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Review

Trachyspermum ammi leaves: Phytochemical Composition, Pharmacological Potential, and Future Perspectives

Ram Pratap Verma*, Shourya Pratap, Amresh Gupta

Institute of Pharmaceutical Sciences and Research, Mahadev Campus, Lucknow Kanpur Road, Unnao- 209859, U.P., India

Corresponding Author:
Ram Pratap Verma
Email:
rampratap062001@gmail.com

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Abstract:
Trachyspermum species, particularly *Trachyspermum ammi* (Ajwain), are traditionally used in folk medicine across Asia and the Middle East. While the seeds have been extensively studied, the leaves remain underexplored despite their rich phytochemical profile. Recent investigations reveal that *Trachyspermum* leaves are reservoirs of essential oils, flavonoids, phenolic acids, and terpenoids, suggesting significant pharmacological potential. This review compiles and discusses the botanical characteristics, chemical constituents, biological activities, and potential applications of *Trachyspermum* leaves, aiming to highlight gaps and future research directions.

Keywords: *Trachyspermum ammi*; phytochemistry; essential oils; pharmacology; flavonoids; traditional medicine.

1. Introduction

The genus *Trachyspermum* (Family: Apiaceae) encompasses species valued for their culinary and medicinal properties commonly known as the carrot or parsley family [1]. This family is recognized for its aromatic plants, often characterized by hollow stems, compound umbels of small flowers, and finely divided leaves [2]. *Trachyspermum* species are typically annual or perennial herbs, native to a wide range of regions across Asia, Africa, and parts of Europe [3, 4]. Among its most famous species is *Trachyspermum ammi*, commonly known as ajwain or carom seeds, which are used both in culinary and medicinal applications due to their distinctive aroma and potent therapeutic properties [5]. Members of the Apiaceae family, including *Trachyspermum*, are important for their essential oils, flavoring agents, and traditional medicinal uses [6, 7]. Botanically, the family is distinguished by its inflorescence structure a compound umbel and schizocarpic fruits that split into mericarps when mature. The family's ecological significance also lies in its role in supporting pollinators, especially bees and other insects attracted to its abundant and accessible nectar. Overall, *Trachyspermum* exemplifies the diverse utility and biological traits of the Apiaceae family, reflecting its importance in natural ecosystems, agriculture, and traditional health practices [8].

Fig 1. *Trachyspermum Ammi* Plant, leaves, flowers, and Seeds

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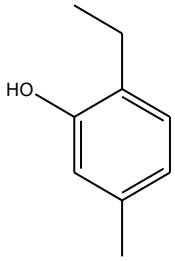
2. Botanical Description

Trachyspermum is a genus of aromatic flowering plants belonging to the family **Apiaceae** (commonly known as the carrot or parsley family). Plants in this genus are typically herbaceous annuals or perennials characterized by their finely divided, feathery leaves and strong aromatic scent. The stems are slender, grooved, and often hollow, supporting a typical **umbelliferous** inflorescence — an umbrella-like cluster of small flowers. Each tiny flower is usually five-petaled, white to pale pink, and radially symmetrical, often attracting a variety of pollinators. The fruits are dry schizocarps that split into two mericarps, a distinguishing trait of the Apiaceae family, and often have prominent ridges and oil canals (vittae) that store essential oils, contributing to the plant's strong aroma. Species like *Trachyspermum ammi* (commonly known as ajwain) are particularly noted for their pungent, thyme-like smell and culinary as well as medicinal uses [9]. Trachyspermum plants prefer warm, sunny environments with well-drained soils and are native to regions spanning the Mediterranean through South Asia. Morphologically, their combination of compound umbels, aromatic qualities, and ribbed fruits place them securely within the defining features of the Apiaceae family, alongside economically important relatives such as coriander, fennel, and carrot [10].

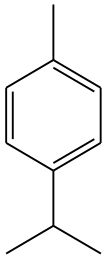
3. Phytochemical Profile of *Trachyspermum* Leaves:

3.1 Essential Oils:

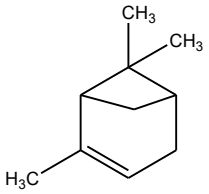
The leaf essential oils predominantly consist of thymol, γ-terpinene, p-cymene, and α-pinene [Kumar et al., 2018]. Thymol, a monoterpenoid phenol, is recognized for its antimicrobial and antioxidant properties [11].



Thymol



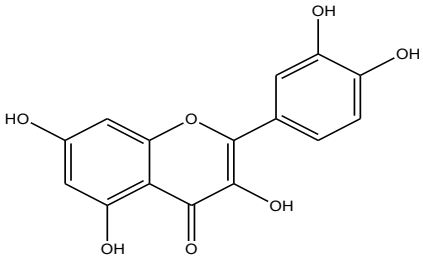
γ-terpinene



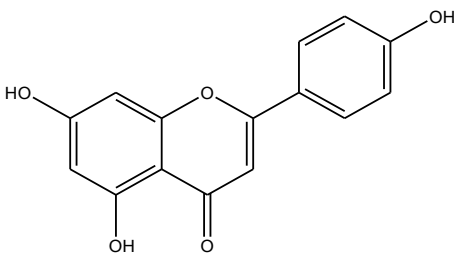
α-pinene

3.2 Flavonoids and Phenolic Compounds:

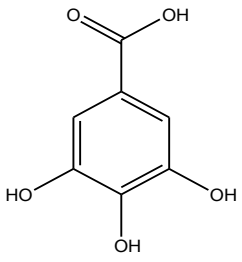
Studies employing HPLC and GC-MS analyses have identified major flavonoids such as quercetin, luteolin, and apigenin in *Trachyspermum* leaves. Phenolic acids including gallic acid, caffeic acid, and chlorogenic acid contribute to their antioxidant profile [12].



