

# *Foeniculum vulgare*: A Review of Its Botany, Phytochemistry, Pharmacology, Traditional uses, Environmental Application, And Toxicology

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**Abstract-** Fennel (*Foeniculum vulgare Mill*) is one of the oldest known spice plants, counted among the world's most important medicinal plants, due to its economic importance and important pharmaceutical industry applications. *Foeniculum vulgare* (fennel) belonging to the *Apiaceae* family is used for many traditional therapeutic purposes. Compiled data on their many in vitro and in vivo pharmacological properties such as antimicrobial, antiviral, anti-inflammatory, antimutagenic, antinociceptive, antipyretic, antispasmodic, antithrombotic, apoptotic, cardiovascular, chemo modulatory, antitumor, hepatoprotective, hypoglycemic, hypolipidemic, and memory-enhancing properties indicate its efficacy.

*Foeniculum vulgare* (fennel) is widely used as a carminative, digestive, galactagogue, and diuretic, gastrointestinal disorders, and in the treatment of respiratory. It is also used as a galactagogue agent for lactating mothers. Its seeds are used as a flavoring in baked goods, meat and fish dishes, alcoholic beverages, ice cream, and herb mixtures.

*Foeniculum vulgare* is responsible for its antioxidant activity. In *Foeniculum vulgare*, volatile aroma compounds make it an excellent flavoring agent. Volatile aroma compounds such as estragole, *trans*-anethole, and fenchone have been reported as major phytoconstituents of *Foeniculum vulgare* (fennel) species. *Foeniculum vulgare* provides a remarkable foundation in pharmaceutical biology for the development/manufacture of new drugs and future clinical uses.

The purpose of the review is to gather information available in this literature regarding botany, traditional uses, phytochemistry, pharmacology, safety, and toxicology of *Foeniculum vulgare*.

**Keywords:** *Foeniculum vulgare Mill*, Taxonomy, Phytochemistry, botanical description, Chemical composition and nutritional value, Traditional and Contemporary Uses, Pharmacological Activities, Environmental Application, Toxicity.

## I. INTRODUCTION

Nowadays medicinal herbs are a good alternative to chemical drugs, one of the major reasons for this is low side effects compared to chemical drugs [1, 2]. Philip Miller first published it in 1768 in the eighth edition of his "Gardner's Dictionary" under the name *Foeniculum vulgare mille*. The name of this plant is written as *Foeniculum vulgare Mill*. It is a medicinal plant that belongs to the *Umbelliferae* (*Apiaceae*) family. *Foeniculum vulgare* has been used by humans since ancient times because of its taste and is cultivated by almost every country [3].

*Foeniculum vulgare Mill* (fennel) is of great importance and used in the pharmaceutical, cosmetic, food, and healthcare industries [4]. It is known worldwide as fennel and is known by over 100 names. It is a traditional and

popular herb everywhere that has a long history of use as a medicine. A series of studies have shown that *Foeniculum vulgare* effectively controls many infectious disorders of bacterial, mycobacterium, fungal, viral, and protozoal origin. [5–9].

*Foeniculum vulgare* has the property of antioxidant, chemopreventive, antitumor, cytoprotective, hypoglycemic, hepatoprotective, and oestrogenic activities [10–14]. Some publications state that *Foeniculum vulgare* has a specific effect on memory enhancement and can also reduce stress [15].

## II. TAXONOMY

Kingdom: *Plantae*,

Division: *Tracheophyta*,

Subdivision: *Spermatophytina*,

Class: *Magnoliopsida*,

Order: *Apiales*,

Family: *Apiaceae*,

Genus: *Foeniculum*,

Species: *Vulgare*, and

Botanical Name: *Foeniculum vulgare* Mill.

## III. BOTANICAL DESCRIPTION

*Foeniculum vulgare* is an ancient seasonal Ayurvedic herb. The fennel plant originated in the southern Mediterranean, and then through naturalization and cultivation, it has grown into forests throughout the northern, eastern, and western Hemi regions, particularly in North America, Asia, and Europe. This herb was well known to the ancient Egyptians, Romans, Indians, and Chinese. The Romans grew it for its aromatic seeds and included it in their diet, which is still practiced today [16].

*Foeniculum vulgare* is an upright, branching herb with softly hairy leaves that can grow up to 6.6 feet (2 m.) Its leaves are up to 40 cm long and finely dissected with filiform (threadlike) about 0.5 mm wide. Its bright golden flowers bloom in July and August. It has a green, smooth and slippery stem with straight stiff branches and many divided leaves in linear segments, length is 0.39–2.4 inches (1–6 cm).

Its fruits are oval, 0.12–0.2 in (3–5 mm) long, and 1.5–2.0 mm wide. The *stylopodium* remains on its fruit. The fruits have long and strong ribs. The best fennel seeds vary in length from three to five rows, they are elliptical, slightly curved, and somewhat thickened at the ends. The fruits of the wild species are smaller, darker and blunter at the ends, and less aromatic than sweet fennel. Its seeds ripen from September to October. The plant can reproduce from root pieces or the crown but it reproduces independently from seed.

## IV. CHEMICAL COMPOSITION AND NUTRITIONAL VALUE

*Foeniculum vulgare* is widely grown for its seeds. They are sweet and dry. Fully ripe seed is a perfect fruit. Its seeds are often dried for later use. *Foeniculum vulgare* is one of the good sources of potassium, sodium,

phosphorus, and calcium. According to USDA data on the Mission variety, fennel is rich in dietary fiber and vitamins. [17].

*Foeniculum vulgare* Leaves and stems have the highest moisture content (76.36 and 77.46 g/100 g), while its inflorescences have the lowest content (71.31 g/100 g). Macronutrient carbohydrates are the most abundant of all parts, ranging from 18.44 to 22.82 g/100 g. It has macronutrients less abundant in protein, reducing sugars, and fats; Protein is present at 1.08 g/100 g in stems and 1.37 g/100 g in inflorescences, the inflorescence and stems of *Foeniculum vulgare* revealed the highest fat content (1.28 g/100 g) and the lowest sugar content (1.49 g/100 g). Based on studies, it can be calculated that a fresh serving of 100 grams of these portions provides an average of 94 kcal of energy. The inflorescence yielded the highest values, while the leaves and stems showed the lowest energy [17].

