



Bioactive Compounds and Therapeutic Potential of *Foeniculum vulgare* (Saunf): Insights from Phytochemical and Pharmacological Studies

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Abstract

Saunf (*Foeniculum vulgare* Mill.), commonly known as fennel, is a widely utilized medicinal and aromatic plant belonging to the Apiaceae family, with a long history of use in traditional systems of medicine such as Ayurveda, Unani, and Siddha. It is extensively valued for its digestive, carminative, galactagogue, and therapeutic properties. The plant is rich in a diverse range of bioactive phytoconstituents, including volatile oils (predominantly trans-anethole, fenchone, and estragole), flavonoids, phenolic acids, fatty acids, and sterols, which contribute significantly to its pharmacological activities.

Recent scientific studies have provided substantial evidence supporting its traditional uses, highlighting its antioxidant, antimicrobial, anti-inflammatory, hepato protective, hypoglycemic, cardioprotective, and anticancer potentials. These biological effects are mediated through mechanisms such as free radical scavenging, modulation of enzymatic pathways, hormonal activity, and inhibition of pathogenic microorganisms. Additionally, fennel exhibits notable effects on gastrointestinal health, respiratory conditions, and reproductive functions, further reinforcing its role as a functional food and phyto medicine.

Despite its wide therapeutic applicability and general safety profile, certain constituents such as estragole require cautious use due to potential toxicological concerns at higher doses. This review comprehensively summarizes the phytochemical composition, therapeutic applications, mechanisms of action, and safety aspects of *Foeniculum vulgare*, while also emphasizing the need for further clinical validation, standardization of extracts, and exploration of its potential in modern drug development and nutraceutical formulations.

Keywords: Saunf, *Foeniculum vulgare*, phyto chemistry, therapeutic uses, fennel seeds, medicinal plants



1. Introduction

Medicinal plants have served as the cornerstone of traditional healthcare systems for centuries, providing a rich source of bioactive compounds for disease prevention and treatment. Among these, *Foeniculum vulgare* (saunf) occupies a prominent position due to its wide spectrum of therapeutic applications and culinary importance^{1, 2}. Native to the Mediterranean region, fennel is now cultivated extensively across Europe, Asia, and Africa, with India being one of the leading producers and consumers. In Indian culture, fennel seeds are commonly consumed after meals as a natural digestive aid, reflecting their long-standing role in promoting gastrointestinal health¹.

Saunf (*Foeniculum vulgare* Mill.), a member of the Apiaceae family, is a highly valued medicinal and aromatic plant widely used in traditional systems of medicine such as Ayurveda, Unani, and Siddha. Historically, it has been employed for its carminative, digestive, expectorant, and galactagogue properties, and is often recommended for managing conditions such as indigestion, flatulence, respiratory disorders, and menstrual irregularities¹. Its widespread traditional use has attracted considerable scientific attention in recent decades, leading to extensive pharmacological investigations.

The therapeutic potential of fennel is primarily attributed to its rich and diverse phytochemical composition. The plant contains significant amounts of volatile oils, particularly trans-anethole, estragole, and fenchone, which are responsible for its characteristic aroma and biological activities. In addition, fennel is a valuable source of flavonoids, phenolic acids, fatty acids, and sterols, which contribute to its antioxidant and disease-preventive properties^{1, 8}. These phyto constituents have been shown to exert multiple pharmacological effects, including antimicrobial, anti-inflammatory, hepato protective, hypoglycaemic, cardio protective, and anticancer activities^{2, 9}



Botanically, *Foeniculum vulgare* is a hardy, perennial herb characterized by erect, hollow stems, finely dissected feathery leaves, and clusters of small yellow flowers arranged in umbels. The fruits, commonly referred to as seeds, are elongated, aromatic, and constitute the most widely used part of the plant. However, other parts such as leaves, roots, and essential oils are also utilized for medicinal and culinary purposes². The inclusion of fennel in various pharmacopoeias and traditional medicinal formulations further highlights its therapeutic significance and safety profile¹.



In recent years, there has been growing interest in fennel as a functional food and nutraceutical due to its ability to provide both nutritional and health benefits. Scientific validation of its traditional claims, coupled with emerging evidence from modern research, underscores its potential role in the prevention and management of chronic diseases. Despite these advances, further studies are required to standardize its extracts, elucidate precise mechanisms of action, and establish clinical efficacy.

