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PHYTOCHEMICAL PROFILE, PHARMACOLOGICAL INSIGHTS AND BIOTECHNOLOGICAL POTENTIAL OF THE GENUS *Prangos*

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ФИТОХИМИЧЕСКИЙ ПРОФИЛЬ, ФАРМАКОЛОГИЧЕСКИЕ АСПЕКТЫ И БИОТЕХНОЛОГИЧЕСКИЙ ПОТЕНЦИАЛ РОДА *Prangos*

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Abstract. The genus *Prangos* (Apiaceae) comprises about 45 perennial aromatic species distributed mainly across the Mediterranean, the Middle East, and Central Asia. Over the past two decades, *Prangos* species have received growing scientific attention due to their remarkable content of coumarins, flavonoids, terpenoids, and essential oils with diverse biological activities. This review summarizes current knowledge on the phytochemical composition, pharmacological effects, and biotechnological potential of *Prangos* species, with particular emphasis on *P. ferulacea* and *P. trifida*. Data from in vitro, in vivo, and biochemical assays are critically assessed. Evidence supports their antimicrobial, antioxidant, anti-inflammatory, and enzyme inhibitory properties, alongside promising industrial and biotechnological applications. The review aims to consolidate recent findings and identify future research directions for exploiting *Prangos* as a source of natural bioactive compounds.

Аннотация. Род *Prangos* (Apiaceae) включает около 45 многолетних ароматических видов, распространенных в основном в Средиземноморье, на Ближнем Востоке и в Центральной Азии. За последние два десятилетия виды *Prangos* привлекли все большее внимание ученых благодаря своему замечательному содержанию кумаринов, флавоноидов, терпеноидов и эфирных масел с разнообразной биологической активностью. В этом обзоре обобщены современные знания о фитохимическом составе, фармакологических эффектах и биотехнологическом потенциале видов *Prangos*, с особым акцентом на *P. ferulacea* и *P. trifida*. Критически оценены данные, полученные in vitro, in vivo и в биохимических исследованиях. Данные подтверждают их антимикробные, антиоксидантные, противовоспалительные и фермент-ингибиторные свойства, а также перспективные промышленные и биотехнологические применения. Цель обзора – обобщить последние результаты и

определить будущие направления исследований по использованию *Prangos* в качестве источника природных биоактивных соединений.

Keywords: *Prangos*, Apiaceae, phytochemistry, bioactive compounds, pharmacology, biotechnology.

Ключевые слова: *Prangos*, Apiaceae, фитохимия, биологически активные соединения, фармакология, биотехнология.

Medicinal plants represent a fundamental source of bioactive compounds with therapeutic relevance in modern and traditional medicine. Among these, the *Prangos* genus of the Apiaceae family occupies a distinctive position due to its diverse secondary metabolites and extensive ethnopharmacological applications. The genus is distributed primarily in the Irano-Turanian floristic region, extending into the Caucasus, Anatolia, and Mediterranean territories [33]. Species such as *P. ferulacea*, *P. pabularia*, and *P. trifida* have been traditionally employed to treat digestive disorders, infections, and inflammation in various folk medical systems [28, 44].

The increasing global interest in natural therapeutics has renewed focus on *Prangos* species as sources of pharmacologically valuable compounds [11]. Studies over the last two decades have demonstrated the genus's potential in combating microbial resistance, oxidative stress, cancer cell proliferation, and metabolic disorders [20, 29]. Additionally, biotechnological investigations into plant tissue cultures, nanoformulations, and enzyme inhibition have expanded the genus's relevance beyond ethnobotany into applied pharmaceutical and industrial research [4-6, 15]. The species occupy an important position in both traditional and modern phytotherapy [12, 13].

The species is widespread across the Fergana Valley [18] and the Lower Dnipro region [26], contributing significantly to ecosystem diversity and soil adaptation. Its seeds serve as food for parasitic Lepidoptera of the Eurytomidae family, revealing its importance in ecological food webs [32]. Several species have also been utilized in animal husbandry and the food industry [22, 43].