About twenty-one fatty acids were identified and quantified from all parts of the *Foeniculum vulgare*. These fatty acids are caproic acid, caprylic acid, capric acid, undecanoic acid, lauric acid, myristic acid, myristolic acid, palmitic acid, pentadecanoic acid, heptadecanoic acid, stearic acid, oleic acid, linoleic acid, -linolenic acid, arachidic acid. , Eicosanoic. Acid, cis-11, 14-eicosadenoic acid, cis-11,14,17-eicosatrienoic acid + hencosaenoic acid, behenic acid, trichosanoic acid and lignoceric acid. Thus, the theory of Barros and colleagues considered polyunsaturated fatty acids (PUFAs) the main group of all the fatty acids found in *Foeniculum vulgare* [17].

On the other hand, Vardava and his co-workers identified monounsaturated fatty acids (MUFAs) as the main group of fatty acids present in fennel [18]. The ratio of 6 to 3 fatty acids in the normal diet of humans plays an important role. The highest levels of n-3 fatty acids found in the leaves contributed to the lowest ratio of 6 to 3 fatty acids, and the lowest levels of n-3 fatty acids found in the inflorescence contributed to the highest ratio of 6 to 3 fatty acids. Fennel is low in many other nutrients. *Foeniculum vulgare* contains more calcium (49 mg/100 g) than Apple (7.14 mg/100 g), raisins (40.0 mg/100 g), Banana (3.88 mg/100 g), Dates (25.0 mg/100 g), Grapes (10.86 mg), Orange (40.25 mg/100 g), Prune (18.0 mg/100 g), and strawberries (14.01 mg/100 g).

Phenolics are an important component of fruit quality based on their contribution to the taste, color, and nutritional properties of fruits. The phenolics analyzed in the fruit of the fennel plant were neochlorogenic acid (1.40%), caffeic acid (2.96%), p-coumaric acid. Huh. (4.325%), chlorogenic acid (2.98%), gallic acid (0.169%), chlorogenic acid (6.873%), Ferulic Acid-7-O-Glucoside (5.223%), Quercetin-7-O-Glucoside (3.219%), rosmarinic acid (14.998%), Ferulic Acid (3.555%), 1,5 Dicapoylquinic Acid (4.095%), hesperidin (0.203 %), cinnamic acid (0.131%), quercetin (17.097%), and apigenin (12.558%) [19].

## V. NUTRIENTS FOUND IN DRIED FENNEL (USDA, USA)

*Composition Quantity (Per 100 g)*

*Proximates:* Moisture 90.21 g. Energy 31 kcal. Protein 1.24 g. Total lipid (fat) 0.2 g. Carbohydrate. Total dietary fiber 3.1g. Sugars 3.93g.

*Minerals:* Calcium, Ca 49 mg. Iron, Fe 0.73 mg. Magnesium, Mg 17 mg. Phosphorus, P 50 mg. Potassium, K 414 mg. Sodium, Na 52 mg. Zinc, Zn 0.2 mg.

*Vitamins:* Vitamin C 12 mg. Thiamin B-1 0.01 mg. Riboflavin B-2 0.032 mg. Niacin B-3 0.64 mg. Vitamin B-6 0.047 mg. Folate 27 µg. Vitamin A 48 µg. Vitamin E 0.58 mg. Vitamin K 62.8µg.

*Lipids:* Fatty acids, total saturated 0.09 g. Fatty acids, total monounsaturated 0.068 g. Fatty acids, total polyunsaturated 0.169 g.

*Essential amino acid:* Leucine 0.63 g. Isoleucine 0.73 g. Phenylalanine 0.45 g. Tryptophane 0.53 g.

*Nonessential amino acid:* Glycine 0.55 g. Proline 0.53 g.

The odor of *F. vulgare*, which is due to its essential oil makes it an excellent flavoring agent. This flavoring agent is used in baked meat and fish dishes, ice cream, and alcoholic beverages. The culinary uses of fennel are so widespread. It has been exported from country to country for centuries [17].

## VI. TRADITIONAL AND CONTEMPORARY USES

*Foeniculum vulgare* is used in Ayurveda, Unani, Siddha, Indian, and Iranian traditional medicine and various traditional systems [20]. Its stem, fruit, leaves, seeds, and the whole plant are used as medicines in the treatment of various diseases.

Uses of *Foeniculum vulgare* as a food ingredient worldwide:

In Italy, *Foeniculum vulgare* is called finuccio, fenuccetti-serve egu, finucciello, finocchiato. The *Foeniculum vulgare* stem is used as a flavoring for pickled olives and the seeds are used in preparing salty meats [20] [21]. In Spain, *Foeniculum vulgare* is called Hinojo, Phenol Fiallo, Milau. The tender leaves and stems of *Foeniculum vulgare*, raw as a snack, are used in salads or stews. Its seeds are used to spice olives, as a preservative for dried figs, and to prepare herbal teas or liqueurs [22].

In *Tras-os-Montes* (Northeast Portuguese) *Foeniculum vulgare* is called Fialho, Fionho, Funcho- Amargo, Irva-Dos. The shoots, tender leaves, and stems of *Foeniculum vulgare* are used in snacks, salads, soups, stews, and condiments. The stems of *Foeniculum vulgare* flowers are used in beverages, spirits, and condiments. *Foeniculum vulgare* stems are used as brochettes and herbal teas. *Foeniculum vulgare* seeds are used as a spice in cakes, biscuits, and sweets, and to flavor chestnuts. The entire *Foeniculum vulgare* plant is used to flavor olive brine, fig preserves, and brandy [17]. In Jammu and Kashmir, India, *Foeniculum vulgare* is given in cattle during diarrhea, which stops diarrhea [23]. *Foeniculum vulgare* is used to treat ailments ranging from simple ailments (eg, cough/cold, cuts) to very complex diseases (eg, kidney disease, cancer) [21, 23].

## VII. PHYTOCHEMISTRY

*Plant Chemicals:* Phytochemical research conducted on *Foeniculum vulgare* isolated a few other classes of fatty acids, hydrocarbons, volatile components, phenolic components, and secondary metabolites from its various parts, some of the phytochemicals found in the essential oil. Some plant constituents of *Foeniculum vulgare* have been used for coloring purposes and as anti-aging agents [24, 25].