Therefore, the present review aims to provide a comprehensive overview of the phytochemical composition and therapeutic applications of *Foeniculum vulgare*, along with its mechanisms of action, safety aspects, and future research perspectives.

2. Botanical Description

Foeniculum vulgare is a hardy, perennial herb belonging to the family Apiaceae. It can grow up to 2.5 meters in height and has hollow stems with finely dissected leaves². The plant produces small yellow flowers arranged in umbels, and its fruits (seeds) are elongated and aromatic³. Two main varieties are recognized:

- Sweet fennel (*F. vulgare* var. *dulce*)
- Bitter fennel (*F. vulgare* var. *vulgare*)²

Fennel typically grows as an erect, branching plant and can reach a height of up to 2–2.5 meters under favourable growing conditions. The stems are smooth, cylindrical, hollow, and green, providing support to the plant while allowing it to grow tall and spread out. These stems often branch toward the upper part of the plant, giving it a light and feathery appearance. The leaves of fennel are finely divided and thread-like, forming delicate segments that resemble soft needles or filaments. These leaves are bright green and highly aromatic when crushed due to the presence of volatile oils. The finely dissected leaf structure helps the plant reduce water loss and also gives it its characteristic feathery look. The plant produces small, bright yellow flowers that are arranged in clusters called umbels, a typical characteristic of plants in the Apiaceae family. Each umbel contains numerous tiny flowers that attract pollinators such as bees and other insects. Flowering usually occurs during the warm season and is followed by fruit formation. The fruits of fennel, commonly referred to as fennel seeds, are actually dry, elongated schizocarps. These fruits are slightly curved, greenish to brown in colour, and strongly aromatic. They contain essential oils that give them their sweet and spicy flavour. Fennel seeds are widely used as a spice in cooking and also in traditional medicine for their digestive and therapeutic properties.

Overall, the botanical structure of fennel including its tall hollow stems, feathery leaves, yellow umbels, and aromatic seeds makes it a distinctive and valuable herb in both agriculture and herbal medicine.

3. Phytochemistry of Saunf

The seeds of *Foeniculum vulgare*, commonly known as Fennel or saunf, contain a wide range of bioactive phytochemicals responsible for their characteristic aroma, flavour, and medicinal properties. Phytochemical investigations have revealed the presence of volatile oils, phenolic compounds, flavonoids, fatty acids, sterols, and other secondary metabolites. These constituents contribute to the plant's antioxidant, antimicrobial, anti-inflammatory, and digestive properties, making fennel an important medicinal and culinary herb.



3.1 Volatile Oils

The essential oil content of fennel seeds ranges from 1–6% and contains key compounds such as trans-anethole, fenchone, estragole, and limonene^{2, 8}. These volatile compounds are responsible for the characteristic aroma and many pharmacological activities of fennel.

The major components of fennel essential oil include trans-anethole, fenchone, estragole, and limonene. Among these, trans-anethole is the predominant compound and contributes largely to the sweet, anise-like flavor of fennel. It also exhibits several pharmacological properties such as antioxidant, antimicrobial, and digestive stimulant activities.

Fenchone is another important constituent that provides a slightly bitter taste and contributes to the carminative and digestive properties of fennel. Estragole enhances the aromatic profile of the essential oil, while limonene imparts a mild citrus-like fragrance and demonstrates anti-inflammatory and antioxidant activities. Collectively, these volatile compounds play a major role in fennel's therapeutic and medicinal applications, particularly in digestive and respiratory health.

3.2 Phenolic Compounds and Flavonoids

Fennel contains various phenolic compounds such as caffeoylquinic acids, rosmarinic acid, quercetin, and kaempferol^{1, 8}. These compounds exhibit strong antioxidant activity and contribute to disease prevention⁹.

Rosmarinic acid is a potent antioxidant with anti-inflammatory and antimicrobial properties. Quercetin is widely recognized for its anti-allergic, anti-inflammatory, and immunomodulatory effects, while kaempferol has been associated with protective effects against cardiovascular diseases and certain cancers.

Due to their antioxidant potential, these phenolic compounds contribute significantly to disease prevention and overall health maintenance.

3.3 Fatty Acids and Lipids

The seeds contain fixed oils rich in petroselinic acid, oleic acid, and linoleic acid². These fatty acids play a role in metabolic regulation and cardiovascular health¹⁰. The principal fatty acids identified in fennel seeds include petroselinic acid, oleic acid, and linoleic acid. Petroselinic acid, a characteristic fatty acid found in members of the Apiaceae family, plays a role in lipid metabolism and cellular functions. Oleic acid, a monounsaturated fatty acid, is known to support cardiovascular health by improving lipid profiles and reducing harmful cholesterol levels. Linoleic acid, an essential polyunsaturated fatty acid, is important for maintaining cell membrane integrity, metabolic regulation, and inflammatory balance. These fatty acids enhance the nutritional and therapeutic value of fennel seeds, particularly in relation to metabolic health and cardiovascular protection.

