Iranian herbal distillates (Hydrosols): From traditional beverages to modern industrial applications

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Research

Abstract

Background: Iranian herbal distillates are traditional aqueous products of hydro-distillation with centuries of use in Persian medicine, culinary practices, and cultural rituals. They are documented in historical texts such as those by Avicenna and remain widely employed as beverages, folk remedies, and flavoring agents. This study aims to comprehensively document the botanical sources, traditional uses, production methods, and industrial potential of Iranian hydrosols through an integrated approach combining systematic literature review and extensive ethnobotanical fieldwork.

Methods: A systematic literature search was conducted across Scopus, PubMed, Web of Science, and Google Scholar. Field surveys were carried out between September 2023 and September 2025, including visits to three industrial distilleries in Shiraz and Kashan, and surveys of 35 herbal shops and traditional markets across five Iranian cities. Data on plant species, production practices, uses, and market status were collected, taxonomically verified, and analyzed using R.

Results: Fifty-three plant species from 28 plant families were documented, with Lamiaceae, Asteraceae, and Apiaceae being the most represented. Aerial parts were the most frequently used plant material. The most commonly reported bioactivities included antimicrobial, antioxidant, and anti-inflammatory effects. Industrial potential was highest in the sectors of functional beverages, flavoring agents, and cosmetics.

Conclusions: Iranian herbal distillates represent a diverse and culturally significant resource with considerable potential for applications in functional foods, cosmetics, and phytopharmaceuticals. To support industrial scale-up, future efforts should focus on production standardization, clinical validation of bioactivities, and sustainable sourcing practices.

Keywords: Ethnobotany, Hydrosols, Functional Beverages, Industrial Applications, Traditional Medicine.

Background

Iranian herbal distillates, traditionally referred to in Persian as "Aragh", are aqueous by-products of the hydro-distillation process of aromatic plants, capturing the water-soluble volatile compounds. Such products are non-alcoholic aqueous distillates. These hydrosols hold a deeply rooted history in Persian culture, with applications spanning traditional medicine, culinary arts, and cultural rituals for millennia (Sajjadi *et al.* 2015). Their use is documented in foundational texts of Persian Medicine, such as those by Avicenna (Ibn Sina), who described the properties of rosewater for cooling and cardiotonic effects (Ibn Sina 1998). These herbal distillates originate from a long tradition of using medicinal plants, many of which have been scientifically proven to possess antimicrobial and therapeutic properties (Malekpourzadeh *et al.* 2023). Beyond medicine, these distillates are indispensable in the Iranian food industry, and as symbolic elements of hospitality (Ghorbani 2005). Owing to its varied climates and complex topography, Iran harbors notable endemic plant diversity (Ghahremaninejad *et al.* 2025), a resource that has long been leveraged for this purpose.

The production of these distillates relies on a diverse range of native Iranian flora. Key species include *Rosa damascena* Mill. for rosewater (Golab), *Mentha spp*. for mint distillate (Aragh-e Na'na), and *Citrus aurantium* L. for orange blossom water (Aragh-e Bahar-Narenj) (Akhgar *et al.* 2012). The specific agro-climatic conditions of regions like Kashan for roses contribute significantly to the unique quality and aromatic profile of these products (Babaei *et al.* 2007).

While traditional methods using copper stills are still practiced, a schematic of which is presented in Figure 1, modern industrial production has adopted stainless steel equipment and controlled distillation parameters to improve efficiency, safety, and standardization (Mahmoudi *et al.* 2020). Scientific investigations have confirmed a range of biological activities for these hydrosols, including antimicrobial, antioxidant, and anti-inflammatory properties, which are attributed to their complex mixture of phenolic compounds, terpenes, and other oxygenated derivatives (Safari *et al.* 2019; Bouyahya *et al.* 2020).

In the context of a growing global demand for natural and plant-based products, Iranian herbal distillates present a significant opportunity for industrial application beyond their traditional uses (Tajkarimi *et al.* 2010). Their potential extends into modern sectors such as functional beverages, natural preservatives in the food industry, active ingredients in cosmetics and aromatherapy, and as natural flavoring agents (Sanchez *et al.* 2020). This paper aims to comprehensively survey these traditional hydrosols, documenting their botanical sources, traditional uses, scientifically validated properties, and considerable potential for future industrial applications on a global scale. Some of these distillates, most notably rosewater (Golab), have achieved such widespread popularity that they are now commonplace consumer goods, readily available in general food markets and supermarkets across the country.

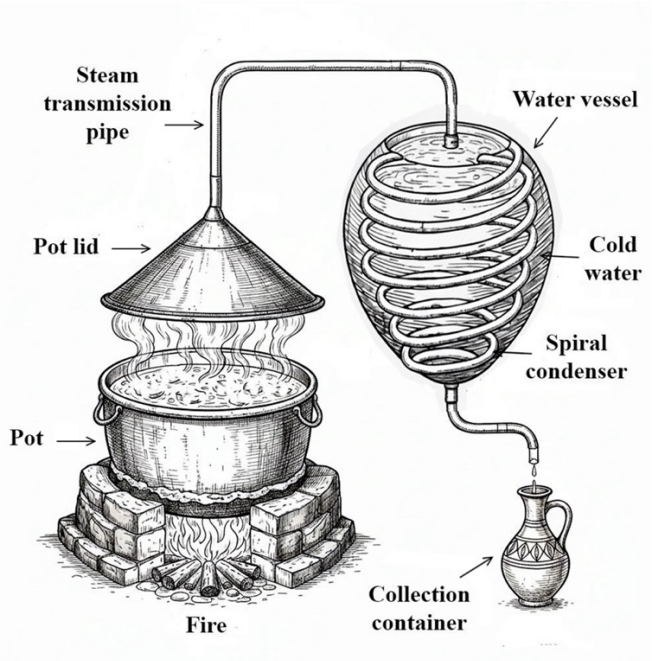

Figure 1. Schematic diagram of a traditional copper distillation unit used for producing Iranian herbal distillates. This traditional apparatus has been used for centuries and forms the foundation of modern industrial practices (Drawn by H. Nazari).