*Volatile Compounds:* There are 87 volatile compounds practically appearing in any of the *Foeniculum vulgare* parts, namely, roots, stem, shoots, flowers, and fruits [26, 27].  $\alpha$ -Thujene, 1,8-Cineol,  $\beta$ -Ocimene, Linalool, Germacrene D, Anisketone, Apiol, *n*-Hexadecanoic acid, Cubebene, Benzene-1-methyl-4-(1-methylethyl)-*p*-cymene, 1,3,6-Octatriene, 3,7-dimethyl-, (E)- 3-carene, 2-Heptene, 3-Methyl-butanal,  $\beta$ -Pinene, Camphene, Hexanal,  $\alpha$ -Pinene,  $\beta$ -Phellandrene,  $\alpha$ -Phellandrene,  $\beta$ -Myrcene, 4-Carene, 2-Heptanohe, Limonene, 4-Methyl-bicyclo[3.1.0]hex-2- ene, Eucalyptol,  $\alpha$ -Pinene,  $\gamma$ -Terpinene, 7-Dimethyl-1,3,7-octriene. 2,4-Dimethyl-benzenamine, 3-Carene, Cathine, 2-Heptanol, 2-Propyn-1-ol, 2,6-Dimethyl-2,4,6-octatriene, Fenchone, 1- Methyl-4-(1-methylethyl)-benzene, cis-Limonene oxide, trans-Limonene oxide, 6-Methylene- bicyclo[3.1.0]hexane, Sabinene hydrate, Fenchyl acetate, Camphor, Benzaldehyde. 1,3- Butanediol, Dicyclopropyl carbinol, Fenchol, 1-Octanol, 5-Methyl-2-heptanol, Tetradecyl- oxirane, Estragole, Trans-*p*-2,8-menthadien-1-ol,  $\beta$ -Terpinol, cis-*p*-2,8-Menthadien, 4-Methyl-1- (methyl ethyl)-3-cyclohexane, 2-Methyl-5-(1-methyl ethyl)-2-cyclohexene-1-one, Phenylmethyl- formic ester, 2,3-Cyclohexen-1-methanol, Epi-bicyclosesquiphellardrene, cis-*p*-Menth-2,8- dienol, 1,4-Dimethoxy-benzene, 1-Methoxy-4-(1-propenyl)-benzene. 1,2,4a,5,8,8a-Hexadehyde- naphthalene, 4-Methyl-bicyclo[3.1.1]hept-3-en-2-ol, trans-Anethole 73.20 73.27 66.71, Allantoic acid, 2-Methyl-5-(1-methyl ethyl)-phenol, Mannoheptulose, 2-Methyl-5-(1-methyl ethyl)-2- cyclohexene-1-ol, 1-Undecanol, Benzothiazole, E-Pinane, 2-Cyclohexene-1-ol, 2-Methyl- bezenemethanol, 4-Methoxy-benzaldehyde, 1,6-Hexanediol, 2-Methoxycyclohexanone,  $\beta$ - Elemenone, Mephenesin, 4-Methoxy-acetophenone, 2-Methyl-3-methylethyl-butanoic acid, Folic acid, 1-(Methoxyphenyl)-2-propanone, 1-Methyl-3-(1-methylethyl)-benzene, 4-Fluorohistamine. 1,2-Dimethoxy-4-(1-propenyl)-benzene, (E)-2-Hydroxy-4-cyano-stilbene, 1-(3-Methoxyphenyl)- 1-propanone (Figure 1).Yield and composition of volatile components found in pentane extracts of *Foeniculum vulgare* leaves, stems, and seeds. They identified 37 volatile compounds using gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) techniques. In the supercritical CO<sub>2</sub> (SCCO<sub>2</sub>) seed extract of *Foeniculum vulgare*, a total

of 28 compounds were identified, including the major compounds fenchone (8.40–14.7%), *trans*-anethole (68.6–75.0%), and methyl chavicol (5.09–9.10%). Were. Only 19 compounds were detected from *Foeniculum vulgare* I hydrodistilled oil [28, 29].

*Fang et al.* [30] *Foeniculum vulgare* essential oil was characterized by the help of three advanced techniques, namely, gas chromatography-mass spectrometry (HSME-GC-MS), solid-phase microextraction- (SPME-) followed by headspace solvent microextraction. ) GC-MS, and steam distillation- (SD-)GC-MS methods. In 2007 *Tognolini et al* investigated the chemical composition of *Foeniculum vulgare* essential oil. It contains a total of 18 compounds, with anethole being the most abundant [31]. By *Telsi et al.* The different maturation stages of the fruit of *Foeniculum vulgare* concluded that the material becomes deficient in the essential oil with increasing maturity. They identified a total of 28 constituents which is 98.0% of the total oil. [32].

The predominant compound in the essential oil present in *Foeniculum vulgare* was *trans*-anethole (72.2%), followed by estragole (7.6%), d-limonene (6.8%), and fenchone, 3.9% [33]. The hexane extract of *Foeniculum vulgare* was analyzed by GCMS and 78 compounds were identified. These include the major compounds 1,3-benzeniol, 1-methoxycyclohexene, o-cymine, sorbic acid, 2- hydroxy-3-methyl-2-cyclopentane-1-one, estragole, limonene-10-ol, and 3-methyl-2. - Cyclopentane-1-one (Figure 1) was the dominant [34].

*Flavonoids*: Flavonoids are generally regarded as antioxidants. The total flavonoid content in the hydroalcoholic extract is approximately  $12.3 \pm 0.18$  mg/g. Flavonoids such as quercetin-3- rutinoside, eriodictyol-7-rutinoside, and rosmarinic acid have been identified in *Foeniculum vulgare* and have been isolated [35]. Of the flavonoids present in *Foeniculum vulgare*, the most prevalent are isoquercetin, quercetin-3-arabioside, quercetin-3-glucuronide, kaempferol-3- glucuronide and kaempferol-3-arabioside, and isorhamnetin glucoside [36].

Quercetin-3-O-galactoside, kaempferol-3-O-rutinoside, and kaempferol-3-O-glucoside have also been found in aqueous extracts of *Foeniculum vulgare* [37]. Flavonoids such as isorhamnetin 3- O- $\alpha$ -rhamnoside, quercetin, and kaempferol were isolated from ethyl acetate extracts of *F. Vulgare*, while extracts of methanol I quercetin 3-O-rutinoside, kaempferol 3-O-rutinoside, and Quercetin 3-O- $\beta$ -glucoside was present. All these flavonoids exhibit antinociceptive and anti-inflammatory activity [38].

