage in the liver and kidney in male mice. *Inter J Appl Biol Pharma Tech*., 2(3):65-83.

Karnick CR. 1991. Aclinical trial of a composite herbal drug in the treatment of diabetes mellitus. *Aryavaid*., 5:36–46.

Khan, N.T. and Jameel, N. 2018. Antifungal activity of Ajawain seeds. *J Biomol Res Ther*., *7*(2):1-2.

Khoja, K.K., Howes, M.J.R., Hider, R., Sharp, P.A., Farrell, I.W. and Latunde-Dada, G.O. 2022. Cytotoxicity of fenugreek sprout and seed extracts and their bioactive constituents on MCF-7 breast cancer cells. *Nutr.,* 14(4):784.

Khound, R., Shen, J., Song, Y., Santra, D. and Su, Q. 2018. Phytoceuticals in fenugreek ameliorate VLDL overproduction and insulin resistance via the insig signaling pathway. *Mol Nutr Food Res.,* 62(5):1700541.

Kim, E., Oh, C.S., Koh, S.H., Kim, H.S., Kang, K.S., Park, P.S., Jang, M.J., Lee, H.R. and Park, I.K. 2016. Antifungal activities after vaporization of ajowan and all spice essential oils and blends of their constituents against three *Aspergillus* species. *J. Essent Oil Res*., 28(3):252-259.

Kivanç, M., Akgül, A. and Doğan, A. 1991. Inhibitory and stimulatory effects of cumin, oregano and their essential oils on growth and acid production of *Lactobacillus plantarum* and *Leuconostoc mesenteroides*. *Inter J Food Microbiol.,* 13(1):81-85.

Kubo, I., Fujita, K.I., Kubo, A., Nihei, K.I. and Ogura, T. 2004. Antibacterial activity of coriander volatile compounds against *Salmonella choleraesuis*. *J Agric Food Chem.,* 52(11):3329-3332.

Kuroda, K., Inoue, N., Ito, Y., Kubota, K., Sugimoto, A., Kakuda, T. and Fushiki, T., 2005. Sedative effects of the jasmine tea odor and (R)-(-)-linalool, one of its major odor components, on autonomic nerve activity and mood states. *Eur J Appl Physiol.,* 95:107-114.

Lee, H.S. 2005. Cuminaldehyde: aldose reductase and α-glucosidase inhibitor derived from *Cuminum cyminum* L. seeds. *J Agric Food Chem., 53*(7):2446-2450.

Lewis, W.H. and Elvin-Lewis, M.P.F. 1977. Plants affecting man's health. *Medic Bot.,* 515.

Majdalawieh, A.F. and Fayyad, M.W. 2016. Recent advances on the anticancer properties of *Nigella sativa*, a widely used food additive. *J Ayur Integ Med.,* 7(3):173-180.

Mechchate, H., Es-Safi, I., Amaghnouje, A., Boukhira, S., A. Alotaibi, A., Al-Zharani, M., A. Nasr, F., M. Noman, O., Conte, R., Amal, E.H.E.Y. and Bekkari, H. 2021. Antioxidant, anti-inflammatory and antidiabetic proprieties of LC–MS/MS identified polyphenols from coriander seeds. *Molecules,* 26(2):487.

Mehri, S., Meshki, M.A. and Hosseinzadeh, H. 2015. Linalool as a neuroprotective agent against acrylamide-induced neurotoxicity in Wistar rats. *Drug Chem Toxicol.,* 38(2):162-166.

Muzzarelli, L., Force, M. and Sebold, M. 2006. Aromatherapy and reducing preprocedural anxiety: A controlled prospective study. *Gastro Nur.,* 29(6):466-471.

Najmi, A., Haque, S.F., Naseeruddin, M. and Khan, R.A. 2008. Effect of *Nigella sativa* oil on various clinical and biochemical parameters of metabolic syndrome. *Dubai Diabetes Endocrinol J.,* 16(2):85-87.

Nalini, N., Manju, V., Menon, VP. 2006. Effect of spices on lipid metabolism in 1,2-dimethylhydrazine induced rat colon carcinogenesis. *J Med Food*, 9(2):237-45.

Ng, W.K., Yazan, L.S. and Ismail, M. 2011. Thymoquinone from *Nigella sativa* was more potent than cisplatin in eliminating of SiHa cells via apoptosis with downregulation of Bcl-2 protein. *Toxicol in vitro*., 25(7):1392-1398.

Noreen, S., Tufail, T., Badar Ul Ain, H. and Awuchi, C.G. 2023. Pharmacological, nutraceutical, functional and therapeutic properties of fennel (*Foeniculum vulgare*). *Inter J Food Prop.,* 26(1):915-927.

