



Cultural and Medicinal Uses of *Ferula foetida*: From Kyrgyzstan to Global Perspectives

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ABSTRACT

Ferula foetida holds significant botanical, medicinal, and economic importance in Kyrgyzstan. This literature review provides an in-depth exploration of medicinal *Ferula*, focusing on its chemical contents, traditional uses, pharmacological activities, and future considerations within the context of Kyrgyzstan. The morphological diversity of *Ferula foetida* is examined alongside their distribution patterns across the varied landscapes of Kyrgyzstan. Chemical constituents, including secondary metabolites, essential oils, and bioactive compounds, are elucidated, highlighting their potential therapeutic significance. Traditional uses of *Ferula foetida* in Kyrgyzstan encompass a wide range of applications in folk medicine. Pharmacological activities, such as antioxidant, anti-inflammatory, and antimicrobial properties, are discussed based on scientific evidence and traditional knowledge. Additionally, future considerations address the sustainable utilization and conservation of *Ferula foetida*. In Kyrgyzstan, particularly in the face of increasing export demands. Excessive exploitation of resources forces agriculturists and biologists in our country to urgently search for ways to balance the exploitation of natural populations, protect reserves, and cultivate valuable plants. The burgeoning export market underscores the economic value of *Ferula foetida*, prompting the need for responsible harvesting practices and conservation efforts to safeguard this valuable botanical resource for future generations.

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Introduction

Due to intense anthropogenic load and climate change, the Earth's vegetation cover is changing rapidly. These changes and trends are almost always undesirable, which challenges states with a predominant agricultural sector of the economy, prompting them to adapt to changing living conditions or move to resource-saving environmental management technologies [1]. Meadows turn into unnatural steppes, and the remains of natural steppes into lifeless wastelands; fresh water becomes a strategic resource, and the unprecedented amplitude of the intensity of surface runoff becomes an element of emergencies [2]. The present value of competitive agricultural technology for many crops has increased during the period of independence by 3–8 times, depending on the specific crop and region; this has already greatly influenced the structure of crop production in Kyrgyzstan and in the future will undoubtedly require corrective actions in response to the destabilization of plant ecosystems, regardless of what it is called [3]. The time has come to change agricultural tactics and switch to new crops that, in our specific conditions, require lower costs for irrigation and chemicals in the production cycle [4]. Conducting field expeditions and environmental monitoring throughout Kyrgyzstan, agronomists and researchers see the prerequisites for seeking to increase the profitability of crop production enterprises in the introduction into cultivation and industrial cultivation of some valuable species of medicinal plants that naturally grow in the Tien Shan and Pamir-Alai [5]. Nowadays, the irregular export of the cheapest and randomly harvested raw materials from the wild should be transformed into stable export items, ensuring profitability and protection from market surprises posed by competitors.

Kyrgyzstan occupies a central position within the Eurasian continent, situated in the northeastern region of Central Asia. The total land area spans approximately 199.95 thousand square kilometers [6]. It stretches

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from west to east - 900 km, from north to south – 450 km. Kyrgyzstan shares its borders with four neighboring countries: Kazakhstan, the western section of China (Xinjiang), Tajikistan, and Uzbekistan [42]. Situated amidst the Tien-Shan and Pamir-Alai mountain ranges, Kyrgyzstan encapsulates a diverse array of landscapes and climatic conditions, which can be classified into four distinct natural and climatic zones: valley-foothill (up to 1,200 meters), mid-mountain (ranging from 1,200 to 2,200 meters), high-mountain (spanning from 2,200 to 3,500 meters), and naval (elevations exceeding 3,500 meters) [7]. The climate of Kyrgyzstan is highly continental, primarily arid, and slightly smoothed by increased cloudiness and precipitation due to the high-mountainous relief. The climate peculiarities are determined by the location of the country in the Northern Hemisphere in the center of the Eurasian continent, as well as the distance from significant water bodies and proximity to deserts [5]. The flora of Kyrgyzstan is characterized by taxonomic diversity: the 4100 species mentioned above of vascular plants belong to 870 genera from 140 families [8]. Among these species, many are officially classified as useful wild plants: spice, medicinal, essential oils, etc. [9]. Among these diverse species, *Ferula foetida* stands out not only for its wide range of traditional uses but also for its potential in contributing to sustainable agricultural practices and economic development, which this review aims to explore comprehensively. This article offers a thorough and current analysis of *Ferula foetida*, examining its classification, physical traits, geographical range, varied applications, active compounds, health benefits, and potential for technological innovation. Moreover, it will consider the preservation challenges facing this species and its natural habitat. The overarching objective is to deepen the appreciation of *Ferula foetida*'s varied uses and importance, ranging from its role in traditional remedies to its possibilities in commercial sectors.