*Phenolic compounds*: Phenolic compounds present in *Foeniculum vulgare* are used for the prevention of diseases induced by oxidative stress such as cardiovascular diseases, cancer, and inflammation. These include glycosides and flavonoid aglycones [37]. In the study, the total phenolic compounds in the methanolic extract of fennel were higher than the flavonoid compounds [19]. *Foeniculum vulgare* has been contained phenolic acids like 3-O-caffeoylquinic acid, 4-O- caffeoylquinic acid, 5-Ocaffeoylquinic acid, 1,3-O-di-caffeoylquinic acid, 1,4-O-dicaffeoylquinic acid, and 1,5-O-di-caffeoylquinic acid (Figure 1) [35].

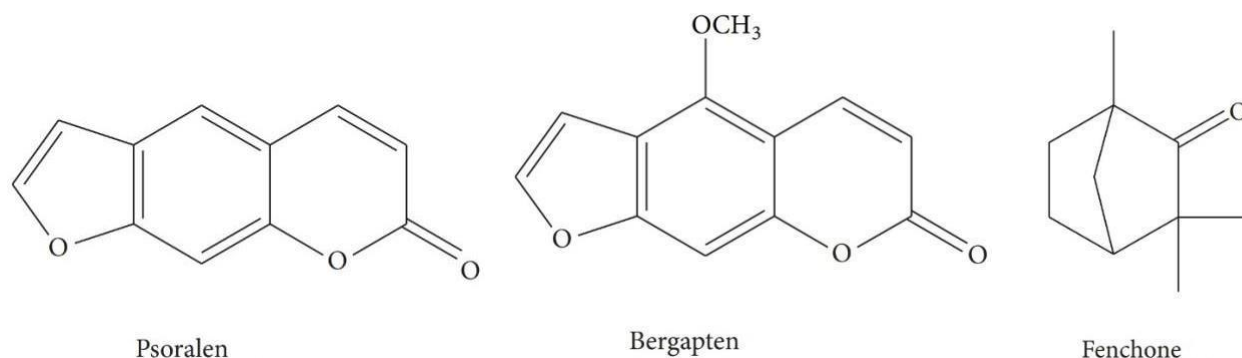
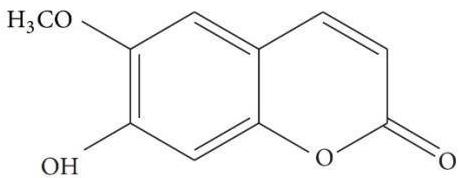
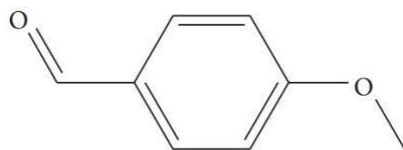