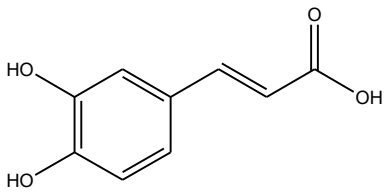
Quercetin



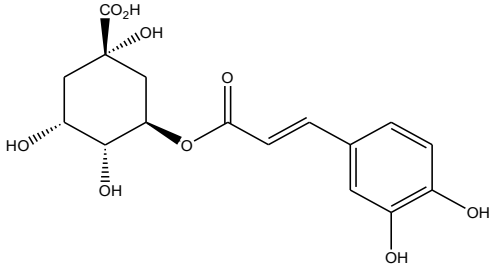
Apigenin



Gallic acid



Caffeic acid



Chlorogenic acid

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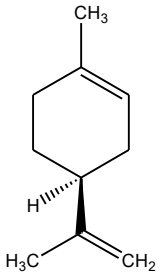
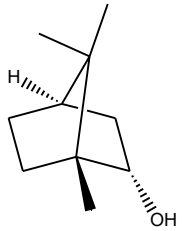
3.3 Terpenoids and Alkaloids

Trachyspermum leaves constituents terpenoids like limonene, borneol and alkaloid are poorly characterized [13].



Limonene



Borneol

4. Pharmacological Activities

4.1. Antimicrobial Properties

Several studies have been reported as broad-spectrum antimicrobial activities of *Trachyspermum* leaf extracts and essential oils against both Gram-positive and Gram-negative bacteria. The leaves have also demonstrated antifungal potential against species such as *Candida albicans* and *Aspergillus niger*. Mechanistically, these effects are largely attributed to membrane disruption by essential oil components like thymol and carvacrol [14].

4.2. Anti-inflammatory and Antioxidant Effects

In vitro and in vivo assays indicate that *Trachyspermum* leaf extracts can significantly inhibit pro-inflammatory mediators, such as nitric oxide and TNF-α. These effects are closely linked to the high flavonoid and phenolic acid content, which also confer substantial radical scavenging activity [15].

4.3. Antidiabetic and Cardioprotective Effects

Emerging evidence suggests that aqueous and ethanolic extracts of *Trachyspermum* leaves can improve glucose metabolism and reduce lipid profiles in diabetic models. These benefits are likely mediated by both antioxidant protection of pancreatic tissue and modulation of lipid-regulating enzymes [16, 17].

4.4. Gastroprotective and Hepatoprotective Effects

Traditional use of *Trachyspermum* leaves for digestive disorders finds support in modern pharmacology. Leaf extracts have shown to reduce gastric ulcer formation and protect liver tissue from chemical-induced damage, possibly through attenuation of oxidative stress and enhancement of mucosal defense mechanisms [18].

5. Ethnomedicinal Uses

The genus *Trachyspermum*, belonging to the Apiaceae family, holds significant importance in ethnomedicine, particularly in South Asian and Middle Eastern traditional healing systems, are widely used for their potent therapeutic properties. Traditionally, the seeds of *T. ammi* are employed to treat a range of gastrointestinal disorders such as indigestion, flatulence, diarrhea, and abdominal colic, owing to their strong carminative and antispasmodic effects [19]. They are also used as a remedy for respiratory conditions like asthma, bronchitis, and cough due to their expectorant and bronchodilatory properties [20]. In folk medicine, *Trachyspermum* seeds are often ground into a paste or infused into teas to alleviate rheumatic pain, enhance digestion, and combat infections, reflecting their antimicrobial and anti-inflammatory activities [21, 22, 23]. The essential oils extract rich in thymol, are noted for their strong antiseptic and fungicidal capabilities and are sometimes applied topically to treat wounds and skin infections [24]. Furthermore, in Unani and Ayurvedic practices, preparations made from *Trachyspermum* are recommended to stimulate appetite, relieve menstrual discomfort, and detoxify the body [25]. Recent scientific studies continue to validate many of these traditional claims, highlighting the ethnomedicinal relevance and pharmacological potential of the *Trachyspermum*.

6. Toxicology and Safety

Acute and sub-chronic toxicity studies on *Trachyspermum* leaf extracts suggest a high margin of safety at therapeutic doses. Nevertheless, the essential oil, when used in high concentrations, may cause mucosal irritation [26]. Comprehensive toxicological profiling, including long-term studies and human trials, remains an urgent need.

7. Future Prospects

Despite promising findings, research on *Trachyspermum* leaves is still in its infancy. Critical gaps include:

- Lack of large-scale clinical trials validating traditional claims
- Limited studies on the pharmacokinetics and bioavailability of leaf constituents
- Inadequate standardization protocols for extracts and essential oils
- Potential synergistic or antagonistic interactions with other phytochemicals or conventional drugs

Exploring these areas will be crucial for translating the therapeutic potential of *Trachyspermum* leaves into evidence-based applications.

8. Conclusion

Trachyspermum leaves, long valued in traditional medicine, are emerging as potent sources of bioactive compounds with multifaceted pharmacological properties. With continued research, they hold promise not only as therapeutic agents but also as functional food ingredients and natural preservatives. A concerted focus on phytochemical standardization, safety assessment, and clinical validation will be key to unlocking their full potential.

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