Oktay, M., Gülçin, İ. and Küfrevioğlu, Ö.İ. 2003. Determination of in vitro antioxidant activity of fennel seed extracts. *LWT - Food Sci. Technol*., 36(2):263-271.

Pandey, A., Bigoniya, P., Raj, V. and Patel, K.K. 2011. Pharmacological screening of *Coriandrum* *sativum* for hepatoprotective activity. *J Pharm Bioallied Sci.,* 3(3):435.

Peng, L., Liu, A., Shen, Y., Xu, H.Z., Yang, S.Z., Ying, X.Z., Liao, W., Liu, H.X., Lin, Z.Q., Chen, Q.Y. and Cheng, S.W. 2013. Antitumor and anti-angiogenesis effects of thymoquinone on osteosarcoma through the NF-κB pathway. *Onco Repo.,* 29(2):571-578.

Platel, K. and Srinivasan, K. 2000. Influence of dietary spices and their active principles on pancreatic digestive enzymes in albino rats. *Food Nahr.,* 44(1):42-46.

Pradhan, M., Sribhuwaneswari, S., Karthikeyan, D., Minz, S., Sure, P., Chandu, A.N., Mishra, U., Kamalakannan, K., Saravanankumar, A. and Sivakumar, T. 2008. In vitro cytoprotection activity of *Foeniculum vulgare* and *Helicteres isora* in cultured human blood lymphocytes and antitumor activity against B16F10 melanoma cell line. *Res J Pharma Tech.,* 1(4):450-452.

Pratyusha, A.C., Manmohan, B., Raju, S., Bhanuprasad, T., Sruthi, V.V. and Kishore, R.N. 2013. Comparative study of anti-ulcer activity of aqueous extracts of leaves of Piper betel Linn and dried fruits of *Cuminum cyminum Linn* and their combination in rats. *Inte J Adv Res.,* 1(4):192-195.

Rajeshwari, U. and Andallu, B. 2011. Medicinal benefits of coriander. *Spatula.,* 1(1):51-58.

Rasul, A., Akhtar, N., Khan, B. A., Mahmood, T., Zaman, S. U. and Khan, H. M. 2012. Formulation development of a cream containing fennel extract: in vivo evaluation for anti-aging effects. *Inter. J. Pharma Sci.,* 67(1):54-58.

Rathore, S.S., Saxena, S.N. and Singh, B. 2013. Potential health benefits of major seed spices. *Int. J. Seed Spices,* 3:01–12.

Rathore, S.S., Saxena, S.N., Kakani, R.K., Sharma, L.K., Agrawal, D. and Singh, B. 2017. Genetic variation in fatty acid composition of fenugreek seed oil. *Legum Res.,* 40:609–617

Rathore, S.S., Sharma, L.K. and Agarwal, D. 2015. Assessment of variability in leaf essential oil of three coriander genotypes. *Int J Seed Spices,* 5:86–88.

Reuter, J., Huyke, C., Casetti, F., Theek, C., Frank, U., Augustin, M. and Schempp, C. 2008. Anti-inflammatory potential of a lipolotion containing coriander oil in the ultraviolet erythema test. *JDDG: J. Dtsch Dermatol Ges.*, 6(10):847-851.

Roman-Ramos, R., Flores-Saenz, J.L. and Alarcon-Aguilar, F.J. 1995. Anti-hyperglycemic effect of some edible plants. *J. Ethnopharmaco.* 48(1):25-32.

Sahoo, H.B., Sahoo, S.K., Sarangi, S.P., Sagar, R. and Kori, M.L. 2014. Anti-diarrheal investigation from aqueous extract of *Cuminum cyminum*. Seed in Albino rats. *Pharmaco Res.,* 6(3):204.

Samadi-Noshahr, Z., Hadjzadeh, M.A.R., Moradi-Marjaneh, R. and Khajavi-Rad, A. 2021. The hepatoprotective effects of fennel seeds extract and trans-anethole in streptozotocin-induced liver injury in rats. *Food Sci. Nutr.,* 9(2):1121-1131.

Samani, K.G. and Farrokhi, E. 2014. Effects of cumin extract on ox LDL, paraoxanase 1 activity, FBS, total cholesterol, triglycerides, HDL-C, LDL-C, Apo A1, and Apo B in in the patients with hypercholesterolemia. *Int. J. Health Sci.,* 8(1):39.

Samojlik, I., Lakic, N., Mimica-Dukic, N., Đaković-Svajcer, K. and Bozin, B. 2010. Antioxidant and hepatoprotective potential of essential oils of coriander and caraway. *J. Agric. Food. Chem.,* 58(15):8848-8853.