Morphological structure

The plant's height can exceed 1.5 m. Every year, there is a brief period of fast expansion and development. The generative shoots grow at a pace of 15 cm per day. A huge napiform root usually characterizes the plant's underground portion. *Ferula foetida* (Bunge) Regel grows a thick, tapering stem between the fourth and seventh years [10]. During this time, the plant forms a basal rosette. The leaves are triangular, long-petiolate, and pinnately divided in many places, with oblong-lanceolate end segments ((Fig 1). The number of leaves varies with the plant's age. Apical leaves have a shorter petiole and are often seen with a single sheath. The plant's flowers are pale yellow, clustered in umbels, without wrappers, and form a vast inflorescence. The plant's fruit is a cremocarp that splits into two one-seeded pericarps with extensive border lines when ripe [10].

It is a perennial plant that can grow as tall as 12 feet in the wild, with a circular mass of leaves measuring 30-40 centimeters in diameter. The basal leaves feature broad sheathing petioles. Flowering stems, towering at 2.5–3 meters in height and 10 centimeters in thickness, possess a hollow structure. Within the cortex of these flowering stems lie schizogenous ducts that generate resinous gum. The blooms are tiny, yellowish, and grow in enormous compound umbels. This plant's fruits are round, thin, flat, and reddish-brown, containing a milky fluid inside. The roots are thick, massive, and pulpy. The distinctive scent is caused by the resin-like gum collected from the stems and roots [11].

Geographical distribution of *Ferula foetida*

Ferula foetida, a member of the *Ferula* genus, is indigenous to Central Asia, Eastern Iran, and western regions of Afghanistan and Pakistan (Fig 2). It stands as the most prevalent species responsible for the production of asafoetida (resin). *Ferula* L. includes about 200 species of flowering plants of the Apiaceae family in the world; some of these species are medicinal, nutritious, fodder, essential oil, and resinous plants. About 185 species of *Ferula* are found worldwide [12] and are mainly located in Central Asia, South Asia, the Middle East, and Siberia [13]. There are 114 species in Central Asia and more than 40 in Kyrgyzstan. 10 species are known as of endemics: *Ferula ferganensis* Lipsky ex Korovin, *Ferula inciso-serrata* Pimenov & J.V. Baranova, *Ferula kirialovii* Pimenov, *Ferula pallida* Korovin, *Ferula pimenovii* Lazkov, *Ferula prangifolia* Korovin, *Ferula renardii* (Regel & Schmalh.) Pimenov, *Ferula tenuisecta* Korovin, *Ferula tschimagamica* Lipsky ex Korovin, *Ferula ugamica* Korovin.

Species of the genus *Ferula*, mainly mountain plants, are found relatively high - at 300 to 3600 m above sea level, both on fine soils, variegated soils, and on gravelly slopes, screes, and pebbles. Like most plants of the Umbelliferae family, species of this genus contain essential oils or resinous substances, coumarins, flavonoids, and, less commonly, saponins in all their parts. In recent years, resins have begun to be produced in our country from the roots of *Ferula foetida* (Bunge) Regel. Over the past decade, most natural populations in Kyrgyzstan have been subject to increased exploitation due to the collection of resin from

underground organs, mainly from adult virginal individuals. As a result, many plants, without reaching the generative stage of development, were exhausted and lost their viability.