3.4 Sterols and Other Constituents

Other important phytochemicals include phytosterols, coumarins, tannins, and alkaloids^{1, 2}. These compounds collectively contribute to the pharmacological effects of fennel. Phytosterols are structurally similar to cholesterol and are known to help reduce blood cholesterol levels by inhibiting its absorption in the intestine. Coumarins possess anticoagulant, antimicrobial, and anti-inflammatory properties, contributing to the medicinal value of fennel. Tannins are polyphenolic compounds that exhibit antioxidant and antimicrobial effects, while alkaloids, although present in smaller amounts, may contribute to various pharmacological activities. The combined presence of these phytochemicals results in the synergistic pharmacological effects of fennel, supporting its traditional use in treating digestive disorders, respiratory conditions, and metabolic diseases.



4. Therapeutic Uses of Saunf

The seeds of *Foeniculum vulgare*, commonly known as Fennel or saunf, have been widely used in traditional medicine systems for centuries due to their diverse pharmacological properties. The therapeutic benefits of fennel are mainly attributed to its essential oils, phenolic compounds, flavonoids, fatty acids, and other bioactive constituents. These compounds contribute to various biological activities such as antioxidant, antimicrobial, anti-inflammatory, digestive, and protective effects on several body systems.

4.1 Digestive and Gastrointestinal Effects

Fennel is widely recognized for its digestive and carminative properties, making it a common remedy for various gastrointestinal disorders. Traditionally, fennel seeds are consumed after meals to aid digestion and prevent digestive discomfort. Fennel is widely used as a digestive aid and helps relieve indigestion, flatulence, and bloating³. Its carminative action is attributed to essential oils that relax gastrointestinal muscles¹. The essential oils present in fennel help stimulate the secretion of digestive enzymes and gastric juices, thereby improving the digestion process.

Fennel is particularly effective in relieving indigestion, flatulence, abdominal cramps, and bloating. The carminative action of fennel is mainly due to compounds such as anethole and fenchone, which help relax the smooth muscles of the gastrointestinal tract. This relaxation reduces intestinal spasms and facilitates the expulsion of trapped gas. Additionally, fennel has mild antispasmodic effects, which make it beneficial for conditions like stomach cramps and digestive disturbances.

4.2 Antimicrobial Activity

Fennel exhibits antibacterial and antifungal properties against various pathogens². Fennel exhibits significant antimicrobial activity against a wide range of microorganisms, including bacteria and fungi. The essential oils extracted from fennel seeds contain bioactive compounds such as anethole, estragole, and limonene, which have been shown to inhibit the growth of several pathogenic microbes. These compounds exert their antimicrobial action by disrupting microbial cell membranes, interfering with enzyme activity, and altering the permeability of microbial cells. As a result, fennel essential oil has been found effective against various food-borne and clinical pathogens. This antimicrobial property makes fennel useful in preventing infections and supporting overall immune health.

4.3 Antioxidant Properties

Fennel is rich in phenolic compounds that scavenge free radicals and reduce oxidative stress^{1, 8}. These compounds play a crucial role in neutralizing free radicals, which are unstable molecules that can cause cellular damage and contribute to the development of chronic diseases⁸. By scavenging free radicals, fennel helps reduce oxidative stress, which is associated with several health conditions such as cancer, cardiovascular diseases, and aging-related disorders. Phenolic compounds like rosmarinic acid, quercetin, and kaempferol contribute significantly to the antioxidant capacity of fennel. Regular consumption of fennel may therefore support the body's natural defence system against oxidative damage.

4.4 Anti-inflammatory Activity

The bioactive compounds in fennel reduce inflammation by inhibiting inflammatory mediators^{1, 2}. Fennel contains several bioactive compounds that possess anti-inflammatory properties. These compounds work by inhibiting the production of inflammatory mediators, such as cytokines and prostaglandins. This makes it useful in conditions like arthritis and inflammatory bowel disease⁹.