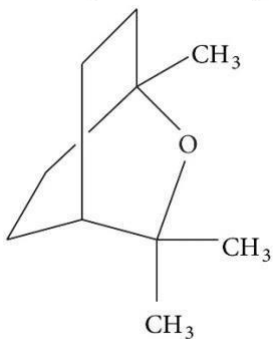
Figure 1



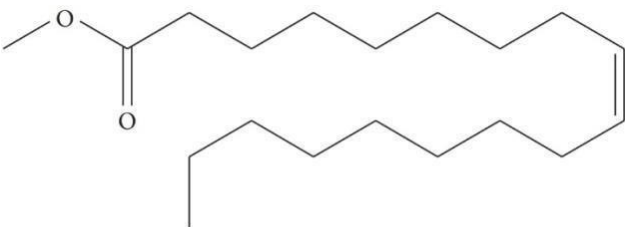
Scopoletin



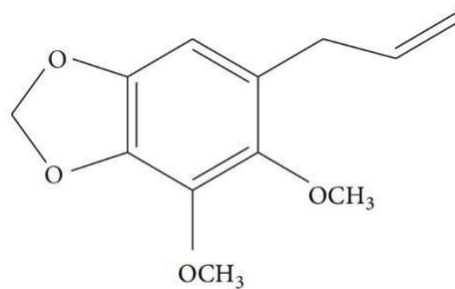
*para*-Anisaldehyde



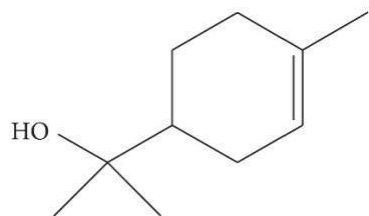
1,8-Cineole



(z)-9-Octadecenoic



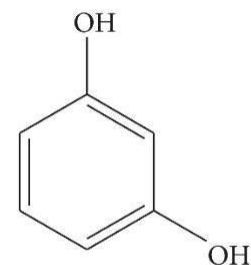
Dillapiol



Terpineol



*trans*-Anethole



1,3-Benzenediol

Figure 1: continued

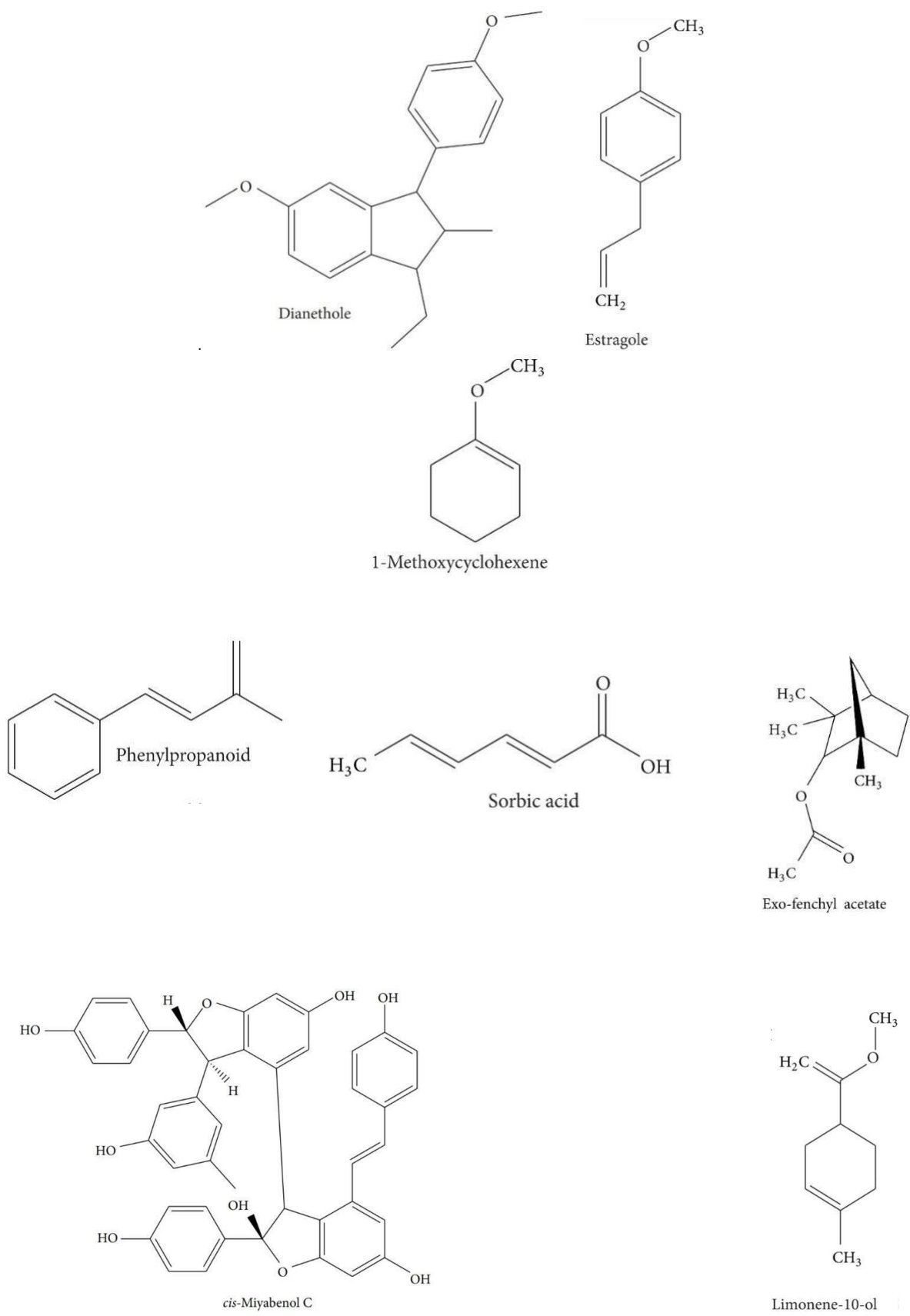
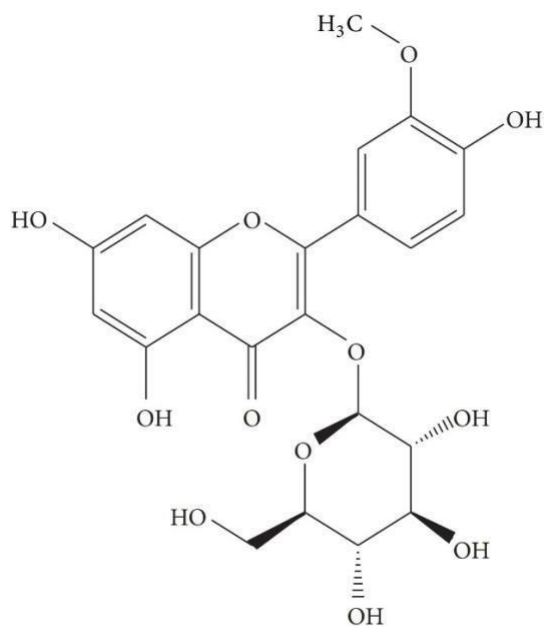
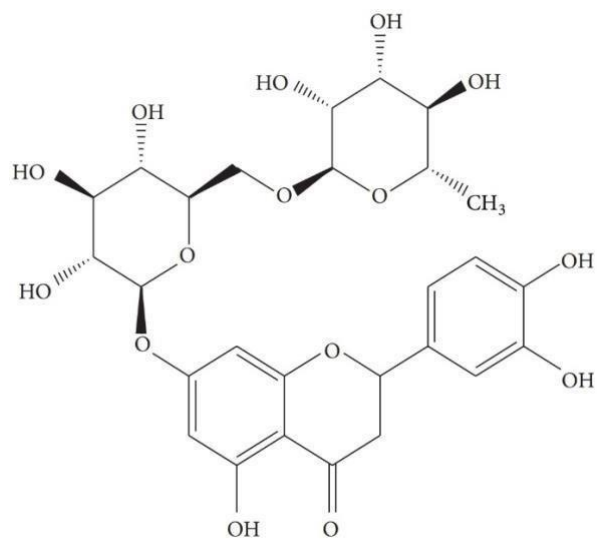


Figure 1: continued.