Fig 1 Illustration of 3-4 years old *Ferula inciso-serrata* from Toktogul, Djalal-Abad

Chemical content

Ferula has various chemical components, including coumarins, particularly sesquiterpene coumarins, volatile oils, sulfur-containing chemicals, and aromatic compounds, all having different biological functions [14].

Coumarins: It belongs to the category of beta-D-glucosiduronic acid. Coumarins have been identified within the *Ferula* genus, with a significant portion deriving from 7-hydroxycoumarin as the primary nucleus [15]. Within the *Ferula* genus, coumarins can be categorized based on their substituents, primarily featuring sesquiterpene coumarins and monoterpene coumarins. Sesquiterpene coumarins are classified as bicyclic, monocyclic, straight-chain, and some furan and other coumarins [14].

Volatile oils: *Ferula*'s volatile oils comprise terpenoids and polysulfide chemicals [16]. The volatile oils often contain a rich array of terpene components, comprising over 80% of their composition, predominantly monoterpenes and sesquiterpenes. Conversely, polysulfide compounds are chiefly characterized by disulfides, trisulfides, bis-disulfides, and thio-disulfides [14].



Fig 2 Distribution areas of *Ferula foetida* in the world

Anticancer activity: The main chemical components of *Ferula* plants that exert anti-tumor effects are ferulic acids [17], sesquiterpenoids [18], and volatile oils [19].

According to an analysis, resin comprises carbohydrates - 67.8% per 100 gms, moisture 16.0%, minerals 7.0%, protein 4.0%, fat 1.1%, and fiber 4.1%. In addition to phosphorus, iron, carotene, riboflavin, and niacin, it contains a high calcium concentration. The calorific value is 297, and it contains 40-64% resinous material composed of ferulic acid, asaresinotannols, umbel-liferone, farnesiferols A, B, and C, about 25% gum composed of glucose, l-arabinose, rhamnose, and glucuronic acid, galactose and volatile oil (3-17%) consisting of disulfides as its major components, notably 2-butyl propenyl disulfide (E- and Z-isomers), with monoterpenes (α - and β -pinene, etc.). The unpleasant odor of the oil is attributed primarily to the disulphide C₁₁H₂₀S₂ [20].

Traditional uses

F. foetida has been utilized in Central Asia for an extended period and in Ayurvedic and herbal medicine traditions. It is valuable in abdominal pain-relieving and reducing vascular disorders, in cases of anxiety disorders, liver troubles, and indigestion. The root of *F. foetida* is one of drugs in practice not only by physicians, but also as a home remedy.

Use in Kyrgyzstan: *F. foetida*, known colloquially as the "Sasyk chair" or "Uuljan", holds a storied heritage deeply ingrained in Kyrgyzstan's cultural and medicinal tapestry. Thriving primarily in the Alai, Fergana, and Ketmen-Tube valleys, this versatile plant has been integral to Kyrgyz traditional medicine for centuries. Revered for its roots, which form a cornerstone in countless remedies, it symbolizes the resilience of Kyrgyz culture and its enduring connection to nature's bounty. One prominent use of *F. foetida* in medicine is its utilization in treating whooping cough. Additionally, it has anticoagulant properties and reduces blood pressure. In the polluted climate of Bishkek, respiratory illnesses are prevalent, and *F. foetida* contributes to addressing these health issues.

Traditional remedies frequently incorporate *F. foetida* to alleviate symptoms associated with common respiratory infections like asthma, whooping cough, and bronchitis.

This is credited to its expectorant qualities, potential anti-inflammatory effects, and antimicrobial properties, all of which are advantageous for respiratory well-being. *F. foetida* is highly esteemed in Kyrgyz traditional medicine for its capacity to address gastrointestinal tract problems, particularly stomach-related issues such as flatulence and distension. Local people in Toktogul, Djalal-Abad, use *Ferula inciso-serrata*'s roots for women's reproductive concerns, teenage skin issues like acne, etc. They cut the root into pieces, dry it out for several days under dark conditions, and then dissolve the piece of root in hot water. When the root is dissolved, locals drink a warm infusion every evening for ten days, rest for one month, and drink again for another ten days (Fig 3). In addition to its medicinal applications, *F. foetida* has also been incorporated into commercial markets. The properties of ferulic acid render it a fitting component in skincare cosmetics, including serums, creams, and anti-aging products. Its anti-inflammatory properties may prevent pimples and reduce the appearance of discoloration. Cell damage can make skin look loose or saggy, while ferulic acid can preserve skin firmness. It also prevents the appearance of new blood vessels under the skin, which leads to reduced skin redness.