Through this mechanism, fennel helps reduce inflammation in the body and may be beneficial in managing inflammatory conditions such as arthritis, inflammatory bowel disorders, and other chronic inflammatory diseases. The presence of flavonoids and phenolic acids further enhances its anti-inflammatory potential.

4.5 Hormonal and Reproductive Effects

Fennel has estrogenic properties and is traditionally used as a galactagogue and for menstrual disorders¹. Its phytoestrogenic compounds mimic estrogen activity in the body². Because of this effect, fennel has traditionally been used to support female reproductive health. It is commonly used as a galactagogue, a substance that helps stimulate milk production in lactating mothers. Fennel has also been used to help regulate menstrual cycles and relieve symptoms associated with menstrual discomfort, such as cramps and hormonal imbalance. The estrogen like compounds in fennel interacts with hormone receptors and contributes to these beneficial effects.

4.6 Respiratory Benefits

Fennel is used in the treatment of cough, bronchitis, and asthma³. Its expectorant properties help in clearing mucus from the respiratory tract. The essential oils present in fennel exhibit expectorant properties, which help loosen and expel mucus from the respiratory tract. This action helps clear the airways and makes breathing easier. Additionally, fennel's mild antimicrobial and anti-inflammatory effects further support respiratory health by reducing infection and inflammation in the respiratory system.

4.7 Cardiovascular Protection

Fennel exhibits cardio protective effects by reducing cholesterol levels and improving lipid metabolism¹⁰. Recent studies highlight its role in cardiovascular health and safety profile¹⁰. The presence of compounds such as flavonoids and phytosterols contributes to the cardio protective properties of fennel. These compounds help reduce oxidative stress in blood vessels and improve circulation. Regular consumption of fennel may therefore play a role in reducing the risk of cardiovascular diseases and supporting overall heart function.

4.8 Antidiabetic Activity

Studies indicate that fennel extracts can lower blood glucose levels and improve insulin sensitivity^{1, 9}. Certain bioactive compounds present in fennel help lower blood glucose levels and improve insulin sensitivity. These effects may occur through mechanisms such as enhancing glucose metabolism, reducing oxidative stress, and protecting pancreatic cells. Due to these properties, fennel may serve as a supportive natural remedy in the management of diabetes.

4.9 Hepato protective Effects

Fennel protects the liver from toxic damage by enhancing antioxidant enzyme activity and reducing oxidative stress¹. The antioxidant compounds present in fennel help protect liver cells from damage caused by toxins, drugs, and oxidative stress. Fennel enhances the activity of antioxidant enzymes, which play a role in detoxification and protection of liver tissues. By reducing oxidative damage, fennel supports the maintenance of healthy liver function.



4.10 Anticancer Potential

Bioactive compounds such as anethole have shown potential in inhibiting tumour growth and inducing apoptosis in cancer cells^{1, 8}. These compounds have been shown to inhibit tumour growth, induce apoptosis (programmed cell death), and suppress the proliferation of cancer cells in experimental studies. The antioxidant and anti-inflammatory properties of fennel further contribute to its potential role in cancer prevention and supportive therapy. Although more clinical studies are required, these findings highlight the promising therapeutic potential of fennel in cancer research.

5. Mechanisms of Action

The pharmacological effects of *Foeniculum vulgare*, commonly known as Fennel, are attributed to the presence of various bioactive phytochemicals such as essential oils, flavonoids, phenolic acids, and fatty acids. These compounds exert therapeutic effects through several biological mechanisms like:

- **Antioxidant action (free radical scavenging)** - One of the most important mechanisms of fennel's therapeutic activity is its antioxidant effect. Fennel contains several antioxidant compounds such as phenolic acids, flavonoids, and essential oil components, which help neutralize harmful molecules known as free radicals. Free radicals are unstable molecules produced during normal metabolic processes or due to environmental stressors such as pollution and radiation.¹
- **Enzyme modulation (anti-inflammatory effects)** - Another important mechanism through which fennel exerts its pharmacological effects is enzyme modulation. Certain bioactive compounds in fennel influence the activity of enzymes involved in inflammatory pathways.² Through this mechanism, fennel demonstrates anti-inflammatory properties, which may help alleviate symptoms associated with inflammatory conditions such as arthritis, gastrointestinal inflammation, and other chronic inflammatory disorders.
- **Hormonal activity (estrogen receptor interaction)** - Fennel also exhibits hormonal activity due to the presence of phytoestrogenic compounds, particularly constituents of its essential oil. These plant-derived compounds have structural similarities to the hormone estrogen and can interact with estrogen receptors in the body. By binding to these receptors, fennel compounds can mimic or modulate the effects of natural estrogen. This mechanism explains the traditional use of fennel in managing female reproductive health issues, such as menstrual discomfort, hormonal imbalance, and low milk production in lactating mothers.¹
- **Antimicrobial action (cell membrane disruption)** - Fennel also demonstrates significant antimicrobial activity, which contributes to its ability to combat infections. The essential oils present in fennel contain compounds such as anethole, fenchone, and limonene, which possess strong antimicrobial properties. Through this mechanism, fennel shows activity against various bacteria, fungi, and other pathogenic microorganisms. This antimicrobial action supports the traditional use of fennel in treating infections and preserving food.²