Saxena, S.N., Rathore, S. and Maheshwari, G. 2016a. Analysis of medicinally important compounds and antioxidant activity in solvent extracts of coriander plant parts. *J Spices Aromat Crops,* 25:65–69

Saxena, S.N., Saxena, S. and Rathore, S. 2016b. Effect of cryogenic grinding on phenolic compounds and antioxidant properties of fenugreek seed extract. *J. Spices Aromat. Crops,* 25:73–78.

Sayyah, M., Mahboubi, A. and Kamalinejad, M. 2002. Anticonvulsant effect of the fruit essential oil of *Cuminum cyminum* in mice. *Pharma Biol.,* 40(6):478-480.

Shahrajabian, M. H., Sun, W. and Cheng, Q. 2021. Pharmaceutical benefits and multidimensional uses of ajwain. *Pharmaco Comm.,* 11(2):1-11

Sharaf, A.A., Hussein, A.M. and Mansour, M.Y. 1963. Studies on the antidiabetic effect of some plants. *Planta Medica*, 11(02):159-168.

Sharma, R.D. 1986. Effect of fenugreek seeds and leaves on blood glucose and serum insulin responses in human subjects. *Nutr Res.,* 6(12):1353-1364.

Sharma, R.D. and Raghuram, T.C. 1990. Hypoglycemic effect of fenugreek seeds in noninsulin dependent diabetic subjects. *Nutr Res.,* 10(7):731-739.

Sharma, R.D. Raghuram, T.C. and Rao, N.S. 1990. Effect of fenugreek seeds on blood glucose and serum lipids in type I diabetes. *Eur J Clini Nutr.,* 44(4):301-306.

Shivakumar, S.I., Shahapurkar, A.A., Kalmath, K.V. and Shivakumar, B. 2010. Anti-inflammatory activity of fruits of *Cuminum cyminum. Der Pharm Lett.,* 2(1):22-24.

Shuid, A.N., Mohamed, N., Mohamed, I.N., Othman, F., Suhaimi, F., Mohd Ramli, E.S. and Soelaiman, I.N. 2012. *Nigella sativa*: A potential antiosteoporotic agent. *Evid.-based Complement. Altern.*,1:1-5.

Sowmya, P. and Rajyalakshmi, P.1999. Hypocholesterolemic effect of germinated fenugreek seeds in human subjects. *Plant Foods Hum. Nutr.,* 53:359–365.

Srivastava, N., Tiwari, G. and Tiwari, R. 2010. Polyherbal preparation for anti-diabetic activity: a screening study. *Indian J. Med. Sci.,* 64(4):163.

Tahraoui, A., El-Hilaly, J., Israili, Z.H. and Lyoussi, B. 2007. Ethnopharmacological survey of plants used in the traditional treatment of hypertension and diabetes in southeastern Morocco. *J Ethnopharmacol.,* 110(1):105-117.

Thabrew, M.I., Dharmasiri, M.G. and Senaratne, L. 2003. Anti-inflammatory and analgesic activity in the polyherbal formulation Maharasnadhi Quathar. *J Ethnopharmacol.,* 1:261-7.

Thangam, C. and Dhananjayan, R. 2003. Anti-inflammatory potential of the seeds of *Carum Copticum. Indian J Pharmacol.*, 35(6):388-391.

Tolkunova, N.N. 2002. Effect of essential oils on microbiologic indices of meat products. *Pishchevaya Promyshlennost.,* (12):56-59.

Tomy, M.J., Dileep, K.V., Prasanth, S., Preethidan, D.S., Sabu, A., Sadasivan, C. and Haridas, M. 2014. Cuminaldehyde as a lipoxygenase inhibitor: in vitro and in silico validation. *Appl Biochem Biotechnol.*, 174:388-397.

Wahab, A.T., Ilyas, Q., Farooq, S., Javaid, S., Ahmed, S., Rahman, A.U. and Choudhary, M.I. 2021. In vitro and in vivo anticandidal activity of *Trachyspermum ammi* (L.) seeds ethanolic extract and thymol-containing hexanes fraction. *Nat Prod Res.,* 35(22):4833-4838.

Willatgamuwa, S.A., Platel, K., Saraswathi, G. and Srinivasan, K., 1998. Antidiabetic influence of dietary cumin seeds in streptozotocin induced diabetic rats. *Nutr Res.*, 18(1):131-142.

Wu, Z.H., Chen, Z., Shen, Y., Huang, L.L. and Jiang, P. 2011. Anti-metastasis effect of thymoquinone on human pancreatic cancer. *Acta Pharm Sin B.*, 46(8):910-914.

Zare, R., Heshmati, F., Fallahzadeh, H. and Nadjarzadeh, A. 2014. Effect of cumin powder on body composition and lipid profile in overweight and obese women. *Complement Ther. Clin. Pract.*, 20(4):297-301.