Furthermore, *P. ferulacea* contributes to the traditional “*Van othu* cheese” formulation in Turkey, enhancing aroma and functional qualities [38].

This review aims to synthesize recent findings regarding the phytochemistry, pharmacology, and biotechnological potential of *Prangos* species. Emphasis is placed on major bioactive compounds, mechanisms of action, and correlations between chemical structure and biological function. Furthermore, emerging research directions and applications are highlighted to encourage future multidisciplinary exploration.

The genus *Prangos* belongs to the subfamily Apioideae, tribe Peucedaneae, within the family Apiaceae. It comprises about 45 recognized species, with the highest diversity found in Iran, Turkey, and Central Asia [35]. These are perennial herbs with strong aromatic odors, thick taproots, and umbellate inflorescences typical of the family. Fruits are schizocarps with distinct vittae (oil ducts), often used as diagnostic features in taxonomy [39].

Prangos ferulacea (L.) Lindl., one of the most studied species, is characterized by robust stems (up to 150 cm high), bipinnate leaves, and yellowish umbels. Other species, such as *P. pabularia* and *P. trifida*, exhibit morphological variability linked to their ecological adaptation. The genus is taxonomically close to *Ferula*, *Peucedanum*, and *Heracleum*, sharing similar coumarin-rich profiles, though differing in fruit anatomy and essential oil composition [24, 25].

Phytogeographically, *Prangos* species occupy dry, rocky, and calcareous habitats at altitudes between 800–2500 m. Such environmental conditions contribute to their secondary metabolite diversity, influenced by altitude, climate, and soil mineral content [40, 41].

The pharmacognostic characteristics of the aerial parts of *P. ferulacea* Lindl. at the early vegetative stage have been investigated. Macroscopic and microscopic features-including tissue structure, stomata, trichomes, and cellulose content - were characterized, and the suitability of its bioactive components for pharmaceutical applications was evaluated. The findings suggest that aerial parts collected during the early vegetative stage are rich sources of high-quality bioactive substances suitable for pharmacological and cosmetic use [16].

P. trifida was recently recorded for the first time in Croatia, refining the known biogeographical range of the genus [31].

The phytochemical profile of *Prangos* species is dominated by coumarins, flavonoids, terpenoids, phenolic acids, and essential oils [1, 28]. These metabolites play a crucial role in the plant's defense mechanisms and serve as pharmacologically active molecules responsible for multiple biological effects.

Coumarins are the most characteristic constituents of *Prangos* species, particularly furanocoumarins and simple coumarins. Studies have reported the presence of xanthotoxin (8-methoxypsoralen), bergapten (5-methoxypsoralen), isopimpinellin, and heraclenin as dominant components [9]. These compounds exhibit antimicrobial, anticoagulant, and photosensitizing properties.

In *P. ferulacea*, coumarins constitute over 70% of the total extractable secondary metabolites [40]. Other species such as *P. platychlaena* and *P. pabularia* contain rare pyranocoumarins and dihydrofurocoumarins, which have demonstrated selective cytotoxicity against cancer cells [20].

Flavonoids, mainly quercetin, kaempferol, rutin, and apigenin derivatives, contribute to the antioxidant and enzyme inhibitory effects of *Prangos* [15]. Quantitative analyses using HPLC and LC-MS/MS indicate that the total flavonoid content in methanolic extracts ranges between 10–25 mg QE/g DW, depending on the species and extraction solvent [23, 26].

Phenolic acids such as caffeic, ferulic, and p-coumaric acids have been identified as minor yet potent antioxidants [4, 5]. The phenolic profile contributes significantly to the radical scavenging potential and overall antioxidant index [28].

Essential oils represent another valuable chemical fraction of *Prangos*. GC-MS analyses have revealed dominant monoterpenes such as β -pinene, α -pinene, limonene, sabinene, and myrcene [34, 36].