Presently, certain areas in Central Asia, including Kyrgyzstan, are witnessing a surge in the sale of resin to neighboring nations, leading to the depletion of stocks. This situation raises concerns regarding the sustainability of plant utilization. Hence, innovative approaches need to be devised to look after the resources of *Ferula* species. To tackle these concerns, various initiatives have been implemented to encourage the sustainable cultivation and conservation of *F. foetida* in Kyrgyzstan. For instance, a moratorium on special permittance of the cultivation of *F. foetida* by the Ministry of Natural Resources, Ecology, and Technical Supervision of Kyrgyz Republic.



Fig 3 a) Root of *Ferula inciso-serrata*, b) traditional use of its roots in Toktogul, Kyrgyzstan

Use in Xinjiang Uyghur Region (China): *Ferula* species serve as a medicinal herb in traditional medicine in Uyghur, boasting a lengthy history of usage [14]. *Ferula* has already been integrated into the Uyghur Medicine Criteria [21]. Additionally, *Ferula* has been included in the calendar version of the Chinese Pharmacopoeia [22]. It stands as a potent remedy for various ailments and possesses a long history of usage in numerous traditional medicines. For instance, Nepali people include *Ferula* as spice in their everyday meals (Chinese Pharmacopoeia Commission, Beijing, China, 2020). *Ferula*'s traditional uses include healing against indigestion, flatulence, stomach pain, intestinal parasites, asthma, and flu [23].

The documented advantages of *Ferula* encompass lump elimination, deworming, antibacterial properties, and other traditional applications [14].

Traditional Chinese medicines (TCMs) significantly impact China's contemporary healthcare system and have demonstrated effectiveness in clinical settings. Even with the lack of standardized criteria for selecting quality control measures has led to uncertainty regarding the certification and effectiveness of herbal medicines. Several studies have documented Q-marker research for the genus *Ferula*. Therefore, using the Q-marker method to identify various markers for the genus *Ferula* is crucial for ensuring its authenticity and conserving plant resources [14]. Moreover, *F. foetida* extends its healing potential to treating intestinal parasites, such as helminths [24]. Broadening its scope, *F. foetida* is prominent in addressing stomach issues within TCM.

Use in Iranian traditional medicine: *F. foetida* is a rich source of resin and is much utilized in folklore medicine [25]. A study published in the European Review for Medical and Pharmacological Sciences found that *F. foetida*'s stem, flower, and leaf extracts have potent antihaemolytic and antioxidant properties, which are very promising for biochemical experiments. The widespread use of traditional medicine continues, and plants remain a significant source of natural antioxidants; ayurvedic texts have categorized *ferula* as an appetizer and a restorer of consciousness [20]. These antioxidants could serve as starting points for developing new pharmaceuticals [21]. The presence of phenols and flavonoids in the extract could be responsible for its biological effects [25]. A study published in the Iranian Journal of Basic Medical Sciences found that *F. foetida*'s extracts have anti-inflammatory antioxidant and immunomodulatory activities that may support its traditional use in these conditions [26].

Use in traditional Indian medicine: *F. foetida* boasts a lengthy history of utilization in traditional Indian medicine - Ayurveda. Below are instances of its traditional application accompanied by references to supporting research: *F. foetida* has been traditionally used as a nervine stimulant, digestive agent, and a sedative [20]. The dried resin is extracted with hot water and taken orally as an emmenagogue [27], and hot water extract of dried gum is given orally as a carminative, antispasmodic, and expectorant in chronic bronchitis. Dried gum resin exudates are eaten to avoid guinea worm disease. *F. foetida* is extensively utilized globally as a flavoring spice in various meals. Traditionally, it has been employed to address a spectrum of ailments like asthma, epilepsy, stomach discomfort, gas, intestinal parasites, poor digestion, and flu. Recent pharmacological and biological research has additionally revealed multiple properties associated with resin, including antioxidant, antiviral, antifungal, cancer prevention, antidiabetic, antispasmodic, blood pressure-lowering, and molluscicidal effects [20].