Materials and Methods

This study employed an integrated research design combining a comprehensive literature review with multi-site ethnobotanical fieldwork to document the botanical sources, traditional uses, production practices, and commercial landscape of Iranian herbal distillates (Aragh).

Literature Review

A comprehensive literature search was conducted using four major databases: Scopus, PubMed, Web of Science, and Google Scholar. Searches included combinations of the keywords “Iranian herbal distillates”, “Aragh”, “hydrosols”, “rosewater”, “mint water”, “traditional beverages”, “ethnobotany”, “aromatic plants”, and “medicinal plants”, connected with Boolean operators (AND/OR).

Publications were eligible for inclusion if they:
(1) Provided information on the botanical identity, traditional uses, chemical constituents, or biological activities of distillates or their source plants.
(2) Were peer-reviewed articles, scholarly books, or authoritative technical reports.
(3) Were written in English or Persian.
(4) Pertained to Iran or contained relevant regional data applicable to Iranian hydrosols.

Studies lacking botanical verification, those focusing exclusively on essential oils without reference to hydrosols, or papers with insufficient methodological detail were excluded. Reference lists of selected sources were also screened to identify additional relevant publications. All bibliographic data were organized and cross-checked for accuracy.

Field Surveys

To complement the literature review with empirical observations, extensive fieldwork was conducted between September 2023 and September 2025 across major production and distribution centers in Iran. The field surveys consisted of:

Production Facilities

Structured visits were carried out in three major distillation companies located in Shiraz and Kashan, two key centers known for large-scale production of rosewater, mint distillates, and other hydrosols. During these visits, interviews were conducted with production managers and technicians to document: plant species used and their sourcing routes, equipment type (traditional copper stills vs. modern stainless-steel systems), distillation parameters (water-plant ratios, heating duration, condensation methods), quality control measures, storage and packaging standards, and the challenges associated with scaling traditional processes into industrial-level production.

Retail and Market Surveys

To capture consumer-facing availability and cultural relevance, surveys were conducted in 35 herbal shops, traditional distilleries, and local markets (Attari) across Karaj, Tehran, Hamedan, Kerman, and Kashan.

These surveys documented: the diversity of distillates offered, market prevalence (categorized as very common, moderately common, or less common/local), pricing patterns and seasonal variation, consumer perceptions and common therapeutic claims, and the extent of reliance on traditional vs. industrially bottled hydrosols.

Photographic documentation was obtained where permitted, including representative images of distillation apparatus, retail displays, and product labeling. Figure 2 provides a representative view of a traditional herbal market (Attari), illustrating the vibrant commercial context where these distillates are traded and highlighting the remarkable diversity of available products.

Interviews

Structured and semi-structured interviews were conducted with distillate producers, retailers, and knowledgeable consumers. Interviews focused on: traditional indications and preparation methods, cultural and regional variations in distillate use, perceived therapeutic value, shifts in consumer demand, and the factors influencing product quality and authenticity. All interviews were performed with informed consent, and no personal identifying information was recorded.

Figure 2. A traditional herbal market (Attari) in Iran, showcasing the diversity and commercial availability of herbal distillates (Aragh) documented in this study. Such outlets serve as crucial hubs for the preservation and transmission of traditional knowledge.

Botanical Verification

Plant species reported during fieldwork were cross-checked with taxonomic references and verified by a botanist at the FUMH Herbarium (Ferdowsi University of Mashhad) and Tehran Herbarium (Kharazmi University). Scientific names were standardized based on The Plant List and Plants of the World Online. Voucher specimens were consulted where available.

Data Management and Analysis

All collected data—including species inventories, plant parts used, traditional uses, and associated industrial applications—were compiled and cleaned using Microsoft Excel and R. Statistical analyses and visualizations (bar charts, donut plots, radar charts, and network graphs) were conducted using R version 4.2.1, incorporating:

- tidyverse (data wrangling and transformation)
- ggplot2 (visualization)
- networkD3 (network analysis)
- viridis (color-blind friendly palettes)

These analyses were designed to:

- Quantify species distribution across botanical families,
- Assess the prevalence of different plant parts used in distillation,
- Identify dominant therapeutic categories,
- Map the industrial potential of documented hydrosols.

Ethical Considerations

This research involved interviews with producers and retailers but did not collect personal identifiers or sensitive data. All participants provided verbal informed consent to share non-personal knowledge related to distillation practices and traditional uses. According to institutional guidelines, the study qualifies as minimal-risk ethnobotanical research.

Results

The systematic survey identified a diverse array of plant species used in the production of traditional Iranian herbal distillates. In total, 53 distinct plant species, utilized for the production of distillates, were documented. These species belonged to 28 different botanical plant families, with the Lamiaceae (mint family), Rosaceae (rose family), and Apiaceae (celery family) being the most predominant. The prevalence of each distillate in the Iranian market was categorized into three levels: (A) Very Common, (B) Moderately Common, and (C) Less Common/Local, as detailed in Table 1. The plant part most frequently employed for hydro-distillation was the aerial parts (including leaves and stems), followed by flowers and seeds. This comprehensive inventory, presented in Table 1, underscores the rich botanical diversity that underpins this traditional practice and highlights the species with the highest commercial and cultural significance.