Isorhamnetin-3-O-glucoside



Eriodictyol-7-rutinoside



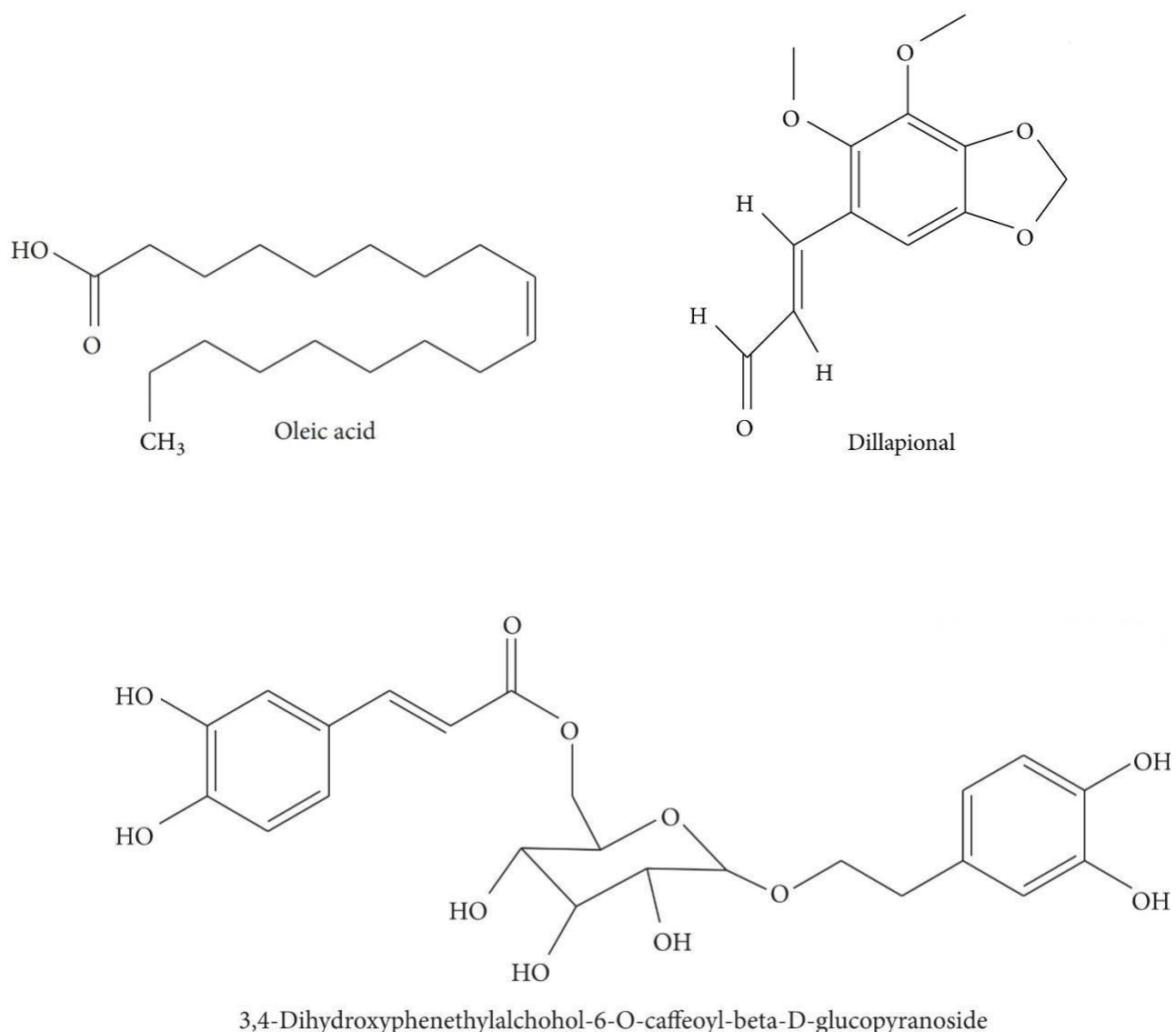


Figure 1: continued.

### VIII. PHARMACOLOGICAL ACTIVITIES

*Foeniculum vulgare* is an important part of the treatment of various diseases and disorders mentioned in Ayurvedic Pharmacopoeia. Compounds isolated from extracts of *Foeniculum vulgare* have been evaluated for several activities, namely, antiaging, anti-colic, antihirsutism, anti-inflammatory, antiallergic, antimicrobial, antiviral, antimutagenic, antinociceptive, antipyretic, antispasmodic, antistress, antithrombotic, anxiolytic, apoptotic, cardiovascular, chemo modulatory action, cytoprotective, antitumor, cytotoxicity, diuretic, estrogenic properties, expectorant, galactogenic, gastrointestinal effects, hepatoprotective, human liver cytochrome P450 3A4 inhibitory, hypoglycemic, hypolipidemic, memory-enhancing properties, nootropic, and oculotropic activities.

*Antimicrobial and antiviral activities:* An aqueous extract of *Foeniculum vulgare* inhibits the growth of *Pseudomonas fluorescens*, *Erwinia carotovora*, and *Pseudomonas glycinea* [39]. The aqueous extract of the seeds inhibited the growth of *Enterococcus faecalis*, *Staphylococcus aureus*, *Escherichia coli*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Salmonella typhimurium*, *Shigella flexneri*, and *Bacillus cereus* [5, 6]. *Galfaraz et al.* [40] investigated the antibacterial effect of the essential oil against *Bacillus cereus*, *Bacillus subtilis*, *Escherichia coli*, *Bacillus megaterium*, *Bacillus pumilus*, *Klebsiella pneumoniae*, *Micrococcus luteus*, *Pseudomonas putida*, *Pseudomonas putida*, and *Candida albicans*. The oil of *Foeniculum vulgare* was found to have significant antimicrobial activities against some microorganisms in comparison with methanolic and ethanolic extracts.

*Robbie et al.* [19] The antimicrobial effect of methanol, ethanol, diethyl ether, and hexane extracts of the seeds of *Foeniculum vulgare* was investigated on two species of Gram-negative bacteria (*Escherichia coli* and *Salmonella typhi*), two species of Gram-positive bacteria (*Bacillus cereus* and *Staphylococcus aureus*), a species of yeast (*Candida albicans*), and a species of mold (*Aspergillus flavus*). The methanolic extract was found to have more effective antimicrobial activity than other extracts. *Srivastava and Bhargava* [41] investigated the antibacterial effect of chloroform and methanol extracts of *Foeniculum vulgare* leaves and flowers *Escherichia coli* and *Staphylococcus aureus*. The methanol extract of the flower of *F. Vulgare* was able to fight against *Escherichia coli*, whereas the chloroform extract failed to exhibit antimicrobial activity against *Staphylococcus aureus*.

*Foeniculum vulgare* has shown significant antifungal activity against the food spoilage fungi *Fusarium oxysporum* and *Aspergillus niger*. It may have important applications as a food additive [42]. *Foeniculum vulgare* showed antifungal activity against pathogenic fungi such as *Aspergillus niger*, *Fusarium solani*, and *Rhizopus solani* [43]. *Foeniculum vulgare* showed antifungal activity against *Candida albicans*. It may be a new and effective antifungal agent for *candidiasis* and other fungal diseases [44].

*Foeniculum vulgare* may reduce the risk of *M. tuberculosis* infection [34]. A total of 78 compounds were identified from *Foeniculum vulgare* with the help of gas chromatography-mass spectra. Twenty of these compounds were tested against *Mycobacterium tuberculosis* and three against MDR strains using Alamar Blue microassay. in which 2,4-undecadienyl was the most active compound against multidrug-resistant *M. tuberculosis* species.

All these literature findings have shown the traditional use of *Foeniculum vulgare* in infectious disorders such as abdominal pain, antiemetic, gout, constipation, dyspepsia, diarrhea, fever, flatulence, gastralgia, gastritis, insomnia, irritable colon, conjunctivitis, mouth ulcers, abdominal pain, skin diseases, respiratory disorders, etc. There is always a need for new antimicrobial agents because of the rapid development of resistance. Its bioactive metabolites of *Foeniculum vulgare* may be a new antimicrobial agent.