6. Traditional and Ethno medicinal Uses

Foeniculum vulgare, commonly known as Fennel, has been widely used in traditional medicine for treating several health conditions. It has traditionally been used to relieve colic, constipation, diarrhoea, fever, insomnia, and kidney disorders due to its digestive, soothing, and mild diuretic properties.^{1, 3}

Apart from its medicinal uses, fennel is widely consumed as a mouth freshener, particularly in India. Roasted or plain fennel seeds are often served after meals in restaurants and households. The seeds help freshen breath due to their aromatic essential oils and also aid digestion by stimulating the secretion of digestive enzymes.



Fennel is also considered an appetite stimulant. Its pleasant aroma and mild sweetness can stimulate the senses and encourage food intake. This property makes fennel useful for individuals experiencing loss of appetite or digestive weakness.³

7. Safety and Toxicological Aspects

Fennel is generally safe when consumed in moderate amounts¹. However, excessive consumption of fennel or its concentrated extracts may lead to certain side effects or allergic reactions in some individuals.² People who are sensitive to plants belonging to the Apiaceae family (which also includes celery, carrot, and parsley) may experience allergic symptoms such as skin irritation, swelling, or respiratory discomfort. Therefore, individuals with known plant allergies should consume fennel with caution.

Another safety concern relates to estragole, a naturally occurring compound present in fennel essential oil. Experimental studies conducted on animals have suggested that very high doses of estragole may have carcinogenic (cancer-causing) potential. However, these effects were observed at levels much higher than those typically consumed through normal dietary intake. In usual culinary quantities, fennel is generally regarded as safe.

Additionally, because fennel contains phytoestrogenic compounds, excessive intake may influence hormonal balance. Therefore, individuals with hormone-sensitive conditions or those taking certain medications should consult a healthcare professional before consuming fennel supplements or large amounts of fennel extract.

8. Future Perspectives

Fennel, has gained increasing scientific attention due to its diverse phytochemical composition and wide range of therapeutic properties. Although fennel has been used for centuries in traditional medicine, modern research continues to explore its potential applications in pharmaceuticals, nutraceuticals, and functional foods.

One important future direction involves advanced pharmacological and clinical studies to further validate the medicinal properties of fennel. While many experimental studies have demonstrated its antioxidant, antimicrobial, anti-inflammatory, and anticancer activities, more clinical trials in humans are needed to confirm its effectiveness and safety for therapeutic use.

Another promising area is the development of natural drugs and herbal formulations derived from fennel extracts and essential oils. The bioactive compounds present in fennel may be used in the formulation of medicines for digestive disorders, metabolic diseases, and inflammatory conditions. Researchers are also exploring fennel as a source of natural preservatives and antimicrobial agents for food and pharmaceutical industries.

Fennel also has potential in the nutraceutical and functional food industry. Because of its health-promoting properties, fennel extracts and powders may be incorporated into dietary supplements, herbal teas, and health foods aimed at improving digestion, immunity, and overall well-being.

In addition, biotechnological and agricultural research may help improve the yield and quality of fennel plants by optimizing cultivation methods and enhancing the concentration of beneficial phytochemicals. Recent studies emphasize the need for:

- Clinical validation of therapeutic effects⁸
- Standardization of extracts
- Exploration of bioactive compounds
- Development of pharmaceutical applications^{9,13}



Overall, continued research on fennel may lead to the development of new therapeutic products and health-promoting formulations, highlighting its importance as a valuable medicinal and nutritional plant in the future.