In *P. ferulacea*, β -pinene often constitutes over 30% of total oil composition, conferring the plant its strong aromatic odor and antimicrobial capacity [41]. Terpenoids also include sesquiterpene hydrocarbons like β -caryophyllene and germacrene D, which possess cytotoxic and anti-inflammatory activities [1].

The seeds and oil of *P. ferulacea* are rich in unsaturated fatty acids, mainly linoleic and oleic acids, as well as macro- and microelements such as potassium, calcium, magnesium, phosphorus, zinc, and iron, highlighting its nutritional and pharmacological value [14].

Chemical profiling of essential oils from *P. pabularia* (Iran) using GC-MS revealed spathulenol (16.09%) and α -bisabolol (14.30%) as the major components in leaf oils, while α -pinene dominated the fruit and flower oils (33.87% and 21.46%, respectively). These terpenoids exhibited allelopathic properties, influencing the growth of neighboring plants [34].

A systematic review of *Prangos* essential oils identified monoterpenes-especially α -pinene, β -pinene, (Z)- β -ocimene, and δ -3-carene -as the predominant constituents. These oils exhibited broad biological activities, including antibacterial, antioxidant, allelopathic, insecticidal, and anticancer effects. The chemical profile varies notably with plant organ and geographical origin [36].

Although alkaloids are not abundant in *Prangos*, traces of indole and quinoline alkaloids have been detected in certain species [7, 8]. In addition, recent studies highlight the presence of polysaccharides and steroidal components with immunomodulatory potential [29, 30].

The diverse phytochemical composition of *Prangos* species translates into a wide spectrum of pharmacological actions. Experimental evidence supports their roles as antimicrobial, antioxidant, anti-inflammatory, cytotoxic, and enzyme inhibitory agents.

Numerous studies have demonstrated potent antimicrobial properties of *Prangos* extracts against both Gram-positive and Gram-negative bacteria, as well as fungi.

Methanolic extracts of *P. trifida* showed significant inhibition zones (up to 25 mm) against *Staphylococcus aureus* and *Escherichia coli* [20]. The activity is mainly attributed to furanocoumarins, which interfere with bacterial DNA replication and membrane integrity [40].

Essential oils of *P. ferulacea* also displayed strong antifungal effects against *Candida albicans* and *Aspergillus niger*, with MIC values below 200 µg/mL [44]. The synergistic action between monoterpenes (especially α -pinene and limonene) enhances this effect [1].

Studies on *P. pabularia* confirm significant antioxidant and antimicrobial activity [9]. Extracts of *P. ferulacea* and *F. orientalis* demonstrated significant anti-leishmanial activity *in vitro* against *Leishmania tropica*; the strongest effects were recorded for ethanol root and chloroform fruit extracts of *P. ferulacea* [10].

The antioxidant properties of *Prangos* species have been confirmed through various assays, including DPPH, ABTS, and FRAP. Methanolic extracts exhibit IC₅₀ values comparable to synthetic antioxidants such as BHT [44].

The presence of flavonoids, phenolic acids, and coumarins contributes to the neutralization of reactive oxygen species and prevention of lipid peroxidation [29]. *In vivo* studies demonstrated that *P. ferulacea* extracts can restore glutathione and catalase levels in oxidative stress models [28]. *Ferula* extracts related to *Prangos* have shown gastroprotective and antioxidant effects in indomethacin-induced ulcer models [42], indicating therapeutic promise for *P. ferulacea* as well.

Coumarins and terpenoids isolated from *P. ferulacea* have exhibited anti-inflammatory effects by suppressing pro-inflammatory cytokines (IL-1 β , TNF- α) and inhibiting COX-2 enzyme activity [19]. Animal models revealed significant reductions in carrageenan-induced paw edema and pain responses, suggesting both peripheral and central analgesic mechanisms [1].

Extracts of *Prangos platychlaena* and *P. pabularia* have shown cytotoxic effects against breast (MCF-7), colon (HT-29), and liver (HepG2) cancer cell lines (Latif et al., 2025). Mechanistic studies indicate that coumarins induce apoptosis through caspase activation and mitochondrial depolarization [2, 15].