Table 1. Inventory of documented Iranian herbal distillates (Aragh), their botanical characteristics, prevalence, and key properties.

Species	Family	Plant Part Used	Prevalence in Iran	Key Traditional Uses	Key Bioactive Compounds (Reported in Literature)	Modern Industrial Potential
Allium sativum L.	Amaryllidaceae	Bulb	B	Hypertension, hypercholesterolemia, antimicrobial, immune booster.	Allicin, alliin, ajoene, S-allyl cysteine (El-Saber *et al.* 2020)	Dietary supplements, natural food preservatives, functional health drinks.
Anethum graveolens L.	Apiaceae	Aerial parts	B	Carminative, galactagogue, digestive aid, diuretic.	Carvone, limonene, α-phellandrene (Kaur & Shah 2009)	Flavoring in food industry, functional beverages for digestion, natural carminative.
Apium graveolens L.	Apiaceae	Aerial parts	B	Diuretic, anti-rheumatic, antihypertensive, sedative.	Apiol, phthalides (e.g., sedanenolide), apiin (Al-Asmari *et al.* 2017)	Functional beverages for blood pressure and diuresis, flavoring agent.
Carum carvi L.	Apiaceae	Seeds	B	Carminative, digestive aid, galactagogue, antimicrobial.	Carvone, limonene (Johri 2011)	Flavoring agent in food and functional digestive beverages.
Coriandrum sativum L.	Apiaceae	Aerial parts	B	Carminative, digestive aid, anti-flatulent, anti-anxiety.	Linalool, γ-terpinene, α-pinene (Al-Snafi 2016)	Flavoring agent in food industry, functional digestive beverages.
Eryngium creticum Lam.	Apiaceae	Aerial parts	C	Diuretic, anti-inflammatory, for kidney stones and urinary issues.	Saponins, flavonoids, essential oil (Elsbaey *et al.* 2022)	Potential for functional beverages targeting kidney and urinary health.
Trachyspermum ammi (L.) Sprague	Apiaceae	Seeds	B	Carminative, digestive aid, antispasmodic, antimicrobial, expectorant.	Thymol, γ-terpinene, p-cymene (Chahal *et al.* 2017)	Flavoring in food industry, natural food preservative, functional digestive beverages, ingredient in cough syrups.
Aloe vera (L.) Burm.f.	Asphodelaceae	Leaves	C	Skin burns and wounds, laxative, moisturizer, anti-inflammatory.	Acemannan, anthraquinones, polysaccharides (Nalimu *et al.* 2021)	Cosmetics, wound care gels, functional beverages (juice), pharmaceuticals.
Achillea millefolium L.	Asteraceae	Aerial parts	A	Digestive disorders, wound healing, anti-inflammatory, amenorrhea.	Azulenes (e.g., chamazulene), sesquiterpene lactones, flavonoids (Ali *et al.* 2017)	Cosmetics (for anti-inflammatory skin care), functional beverages for digestion.
Arctium lappa L.	Asteraceae	Aerial parts	B	"Blood purifier", skin conditions (eczema, acne), diuretic.	Lignans (e.g., arctiin), inulin, phenolic acids (Yosri *et al.* 2023)	Cosmetics for acne-prone skin, functional detox beverages, prebiotic supplements.
Artemisia absinthium L.	Asteraceae	Aerial parts	C	Digestive stimulant, anthelmintic, febrifuge, appetite enhancer.	Thujone, sesquiterpene lactones (e.g., absinthin) (Mohammed 2022)	Bittering agent in beverages, potential anthelmintic drugs.

Cichorium intybus L.	Asteraceae	Aerial parts	A	Digestive aid, liver tonic, diuretic, prebiotic.	Inulin, sesquiterpene lactones (e.g., lactucin), chicoric acid (Street 2013)	Prebiotic food additive, functional beverages for liver and digestive health.
Matricaria chamomilla L.	Asteraceae	Aerial parts	B	Sedative, anti-inflammatory, antispasmodic, for skin irritation.	Bisabolol, chamazulene, apigenin (Singh *et al.* 2011)	Functional relaxing beverages, cosmetic skin care, herbal teas.
Silybum marianum (L.) Gaertn.	Asteraceae	Flowers	B	Hepatoprotective, liver regeneration, antioxidant.	Silymarin complex (silybin, silychristin), taxifolin (Javeed *et al.* 2022)	Pharmaceutical hepatoprotective drugs, dietary supplements for liver health.
Tanacetum balsamita L.	Asteraceae	Aerial parts	C	Digestive aid, carminative, anti-inflammatory, for colds.	Camphor, carvone, 1,8-cineole (Vukic *et al.* 2022)	Potential flavoring agent, ingredient in functional digestive beverages.
Tanacetum parthenium (L.) Sch.Bip.	Asteraceae	Aerial parts	C	Prophylaxis for migraines, anti-inflammatory, antipyretic.	Parthenolide, camphor, flavonoids (Michalak et al. 2024)	Dietary supplements for migraine prevention, herbal pain relief formulations.
Tragopogon spp.	Asteraceae	Aerial parts	B	Diuretic, hepatoprotective, digestive aid.	Inulin, phenolic acids, flavonoids, saponins (Maleki *et al.* 2021)	Prebiotic functional foods and beverages, ingredient in herbal liver tonics and detox formulations.
Borago officinalis L.	Boraginaceae	Flowers	C	Diuretic, diaphoretic, anti-inflammatory, for respiratory issues.	Gamma-linolenic acid (GLA), mucilage, saponins (Slama *et al.* 2024)	Dietary supplements (seed oil for GLA), functional anti-inflammatory beverages.
Nasturtium officinale W.T.Aiton	Brassicaceae	Aerial parts	C	Diuretic, depurative, nutrient-rich tonic.	Gluconasturtiin, phenethyl isothiocyanate, vitamins (Negi *et al.* 2023)	Functional health drinks, nutrient-rich ingredient in salads/beverages.
Dipsacus laciniatus L.	Caprifoliaceae	Flowers	C	Analgesic, anti-inflammatory, for joint pain and wound healing.	Iridoids (e.g., loganin), saponins, alkaloids (Nănescu *et al.* 2023)	Potential for topical analgesics and anti-inflammatory formulations.
Valeriana officinalis L.	Caprifoliaceae	Roots	B	Sedative, anxiolytic, for insomnia and nervous unrest.	Valerenic acid, valepotriates, bornyl acetate (Patočka & Jakl 2010)	Herbal sleep aids, calming functional beverages, dietary supplements.
Alhagi maurorum Medik.	Fabaceae	Aerial parts	A	Kidney stones, jaundice, digestive ailments, expectorant.	Flavonoids, alkaloids, tannins (Ahmad *et al.* 2015)	Potential for functional beverages targeting kidney and liver health.
Medicago sativa L.	Fabaceae	Aerial parts	B	Nutrient tonic, diuretic, for arthritis and cholesterol.	Saponins, flavonoids, coumarins, phytoestrogens (Wrona *et al.* 2019)	Dietary supplements, functional beverages for cholesterol management.