*Anti-inflammatory activity:* The anti-inflammatory activity of methanol extract of *Foeniculum vulgare Mill* was evaluated using three screening protocols, carrageenan-induced paw edema, arachidonic acid-induced ear edema, and formaldehyde-induced arthritis. *Kataoka et al* studied the anti-inflammatory effects of *Foeniculum vulgare Mill*. The results showed that the methanol extract of *Foeniculum vulgare Mill* seeds inhibits inflammation via *cyclooxygenase* and through the *lipoxygenase* pathway [46, 47].

*Antibacterial Activity:* *Foeniculum vulgare Mill* is used to treat several fungal, bacterial, viral, and mycobacterial infectious diseases [39]. *Foeniculum vulgare Mill* has antibacterial activity due to compounds such as linoleic acid, undecanoal, 1,3-benzenediol, oleic acid, and 2,4-undecadienyl. *Foeniculum vulgare Mill* contains 5-hydroxy-furanocoumarin which plays an important role in the antibacterial activity of this plant [48]. Aqueous extract of *Foeniculum vulgare Mill* shows bactericidal activity against *Enterococcus faecalis*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Salmonella typhi*, *Salmonella typhimurium* and *Shigella flexneri* [37]. The essence of *Foeniculum vulgare Mill* showed very strong antibacterial activity against pathogens in food such as

*Escherichia coli*, *Listeria monocytogenes*, *Salmonella typhimurium*, *Staphylococcus aureus*, as well as enormous activity against *Helicobacter pylori* and *Campylobacter jejuni* [49, 50].

**Antifungal Activity:** In the studies, *Foeniculum vulgare* Mill extract has antifungal activity against various fungal species such as *Candida albicans*, species of *Aspergillus*, and dermatophytes [20]. Antifungal activity of *Foeniculum vulgare* Mill essence on *Sclerotinia sclerotiorum* was investigated. The antifungal effect of this plant against *Sclerotinia sclerotiorum* was observed based on the existence of microorganisms [51].

**Hepatoprotective activity:** *Foeniculum vulgare* Mill's serum reduces aspartate aminotransferase (AST), alkaline phosphatase (ALP), alanine aminotransferase (ALT), and bilirubin levels. The components *d-limonene* and *-myrcene* found in the essential oil of *Foeniculum vulgare* Mill play an important role in protecting the liver from CCl<sub>4</sub> toxicity [11].

**Anxious Activity:** Anxiety is an unpleasant feeling of fear and worry. When anxiety becomes excessive, it can be considered an anxiety disorder. Naga Kishore *et al* [52] investigated the anxiolytic activity of the ethanolic extract of *Foeniculum vulgare* fruit. Doses of 100 to 200 mg of the extract per kg of animal body weight have shown a significant role in comparison to the reference anxiolytic drug called diazepam (1 mg/kg).

**Antiallergic Activity:** Methanolic extract of *Foeniculum vulgare* fruit showed an inhibitory effect on 2,4-dinitrofluorobenzene. It has an inhibitory effect on immunologically induced swelling. It suggests the possible immunosuppressive properties of *Foeniculum vulgare* Mill's [53].

**Antistress Activity:** *Foeniculum vulgare* Mills are being investigated as remedies for several stress-related disorders [54]. The extract of the entire plant of *Foeniculum vulgare* Mill's acts as an antistress agent [15].

**Nootropic Activity:** Alzheimer's disease is a neurodegenerative disorder. Dementia is one of the age-related mental problems and is characterized as Alzheimer's disease. Methanol extract of the whole plant of *Foeniculum vulgare* administered for eight days ameliorated the effect of scopolamine and anti-aging effect in mice. Thus, *Foeniculum vulgare* Mill's may be employed in the treatment of cognitive disorders such as Alzheimer's disease and dementia as a nootropic and anticholinesterase agent [55].

**Memory-Enhancing Property:** *Foeniculum vulgare* Mill's an ayurvedic herb possessing multiple neuropharmacological activities. The antidepressant activity of *Foeniculum vulgare* Mill's has been well documented in ethnomedicine. The whole plants of Fennel extract exhibited a memory-enhancing effect against scopolamine-induced amnesic rats. This overall progress suggests that *Foeniculum vulgare* Mill's extract possesses memory-enhancing property [15].

**Antihirsutism Activity:** Idiopathic hirsutism is defined as the occurrence of male-like hair growth in women who have normal ovulatory menstrual cycles and normal levels of serum androgens. Perhaps it may be a disorder of peripheral androgen metabolism. Traditionally, the *Foeniculum vulgare* mill has been used as an estrogenic agent. It is known to increase milk secretion, facilitate birth, promote menstruation, and increase libido. Javidnia detected the antihirsutism activity of *Foeniculum vulgare* seed ethanolic extract idiopathic hirsutism by preparing a cream containing 1 and 2% fennel extracts. In which it was found that treatment with a cream containing 2% aniseed was better than a cream containing 1% aniseed and both were more potent than a placebo [56].

**Estrogenic Properties:** Anatole is the main part of the plant *Foeniculum vulgare* which exerts estrogenic properties. Researches have shown that the pharmaceutical agents dianthol and photoanatole are polymers of anthol [47]. *Foeniculum vulgare* has estrogenic effects and is used Ayurvedically to treat infertile women. Research reported that extracts of *Folliculum Vulgare* increased serum concentrations of follicle-stimulating hormone and decreased yolk hormone and testosterone in the treatment groups [57]. The oil of *Foeniculum vulgare* is useful for promoting menstruation, exhibiting estrogenic activity, and reducing female climacteric symptoms, and increasing libido [47].

**Anti-Aging Effects:** Rasul and his coworker developed a base and formulation containing 4% concentrated

*Foeniculum vulgare* seed extract. This formulation shows an anti-aging effect with supporting experimental data related to skin moisture and Tran's epidermal water loss, this formulation possesses potential anti-aging effects [25].

*Bronchodilatory Effect:* *Foeniculum vulgare* Ethanol extract and *Foeniculum vulgare* essential oil exhibited bronchodilatory activity on contracted tracheal chains of guinea pig. *Foeniculum vulgare* may contribute to its sedative effect on guinea pig tracheal chains [73].