Moreover, *P. ferulacea* essential oil significantly reduced tumor cell viability while sparing normal fibroblasts, highlighting its selective toxicity [29].

The enzyme inhibitory potential of *Prangos* species is particularly relevant for diabetes, obesity, and neurodegenerative diseases. *In vitro* analyses demonstrated α -glucosidase, α -amylase, and acetylcholinesterase inhibition comparable to standard drugs [44]. Compounds such as bergapten and xanthotoxin exhibit dual enzyme inhibition, suggesting their potential in managing postprandial hyperglycemia and cognitive decline [4].

Recent advances in nanobiotechnology have highlighted the potential of *Prangos* extracts in drug delivery systems. A chitosan-based nanoformulation of *P. acaulis* extract demonstrated enhanced cytotoxicity against HT-29 (colon carcinoma) and MCF-7 (breast adenocarcinoma) cell lines by improving cellular uptake and bioavailability [17]. These findings indicate that *Prangos*-derived phytochemicals can be effectively incorporated into nanocarriers for targeted cancer therapy.

P. ferulacea extract has been applied as a natural dye for polyester, wool, and nylon fabrics, offering an eco-friendly alternative to synthetic dyes. Optimization using artificial intelligence (AI)-based models improved dye fastness and reduced water and chemical consumption, thus supporting sustainable textile technologies [17, 37]. The plant's colorant compounds, mainly coumarins and flavonoids, provided stable chromatic intensity and UV resistance, meeting international fastness standards.

Beyond pharmacology, *Prangos ferulacea* plays a significant role in rangeland ecosystems. Its deep root system enhances soil stability, reduces erosion, and supports biodiversity in semi-arid zones [21]. In Turkey and Iran, *P. ferulacea* and *Ferula communis* have been explored as supplementary forage sources due to their favorable digestibility and mineral composition [27].

In Eastern Anatolia, Turkey, a newly described species, *P. munzurensis*, was morphologically and ecologically characterized. Detailed analyses of its floral and foliar morphology, together with comparisons to other *Prangos* species, were performed. The study also documented the ecological preferences, soil, and climatic conditions of its habitat, illustrating its adaptive mechanisms and contribution to biodiversity [21].

In the Hissar mountain flora, *P. ferulacea* exhibits strong adaptive potential under diverse environmental conditions [27]. *P. ferulacea* serves as a food plant for several insect species, including *Apochima diaphanaria* larvae, underscoring its ecological relevance [2].

The integration of *Prangos* into rangeland management plans is considered a sustainable strategy for combating desertification and improving soil fertility.

Biotechnological propagation of *Prangos* species through in vitro techniques allows the production of genetically uniform and phytochemically consistent plant material. Gene expression analyses have revealed high transcription levels of phenylalanine ammonia-lyase (PAL) and chalcone synthase (CHS) in *P. ferulacea*, confirming its biosynthetic potential for phenolics and flavonoids [3]. Furthermore, in vitro cultures can be utilized for elicitor-induced enhancement of coumarin biosynthesis, paving the way for commercial-scale production of natural bioactive compounds.

A new steroidal molecule, Daucoesterol, was isolated from *P. aricakensis*, demonstrating antibacterial activity through molecular docking interactions with DD-peptidase and DNA gyrase enzymes [15]. Similarly, *P. pabularia* yielded a newly characterized coumarin with unique structural features confirmed by NMR and MS analyses [7]. These discoveries highlight the genus as an underexplored source of novel natural compounds with therapeutic potential.

The genus *Prangos* (Apiaceae) represents a valuable phytochemical reservoir with significant pharmacological, ecological, and industrial potential. Its diverse composition - rich in coumarins, terpenoids, flavonoids, and phenolic acids-supports multiple biological effects, including antimicrobial, antioxidant, anti-inflammatory, and enzyme inhibitory activities.

Biotechnological advancements, including nanoformulation, tissue culture, and chemometric profiling, have further broadened the application of *Prangos* species in pharmaceutical, nutraceutical, and green chemistry sectors.

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