Trigonella foenum-graecum L.	Fabaceae	Aerial parts	C	Galactagogue, hypoglycemic, digestive restorative.	Diosgenin, trigonelline, 4-hydroxyisoleucine (Goyal *et al.* 2016)	Dietary supplements for blood sugar and lactation, functional foods.
Juglans regia L.	Juglandaceae	Leaves	B	Astringent, anti-inflammatory, anthelmintic (from leaves/bark).	Juglone, flavonoids, tannins (Savage 2001)	Natural dye, cosmetic ingredient for skin, potential anthelmintic.
Dracocephalum kotschyi Boiss.	Lamiaceae	Aerial parts	C	Anti-inflammatory, analgesic, for headache and stomachache.	Flavonoids, terpenoids, rosmarinic acid (Ashrafi *et al.* 2017)	Potential for phytopharmaceuticals targeting pain and inflammation.
Lavandula stoechas L.	Lamiaceae	Aerial parts	B	Antiseptic, anti-inflammatory, for headaches and respiratory issues.	Fenchone, camphor, 1,8-cineole (Zengin *et al.* 2023)	Aromatherapy, cosmetic formulations for skin care, natural antiseptic.
Marrubium vulgare L.	Lamiaceae	Aerial parts	C	Expectorant, for coughs and bronchitis, bitter digestive tonic.	Diterpene lactones (e.g., marrubiin), flavonoids (Aćimović *et al.* 2020)	Ingredient in cough syrups and functional bitter tonics for digestion.
Melissa officinalis L.	Lamiaceae	Aerial parts	B	Sedative, carminative, antiviral, for anxiety and indigestion.	Citral (neral, geranial), citronellal, rosmarinic acid (Petrisor *et al.* 2022)	Calming functional beverages, flavoring agent, topical antiviral creams.
Mentha longifolia (L.) L.	Lamiaceae	Aerial parts	A	Carminative, digestive aid, antimicrobial, for colds.	Pulegone, piperitenone oxide, 1,8-cineole (Okut *et al.* 2017)	Flavoring in food and oral care products, functional digestive beverages.
Mentha spicata L.	Lamiaceae	Aerial parts	A	Carminative, digestive aid, anti-nausea, antimicrobial.	Carvone, limonene, 1,8-cineole (Chauhan *et al.* 2009)	Flavoring agent in chewing gum, toothpaste, and functional beverages.
Pimpinella anisum L.	Apiaceae	Fruits	B	Carminative, expectorant, antispasmodic, galactagogue.	trans-Anethole, estragole, anisaldehyde (Shojaii & Abdollahi Fard 2012)	Flavoring in liquors, confectionery, digestive drinks.
Salvia rosmarinus Spenn.	Lamiaceae	Aerial parts	C	Cognitive enhancer, antioxidant, circulatory stimulant, antimicrobial.	1,8-cineole, camphor, α-pinene, rosmarinic acid (Leporini *et al.* 2020)	Functional beverages for cognition, natural antioxidant preservative, cosmetics.
Satureja hortensis L.	Lamiaceae	Aerial parts	C	Digestive aid, carminative, antimicrobial, expectorant.	Carvacrol, γ-terpinene, p-cymene (Fierascu *et al.* 2018)	Flavoring in food, natural food preservative, functional digestive beverages.
Teucrium polium L.	Lamiaceae	Aerial parts	C	Antidiabetic, anti-inflammatory, cholagogue, for digestive issues.	Diterpenes, flavonoids, essential oil (Toplan *et al.* 2022)	Potential for phytopharmaceuticals targeting diabetes and inflammation.
Thymus spp.	Lamiaceae	Aerial parts	A	Antiseptic, antimicrobial, expectorant, for respiratory infections.	Thymol, carvacrol, p-cymene, linalool (Borugă *et al.* 2014)	Natural food preservative, mouthwash, functional respiratory health drinks.