9. Conclusion

Saunf (*Foeniculum vulgare*) is a versatile medicinal plant with a rich phytochemical profile and diverse therapeutic applications. Scientific evidence supports its traditional uses, particularly in digestive health, antimicrobial activity, and cardiovascular protection^{1, 8, 10}. These compounds are responsible for many of the beneficial effects associated with fennel, including antioxidant, antimicrobial, anti-inflammatory, and digestive-supporting properties. Scientific studies have increasingly validated many of the traditional medicinal uses of fennel. In particular, fennel has been widely recognized for its role in improving digestive health, as it helps relieve indigestion, bloating, flatulence, and intestinal discomfort. Its carminative and antispasmodic properties make it especially useful for gastrointestinal disorders.

In addition, fennel has demonstrated significant antimicrobial activity, which allows it to inhibit the growth of various bacteria and fungi. This property contributes to its use in preventing infections and maintaining overall health. Fennel also exhibits cardio protective effects, as certain compounds present in the seeds help regulate cholesterol levels, improve lipid metabolism, and protect blood vessels from oxidative stress. Beyond these well-known benefits, fennel also shows potential in several other therapeutic areas, including anti-inflammatory, anti-diabetic, hepato protective and anticancer activities. These pharmacological effects highlight the importance of fennel as a valuable medicinal plant in both traditional and modern healthcare systems.

With on-going scientific research and further clinical validation, fennel has the potential to play a significant role in modern pharmacotherapy, herbal medicine, and functional food development. Its natural origin, safety profile, and diverse biological activities make it a promising candidate for the development of new therapeutic agents and health-promoting products in the future.

References

1. Badgujar SB, Patel VV, Bandivdekar AH. *Foeniculum vulgare* Mill: A review of its botany, phytochemistry, pharmacology, contemporary application, and toxicology. **Biomed Res Int.** 2014; 2014:842674. doi:10.1155/2014/842674
2. Rather MA, Dar BA, Sofi SN, Bhat BA, Qurishi MA. *Foeniculum vulgare*: A comprehensive review of its traditional use, phytochemistry, pharmacology, and safety. **Arab J Chem.** 2012. doi:10.1016/j.arabjc.2012.04.011
3. Garg C, Khan SA, Ansari SH, Suman A, Garg M. Chemical composition, therapeutic potential and perspectives of *Foeniculum vulgare*. **Pharmacogn Rev.** 2009;3(6):346–352.
4. Pushkar P. *Foeniculum vulgare*: A review of its botany, phytochemistry, pharmacology, traditional uses, environmental application, and toxicology. **ResGate Publ.** 2022.
5. Diaz-Maroto MC, Perez-Coello MS, Cabezudo MD. Effect of drying method on the volatile components of fennel (*Foeniculum vulgare* Mill.). **J Agric Food Chem.** 2005.
6. Grieve M. *A modern herbal*. New York: Dover Publications; 1931.
7. Malhotra SK. Fennel and fennel seed. New Delhi: Indian Council of Agricultural Research; 2012.
8. Rafieian F, Amani R, Rezaei A, Karaça AC, Jafari SM. Exploring fennel (*Foeniculum vulgare*): Composition, functional properties, potential health benefits, and safety. **Crit Rev Food Sci Nutr.** 2024;64(20):6924–6941. doi:10.1080/10408398.2023.2176817
9. Noreen S, Tufail T, Ain HBU, Awuchi CG. Pharmacological, nutraceutical, functional and therapeutic properties of fennel (*Foeniculum vulgare*). **Int J Food Prop.** 2023;26(1):915–927. doi:10.1080/10942912.2023.2192436



10. Zahi A, Rani A, Aktary N, Rahman M, Mekhfi H, Ziyyat A, et al. Cardiovascular effects, phytochemistry, drug interactions, and safety profile of *Foeniculum vulgare* Mill. (fennel): A comprehensive review. **Pharmaceuticals**. 2025;18(11):1761. doi:10.3390/ph18111761
11. Vella FM, Pignone D, Laratta B. The Mediterranean species *Calendula officinalis* and *Foeniculum vulgare* as valuable sources of bioactive compounds. **Molecules**. 2024;29(15):3594. doi:10.3390/molecules29153594
12. Yaldiz G, Camlica M, Apaydın H. Genotypic variation in morphological traits, yield, essential oil profiles, and mineral composition of fennel (*Foeniculum vulgare* L.) across two growing seasons. **Sci Rep**. 2025; 15:34989. doi:10.1038/s41598-025-18991-y
13. Singh Y, Josphal C, Nair R, Tripathi N. Potential of fennel (*Foeniculum vulgare* Mill.) as phytomedicine: A review. **Plant Cell Biotechnol Mol Biol**. 2025;26(9–10):10–23.