Pharmacological activities

F. foetida, a traditional medicinal plant, has been historically utilized to address a broad spectrum of health concerns. Renowned for its diverse pharmacological properties, including antibacterial, anti-inflammatory, antioxidant, anticarcinogenic, antitumor, antihelminthic, and hepatoprotective activities, as outlined in Figure

4 below, it harbors numerous bioactive compounds such as umbelliprenin, methyl galbanate, ferutinin, teferin, ferulic acid, and eferidin. Extensively studied through both in vitro and animal model experiments, these compounds have exhibited promising potential in treating neurological disorders, dizziness, asthma, headache, inflammation, bronchitis, rheumatism, and gastrointestinal disorders [28].

Gastrointestinal tract healing: *F. foetida* has traditionally been used for several stomach diseases. Studies have shown that *F. foetida* herb is one of the best remedies available for flatulence and distension of the stomach [20].

Table 1 The chemical constituent accountable for the pharmacological effects [20]

Pharmacological activity	Responsible chemical constituent
Anticancer	α -pinene; α -terpineol; diallyl-disulfide; ferulic-acid; isopimpinellin; luteolin; umbelliferone; vanillin
Anti-inflammatory	α -pinene; azulene; B-pinene; ferulic-acid; isopimpinellin; luteolin; umbelliferone
Antileukemic	Luteolin
Antimutagenic	Diallyl-sulfide; ferulic-acid; luteolin; umbelliferone; vanillin
Antineoplastic	Ferulic-acid
Antitumor	Diallyl-disulfide; diallyl-sulfide; ferulic-acid; luteolin; vanillin
Antiviral	α -pinene; diallyl-disulfide; ferulic-acid; luteolin; vanillin
Antibacterial	α -pinene; α -terpineol; azulene; diallyl-disulfide; diallyl-sulfide; ferulic-acid; luteolin; umbelliferone
Antispasmodic	Azulene; ferulic-acid; luteolin; umbelliferone; valeric-acid
Antiseptic	α -terpineol; azulene; B-pinene; diallyl-sulfide; umbelliferone
Lipoxygenase-inhibitor	Luteolin; umbelliferone
Antiulcer	Azulene
Hepatoprotective	Ferulic-acid; luteolin
Anti-HIV	Diallyl-disulfide; luteolin
Antinitrosaminic	Ferulic-acid
Antioxidant	Ferulic-acid; luteolin; vanillin
Antiaggregant	Ferulic-acid
Tranquilizer	α -pinene; valeric-acid
Antiproliferative	Diallyl-disulfide
Apoptotic	Luteolin
Anticarcinogenic	Ferulic-acid; luteolin
B-Glucuronidase-Inhibitor	Luteolin
Immunostimulant	Diallyl-disulfide; ferulic-acid
Antihepatotoxic	Ferulic-acid; glucuronic-acid
Antiprostaglandin	Umbelliferone
Antihyaluronidase	Luteolin
Cytotoxic	Luteolin
Sedative Ornithine-Decarboxylase-Inhibitor	α -pinene; α -terpineol; valeric-acid Ferulic-acid
PTK-Inhibitor	Luteolin

Anti-inflammatory and analgesic: *F. foetida* has been reported to have anti-inflammatory and analgesic properties. Studies have shown that root extracts have significant anti-inflammatory, anti-nociceptive, and analgesic effects [29].

Antibacterial: *F. foetida* has potent antibacterial activity against a range of bacteria. The dry roots affected *Staphylococcus aureus*, *Bacillus subtilis* and *Sporosarcina* [14].

Antifungal activity: *F. foetida*'s oils have been found to have antifungal activity against several fungal pathogens, including *Aspergillus niger* and *Candida albicans*. The highest antifungal activity of this plant was reported with methanolic extract [31].