Ziziphora tenuior L.	Lamiaceae	Aerial parts	C	Carminative, antiseptic, for colds and gastrointestinal disorders.	Pulegone, 1,8-cineole, limonene (Sarikurkcu *et al.* 2019)	Flavoring agent, functional digestive beverages, natural antiseptic.
Cinnamomum verum J.Presl	Lauraceae	Bark	B	Carminative, antimicrobial, antidiabetic, blood circulation.	Cinnamaldehyde, eugenol, camphor (Singh *et al.* 2021)	Flavoring in food/beverages, natural preservative, supplements for blood sugar.
Althaea officinalis L.	Malvaceae	Flowers	C	Demulcent for sore throats and coughs, soothing gastrointestinal tract.	Mucilage polysaccharides, flavonoids, phenolic acids (Shahsavari & Derikvand 2022)	Pharmaceutical syrups for coughs, functional soothing teas and beverages.
Malva sylvestris L.	Malvaceae	Flowers	B	Demulcent, emollient, for sore throats, coughs, and skin irritation.	Mucilage polysaccharides, anthocyanins, flavonoids (Batiha *et al.* 2023)	Soothing syrups and lozenges, cosmetic creams for sensitive skin.
Myrtus communis L.	Myrtaceae	Aerial parts	C	Antiseptic, astringent, for respiratory and urinary infections.	Myrtenyl acetate, 1,8-cineole, α-pinene (Usai *et al.* 2018)	Cosmetics (astringent), mouthwash, functional beverages for respiratory health.
Olea europaea L.	Oleaceae	Leaves	C	Antihypertensive, antioxidant, anti-inflammatory (from leaves).	Oleuropein, hydroxytyrosol, flavonoids (Ghanbari *et al.* 2012)	Functional beverages for cardiovascular health, cosmetic antioxidants.
Fumaria officinalis L.	Papaveraceae	Aerial parts	A	Detoxifier, for skin diseases, cholagogue, mild laxative.	Isoquinoline alkaloids (e.g., protopine), fumaric acid (Păltinean *et al.* 2016)	Potential ingredient in detox teas and skin health formulations.
Platanus orientalis L.	Platanaceae	Leaves	C	Astringent, anti-inflammatory (external use), for wounds.	Tannins, flavonoids, phenolic acids (Li *et al.* 2023)	Potential for topical astringent lotions and skin care products.
Oryza sativa L.	Poaceae	Hull	B	Demulcent, soothing for digestive tract, nutrient source.	Oryzanol, flavonoids, vitamins (Zhou et al. 2023)	Base for functional beverages, soothing agent in cosmetic lotions.
Nigella sativa L.	Ranunculaceae	Seeds	C	Immune booster, bronchodilator, digestive, for various chronic diseases.	Thymoquinone, nigellicine, fixed oils (Dąbrowski *et al.* 2024)	Dietary supplements, functional foods for immunity, seed oil for cosmetics.
Rosa canina L.	Rosaceae	Flowers	C	Immune booster (high Vitamin C), anti-inflammatory, diuretic.	Vitamin C, flavonoids, carotenoids, phenolics (Roman *et al.* 2013)	Functional beverages for immunity, dietary supplements, cosmetic oils.
Citrus medica L.	Rutaceae	Fruits	C	Digestive issues, anxiety, asthma, antimicrobial.	Limonene, γ-terpinene, citral (Tundis *et al.* 2023)	Flavoring in food and beverages, aromatic component in cosmetics.
Citrus × aurantium L.	Rutaceae	Flowers	A	Sedative, anxiolytic, digestive aid, cardiotonic.	Linalool, limonene, α-terpineol (Fernández-Cabal *et al.* 2025)	Flavoring agent, calming functional beverages, natural perfume for cosmetics.

Salix aegyptiaca L.	Salicaceae	Flowers	A	Analgesic, anti-inflammatory, antipyretic (source of salicin).	Salicin, tannins, flavonoids (Abdalrahman *et al.* 2024)	Natural source for salicylates used in herbal pain relief formulations.
Salix alba L.	Salicaceae	Leaves	C	Analgesic, anti-inflammatory, antipyretic (source of salicin).	Salicin, salicylic acid, tannins (Piątczak *et al.* 2020)	Natural source for salicylates used in herbal pain relief formulations.
Camellia sinensis (L.) Kuntze	Theaceae	Leaves	C	Stimulant, diuretic, astringent, improves mental focus.	Catechins (e.g., EGCG), caffeine, theanine (Wang *et al.* 2022)	Energy drinks, cognitive health supplements, antioxidant-rich functional beverages.
Urtica dioica L.	Urticaceae	Aerial parts	B	Diuretic, anti-inflammatory, for benign prostatic hyperplasia (BPH), arthritis.	Flavonoids, lignans, sterols, minerals (Urović *et al.* 2024)	Functional beverages for prostate and joint health, dietary supplements.
Elettaria cardamomum (L.) Maton	Zingiberaceae	Fruits	C	Carminative, digestive aid, breath freshener, expectorant.	1,8-cineole, α-terpinyl acetate, limonene (Blažeković *et al.* 2025)	Flavoring in food, beverages, and confectionery, functional digestive drinks.
Zingiber officinale Roscoe	Zingiberaceae	Rhizome	C	Anti-nausea, anti-inflammatory, digestive stimulant, circulatory stimulant.	Gingerols, shogaols, zingerone (Liu *et al.* 2019)	Functional beverages for digestion/nausea, flavoring agent, supplements.
Tribulus terrestris L.	Zygophyllaceae	Fruits	A	Tonic, aphrodisiac, diuretic, for urinary issues.	Saponins (e.g., protodioscin), alkaloids, flavonoids (Uysal *et al.* 2023)	Dietary supplements for libido and sports performance, functional tonics.

The analysis of botanical sources revealed a distinct dominance of specific plant families (Figure 3). The Lamiaceae (mint), Asteraceae (daisy), and Apiaceae (celery) families collectively accounted for the majority of species used, highlighting their cultural and practical significance in the tradition of distillate production.