*Antioxidant Activities:* Phenolic compounds in *Foeniculum vulgare* such as caffeoylquinic acid, quercetin-3-O-galactoside, rosmarinic acid, eriodictyol-7-orutinoside, kaempferol-3-O-glucoside showed antioxidant activity [41]. In another study, the antioxidant activity of aqueous and ethanol extracts of *Foeniculum vulgare* seeds was evaluated by using different antioxidant methods such as total antioxidant, superoxide anion radical scavenging, free radical scavenging hydrogen peroxide scavenging, metal chelating activity. The study showed that *Foeniculum vulgare* seed was a potential source of natural antioxidants [12]. *Foeniculum vulgare* act as Natural antioxidants that can be used to protect human beings from oxidative stress damage [74]. Phenolic compounds of *Foeniculum vulgare*, including caffeoylquinic acid, quercetin-3-O-galactoside, rosmarinic acid, eriodictyol-7-orutinoside, and kaempferol-3-O-glucoside, showed antioxidant activities [37]. *Foeniculum vulgare* volatile oil showed strong antioxidant activity but water and Ethanol extracts of *Foeniculum vulgare* showed less antioxidant activity compared with its essential oil [26].

*Anti-anxiety activity:* *Foeniculum vulgare* use in the treatment of estrogen deficiency abnormalities. Estrogens hormones are involved in the phenomenon of anxiety. *Foeniculum vulgare* probably is an herbal remedy that has drowsiness or dizziness effects mediated by the GABA-ergic system and estrogen receptors [75]. *Foeniculum vulgare* extract showed stress reduction and memory enhancement in rats with several functions such as anti-stress proceeding, increase in memory and antioxidant effects may reduce stress and stress-related disorders [15].

## IX. ENVIRONMENTAL APPLICATION

*Foeniculum vulgare*, not only exhibited pharmacological activities but also revealed a few environmental activities. These activities play a key role in the management of mosquitoes, nematodes, insects, and some harmful larvae of malaria vector. *Foeniculum vulgare* extracts have been evaluated for their insecticidal, repellent, acaricidal, larvicidal, and nematocidal activity.

*Insecticidal Activities:* *Foeniculum vulgare* fruit biologically active constituents, that is, phenylpropenes (E)-anethole and estragole, and the monoterpene (+)-fenchone exhibited prominent insecticidal activities against *Callosobruchus Chinensis*, *Sitophilus oryzae*, and *Lasioderma serricorne* using direct contact application and fumigation methods. *Foeniculum vulgare* is A naturally occurring insect-control agent that could be useful for managing field populations of *S. oryzae*, *C. Chinensis*, and *L. serricorne* [76].

*Acaricidal Activity:* *Foeniculum vulgare* oil shows significant acaricidal activity against *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*. P-anisaldehyde was the most toxic compound. P-anisaldehyde is much more effective compared with thymol benzyl benzoate, and estragol [77].

*Repellent Activity:* *Foeniculum vulgare* methanolic extract of fruits was spectroscopic. *Foeniculum vulgare* repellent activity of (+)-fenchone and (E)-9-octadecenoic acid constituents was tested against hungry *Aedes aegypti* females with the help of skin and patch tests and compared with that of the commercial repellent agent called (Z)-9-octadecenoic acid and N, N- diethylm-toluamide (DEET). Thus, (E)-9-octadecenoic acid and (+)-Fenchone are potential mosquito repellent agents [78].

*Larvicidal Activity:* The *Foeniculum vulgare* oil was the most effective against *A. stephensi* with LC (50) and LC (90) [79]. The larvicidal activity of essential oil of *Foeniculum vulgare* seed against *Culex pipiens* mosquito. Thus, *Foeniculum vulgare* can serve as a natural larvicidal agent [80].

## X. TOXICITY

Shah and his coworker in 1991 investigated the detailed toxicity account of *Foeniculum vulgare* ethanolic extract

of fruit that showed general symptoms of toxicity and mortality for only 24 h in acute toxicity and showed toxicity on mice with 90 days long term treatment . Thus, *Foeniculum vulgare* fruit ethanolic extract is safe based on both acute or long-term toxicity studies [81]. Long term treatment does not show any type of toxicity against several parameters tested, namely, bizarre reactions, locomotor activity, sensitivity to sound, social interaction, tail posture, convulsions, aggressive behavior, ataxia, paralysis, tremors, prostration, exophthalmos, urination, the pattern of respiration, pupil size, defecation, salivation, nasal discharge, cyanosis, and piloerection [62]. Estragole compounds of *Foeniculum vulgare* extract led to the development of malignant tumors in rodents but carcinogenicity in humans has not been established, so the use of Estragole compounds is restricted [82]. It has been reported that normal therapeutic doses of 695 mg/kg of Anatole cause mild liver toxicity [83].

## XI. CONCLUSIONS

The scientific research on *Foeniculum vulgare* has shown that it is an important medicinal plant used in ethnomedical treatments, especially for abdominal pains, antiemetic, colic in children, conjunctivitis, aperitif, arthritis, cancer, constipation, depurative, diarrhea, dieresis, emmenagogue, irritable colon, kidney ailments, fever, flatulence, gastralgia, gastritis, insomnia, as a laxative, leucorrhoea, liver pain, mouth ulcer, and stomachache without any serious side effects.

Studies have shown that various extracts of *Foeniculum vulgare* have pharmacological actions, such as anti-aging, anti-inflammatory, antimicrobial, antiallergic, anticolitic, antihirsutism, antiviral, antimutagenic, antinociceptive, antipyretic, antispasmodic, antistress, antithrombotic, anxiolytic, apoptotic, cardiovascular, chemo modulatory action, cytotoxicity, diuretic, cytoprotection and antitumor, estrogenic properties, expectorant, galactogenic, gastrointestinal effect, hepatoprotective, human liver cytochrome P450 3A4 inhibitory, hypoglycemic, hypolipidemic, memory-enhancing property, nootropic, and oculohypotensive activity supporting its traditional use. Most effective antimicrobial and antioxidant properties, the studies have shown health benefits of *Foeniculum vulgare* various phytochemicals compounds like volatile compounds, flavonoids, phenolic compounds, fatty acids, and amino acids and also contains mineral and trace elements like calcium, aluminum, chromium, copper, barium, cadmium, cobalt, iron, magnesium, manganese, nickel, lead, strontium, and zinc [84].

*Foeniculum vulgare* also contains fat-soluble vitamins such as vitamins A, E, and K. *Foeniculum vulgare* contains water-soluble vitamins like ascorbic acid, thiamine, riboflavin, niacin, and pyridoxine; essential amino acids like leucine, isoleucine, phenylalanine, and tryptophane. Researchers have proven that *Foeniculum vulgare* is a very useful herb used to treat various diseases and traditional use without any side effects.

*Foeniculum vulgare* needs to be further studies to fully recognize its beneficial effects for society.

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