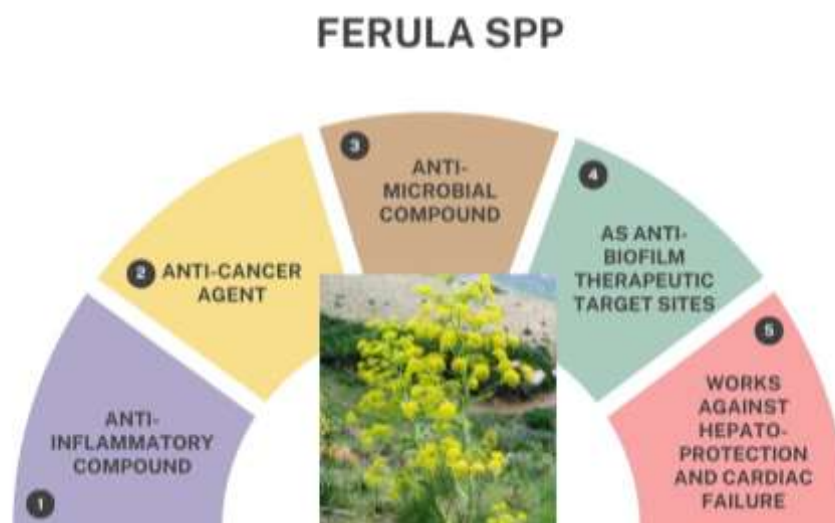


Fig 3 Multi-faced action of Ferula species

Antioxidant activity: Studies have shown that *F. foetida*'s essential oil extracts obtained from gum resins have significant antioxidant activity that may be used as safe and effective natural antioxidants in the food industry to improve the oxidative stability of fatty foods during storage [32].

Immunomodulatory effects: Some compounds, such as terpenes and several other natural agents present in essential oils of Ferula species have shown immunomodulatory properties [33].

Anticancer activity: Research has indicated that *F. foetida* demonstrates anticancer activity owing to its antiproliferative characteristics, notably by compounds like serotonin. These substances have demonstrated efficacy in restraining the proliferation of breast cancer cells [34]. Umbelliprenin compounds induced apoptosis and showed cytotoxic and cytostatic effects against human solid cancer cells (melanoma) [35].

Hepatoprotective: *F. foetida* has been documented to possess hepatoprotective attributes, shielding the liver from harm induced by diverse toxins and pharmaceutical agents. The extract was effective against oxidative damage induced by CCl₄ [36].

Neuroprotective: *F. foetida* has been found to exhibit neuroprotective and nerve-stimulating effects in glutamate-induced neurotoxicity. The extract demonstrated antiapoptotic effects in cerebellar granule neurons, shedding light on the advantageous impacts of *F. foetida* extract in treating neurological ailments [37].

Antiulcer properties: *F. foetida* is reported to have gastric antiulcer properties. The gum resin has shown that this effect may be or mainly related to antioxidant, anticholinergic, and antihistaminergic effects [30].

Antihelmintic activity: *F. foetida* is used in traditional medicine to treat diabetes. Aqueous and dry root latex powder extracts from Ferula have exhibited significant antihelmintic activity against *Pheretima posthuma* and liver fluke *Fasciola gigantica* [38].

Antispasmodic activity: *F. foetida* has been reported to have antihelmintic properties. Studies have shown that *F. foetida* aqueous gum extract has significant antispasmodic and hypotensive activity in reducing blood pressure and decreased contractions induced by acetylcholine, histamine, and KCl in the isolated guinea-pig ileum [39].

Antitumor activity: *F. foetida* has been found to have potential anticancer and antitumor activity. Studies have shown that *F. foetida*'s flowers and leaves have a cytotoxic effect on cancer cell lines, including liver (HEPG2) carcinoma cells, cervical (HELA), and breast (MCF7) [40]. Toxic effect: *F. foetida* has been linked to potentially increasing the effectiveness of warfarin [41]. Chromosomal damage has been linked to the coumarin compounds found in *F. foetida* [20].