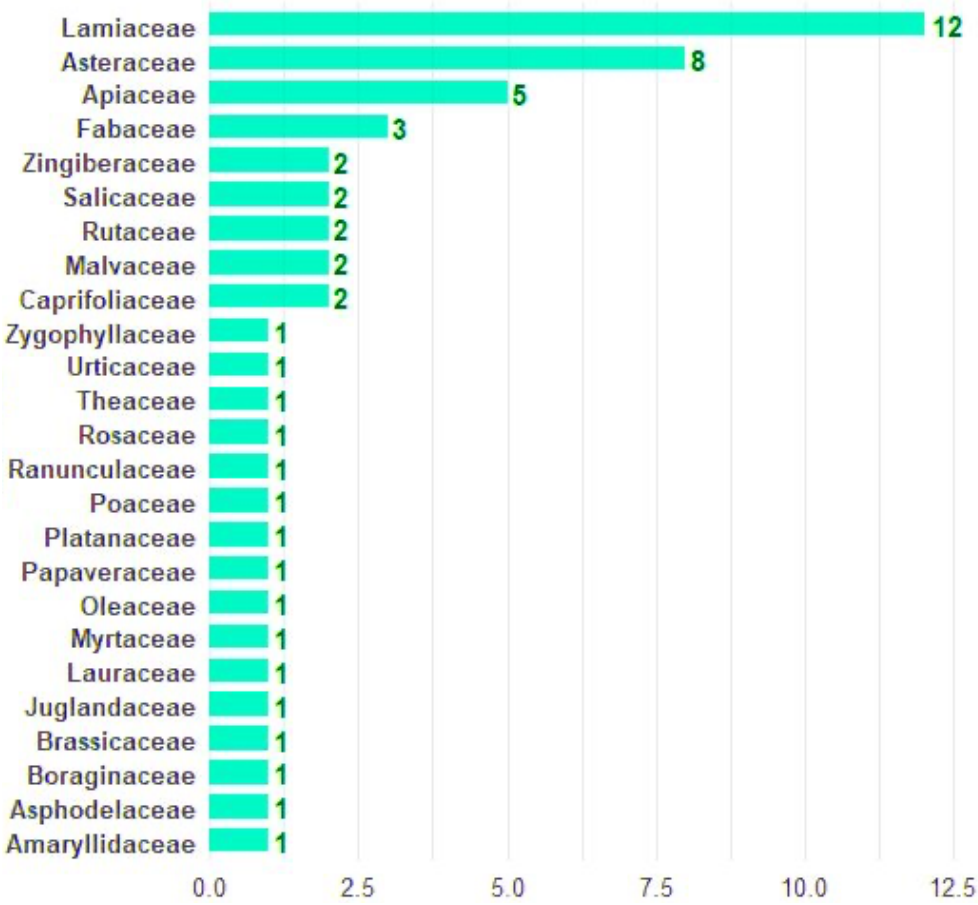

Figure 3. Distribution of documented plant species by botanical family.

To elucidate the interconnected pathways from botanical origin to industrial application, a Sankey diagram was constructed (Figure 4). This visualization maps the flow of species count across three critical stages: plant family, the specific plant part utilized in distillation, and the resultant primary industrial potential. The diagram quantitatively reveals dominant and specialized value chains, such as the strong flux from the Lamiaceae family through aerial parts toward functional beverages, and the distinct stream from Rosaceae flowers to the cosmetics industry.

Regarding the plant parts utilized for hydro-distillation, aerial parts were overwhelmingly the primary material (Figure 5). This preference suggests a traditional knowledge of the high concentration of desirable volatile compounds in the leaves and stems of aromatic plants.

To further unravel the complex relationships between plant species and their associated therapeutic properties, a network analysis was conducted and visualized in Figure 6. This graph maps the intricate connections where plant nodes are linked to their documented medicinal uses, revealing functional clusters and highlighting species with multifunctional therapeutic applications within the traditional Iranian pharmacopeia.

The assessment of industrial potential across various sectors revealed that functional beverages represent the most promising application (Figure 7). The radar chart visualization effectively demonstrates the multi-dimensional commercial opportunities these traditional hydrosols present beyond their conventional uses.

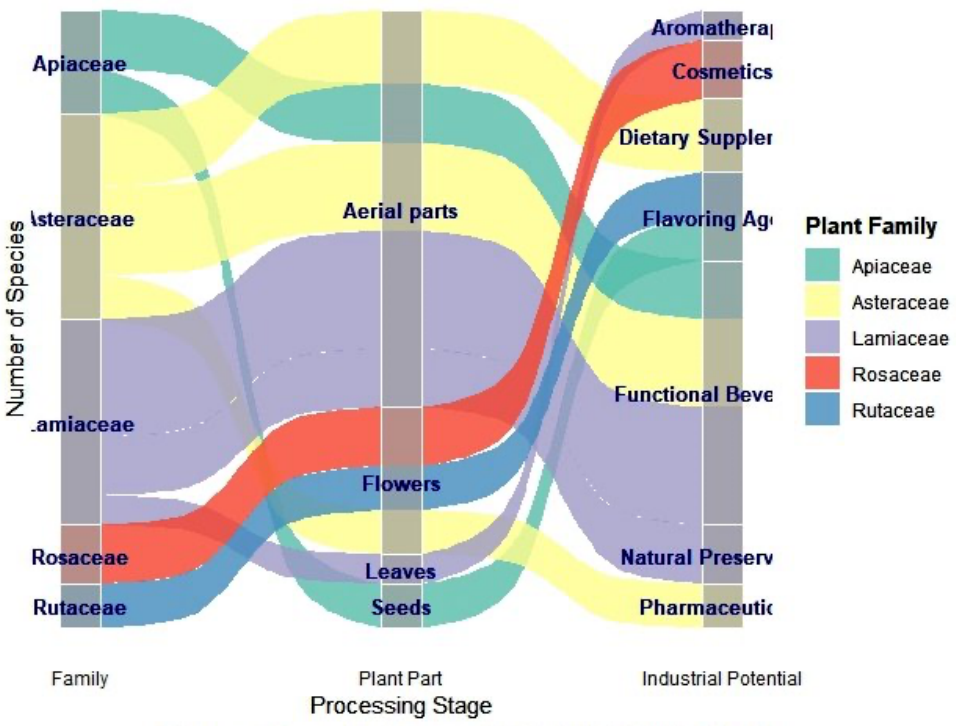

Figure 4. Sankey diagram illustrating the flow of Iranian herbal distillates from botanical family through the plant part utilized to their primary industrial potential. The width of the streams corresponds to the number of species associated with each pathway. This visualization highlights key relationships, such as the dominant use of Lamiaceae aerial parts for functional beverages and the specialization of Rosaceae flowers in cosmetic applications.

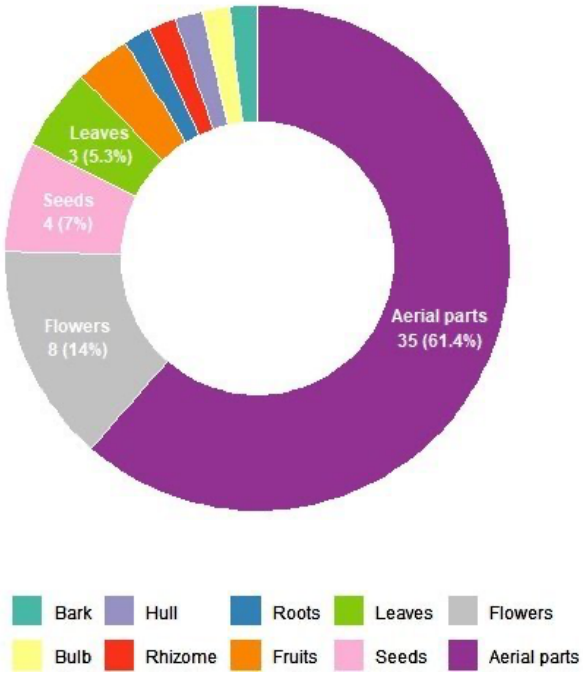

Figure 5. Plant parts utilized in the hydro-distillation process for producing Aragh.

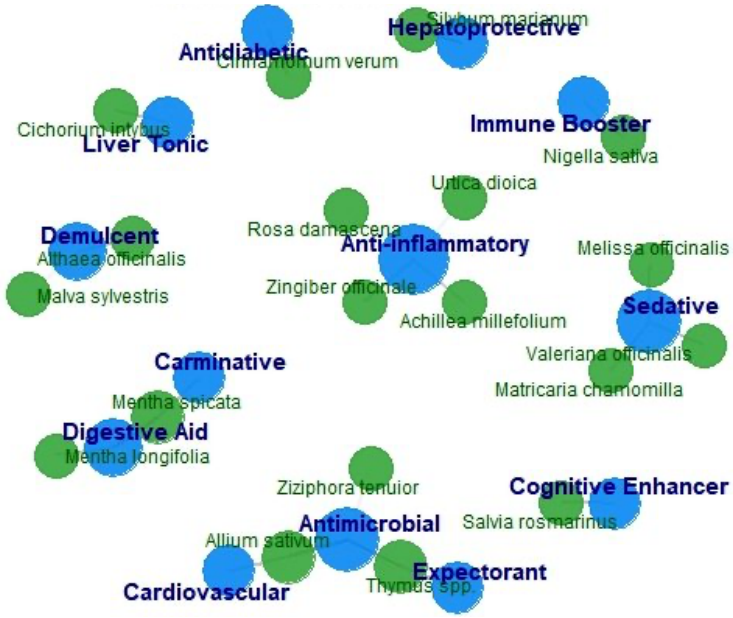

Figure 6. Network graph illustrating the complex relationships between medicinal plants and their therapeutic properties in Iranian herbal distillates. Plant species (green nodes) are connected to their documented medicinal properties (blue nodes). The visualization reveals functional clusters, such as the central role of plants from the Lamiaceae family in digestive and antimicrobial applications, and highlights plants with multiple therapeutic uses, indicating their high value in traditional medicine.

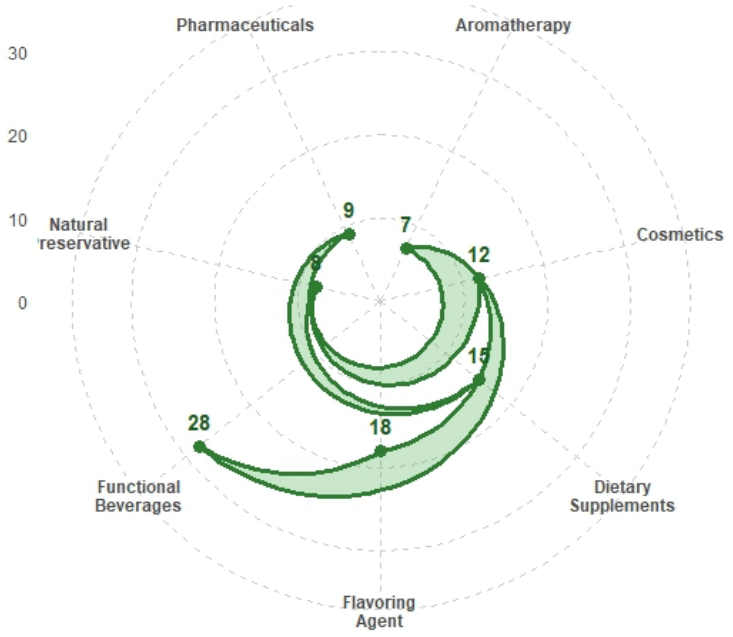

Figure 7. Industrial potential of Iranian herbal distillates across key commercial sectors, visualized using a radar chart. Each axis represents a different industrial sector, and the distance from the center corresponds to the number of species with potential applications in that sector. The prominent spike towards "Functional Beverages" highlights it as the most promising domain, followed by "Flavoring Agent" and "Dietary Supplements". This visualization underscores the versatile and multi-faceted commercial value of these traditional products.