Fig 4 Different bioactivities of *Ferula* species

Future considerations

Extensive research and awareness efforts are necessary in Batken, Jalal-Abad regions and neighboring areas of Kyrgyzstan. While *F. foetida*'s leaves, flowers, and root extracts remain integral to ethnomedicinal therapies, comprehensive knowledge of their formulations and applications is primarily preserved in literature and among a select cadre of regional physicians. As root harvesting threatens plant sustainability, proactive measures must be taken to protect these invaluable botanical resources from overexploitation. Though some facets of ethnomedicinal science have been explored, there remains a compelling need for further investigation across diverse fronts, including cancer treatment, antioxidant properties, geographical mapping, metabolomics, bioinformatics, genomics, proteomics, and data-driven analyses. Examination of secondary metabolites like ferulic compounds should leverage *in vitro* methodologies to circumvent animal-related ethical concerns. While much research has centered on the pharmacological and therapeutic potentials of *F. foetida*, its biotechnological dimensions, such as cell culture techniques, warrant greater scrutiny. The natural habitats of *F. foetida* in Batken, particularly in Leilek and Margun villages, necessitate commercial viability and ecological preservation attention. Collaborative efforts among forestry agencies, research entities, and non-governmental organizations are imperative to safeguard *F. foetida* and its wild endemic species, employing a blend of scientific innovations and traditional conservation practices.

Future considerations for the study of *F. foetida* should include the preservation and sustainable use of this critical species and the advancement of biotechnological methods, such as tissue culture, to promote conservation and commercial viability. Tissue culture techniques can play a crucial role in propagating *F. foetida*, especially given the plant's slow natural reproduction rates and the threats posed by overharvesting. By establishing *in vitro* propagation protocols, it is possible to produce large quantities of the plant without further depleting wild populations. This method also allows for the genetic enhancement of plant, potentially introducing traits that could increase resistance to diseases and environmental stresses, thereby supporting the development of varieties suited for different climatic and soil conditions.

Integrating these biotechnological strategies with traditional cultivation practices will help conserve this valuable species and ensure its sustainable commercial production. This dual approach promises to secure the future of *F. foetida* both as a cultural heritage and an economic resource in Kyrgyzstan and beyond, aligning with global efforts in conservation biology, biodiversity and sustainable agriculture.

Conclusion

In summation, this comprehensive literature review on the phytochemistry and pharmacological activities of *F. foetida* underscores its profound significance within Kyrgyzstan and throughout Central Asia. Scientific inquiry has illuminated the traditional applications of this botanical treasure across a spectrum of health concerns, validating its efficacy by identifying a plethora of bioactive compounds with considerable therapeutic potential. Indeed, the role of *F. foetida* across Central Asian nations is immeasurable, its historical reputation as a panacea for neurological, gastrointestinal, and cytotoxic maladies enriched by the discovery of phytochemical gems like umbelliprenin, ferulic acids, azulene, luteolin, and vanillin derivatives. These bioactive constituents exhibit various pharmacological activities, including antioxidant, anti-

inflammatory, antimicrobial, anticancer, and antihyperglycemic effects, harmonizing with the plant's traditional applications. However, beyond its medicinal virtues, *F. foetida* assumes a pivotal economic role in Central Asian countries. However, rampant over-harvesting and habitat degradation underscore pressing sustainability concerns. *F. foetida* transcends mere botanical taxonomy; it embodies a cultural and medicinal legacy deeply ingrained in diverse traditions worldwide.

Biotechnological approaches, including genetic engineering and molecular breeding, could be harnessed to enhance the production of specific bioactive compounds found in *F. foetida*. These compounds, particularly ferulic acids and other secondary metabolites, are of significant pharmaceutical and industrial interest due to their medicinal properties. Advanced biotechnological tools can help identify and amplify the critical genes involved in the biosynthesis pathways of these compounds, leading to increased yields and more efficient use of the plant in pharmaceuticals and nutraceuticals. Furthermore, community involvement and robust legislative protections are essential to ensure sustainable management and preservation of *F. foetida*, combining traditional knowledge with advanced biotechnological strategies to safeguard this valuable botanical legacy for future generations.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical standards

The study is proper with ethical standards.

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