Note: Notwithstanding their traditional use and general safety, it is strongly recommended that these herbal distillates be consumed for therapeutic purposes under the supervision of a qualified healthcare practitioner or phytotherapist.

Discussion

This study provides a systematic analysis of Iranian herbal distillates (Aragh), bridging traditional knowledge with modern scientific validation and industrial potential. Our findings reveal several key insights that both confirm and expand upon existing research in this field.

The documented 53 plant species from 28 families demonstrate the remarkable biodiversity underpinning this traditional practice. The dominance of Lamiaceae (11 species), Asteraceae (9 species), and Apiaceae (7 species) aligns with findings from Ghorbani (2005), who reported similar family distributions in traditional Iranian medicine. However, our research specifically highlights how these families have been preferentially selected for hydro-distillation, suggesting their particular suitability for this extraction method due to their rich volatile compound profiles.

The market prevalence analysis reveals a sophisticated commercial structure, with 14 species classified as very common (A), 22 as moderately common (B), and 17 as less common/local (C). This stratification echoes the market patterns observed by Sajjadi *et al.* (2015) but provides unprecedented detail on the availability spectrum of these traditional products. The widespread availability of certain distillates like rosewater and mint water contrasts sharply with the localized availability of species like *Dracocephalum kotschyi*, indicating both robust traditional markets and opportunities for commercialization of lesser-known species.

Our findings align with recent urban ethnobotanical research in Iran (Jalali *et al.* 2025), further validating the continued significance of Lamiaceae, Asteraceae, and Apiaceae families in contemporary Iranian herbal practice, while specifically highlighting their distinct utilization for hydro-distillation. Also, a study in the village of Pasqaleh, Tehran (Maghsudi & Parsapajouh, 2022) shows that herbal extracts such as mint and rose water play a central role in local traditional medicine and emphasizes the cultural and therapeutic importance of these products in indigenous Iranian communities.

Our analysis of plant parts used in distillation shows a clear preference for aerial parts (66%), followed by flowers (15%) and seeds (8%). This finding corroborates the traditional knowledge documented by Zargari (1990) and aligns with modern phytochemical understanding, as aerial parts typically contain higher concentrations of volatile oils. The validation of these traditional practices through scientific literature demonstrates the sophisticated empirical knowledge developed over centuries of practice.

The pharmacological properties documented—particularly the high frequency of antimicrobial, antioxidant, and anti-inflammatory activities—receive strong support from contemporary research. The antimicrobial efficacy of Mentha and Thymus distillates reported in our study aligns with experimental findings by Safari *et al.* (2019) and Tajkarimi *et al.* (2010). Similarly, the antioxidant properties we documented for rosewater and other distillates confirm the results of Mahmoudi *et al.* (2020), who demonstrated significant antioxidant activity in *Mentha pulegium* hydrosol.

The industrial potential analysis positions Iranian distillates within the global trend toward natural products identified by Sanchez *et al.* (2020). Our identification of functional beverages as the most promising sector (28 species) reflects the growing consumer demand for health-oriented drinks, while the significant potential in natural preservatives (8 species) addresses the clean-label movement in food processing. The applications in cosmetics and aromatherapy further expand their commercial viability in the rapidly growing natural personal care market.

While this research demonstrates the significant potential of Iranian herbal distillates, several considerations emerge. The safety concerns highlighted by Blumenthal *et al.* (2000) regarding proper usage of herbal products remain relevant, even as some distillates like rosewater have achieved mainstream food status. Furthermore, the standardization challenges identified by Sefidkon *et al.* (2006) for *Rosa damascena* oil production apply equally to hydrosols, emphasizing the need for quality control in industrial applications.

In conclusion, this study not only documents the rich tradition of Iranian herbal distillates but also provides a scientific foundation for their modern applications. By systematically analyzing botanical sources, traditional uses, pharmacological properties, and industrial potential, we bridge the gap between ethnobotanical knowledge and contemporary market opportunities. Future research should focus on clinical validation of bioactivities, standardization of production methods, and sustainable sourcing strategies to fully realize the global potential of these traditional products while preserving their cultural heritage.

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Declarations

Ethics approval and consent to participate: All participants involved in the interview process gave their prior informed oral consent.

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Literature cited

Abdalrahman MR, Göçeri A, Sofi SA, Alma MH, Kireçci E, Yılmaz MA. 2024. Investigation of chemical composition and biological activity of *Salix aegyptiaca* L. roots. KSU Journal of Agriculture and Nature 27(6):1237-1248. doi: 10.18016/ksutarimdoga.vi.1402758

Aćimović M, Jeremić K, Salaj N, Gavarić N, Kiprovski B, Sikora V, Zeremski T. 2020. *Marrubium vulgare* L.: A phytochemical and pharmacological overview. Molecules 25(12):2898. doi: 10.3390/molecules25122898

Ahmad N, Bibi Y, Saboon RI, Zahara K, Idrees S, Khalid N, Bashir T, Tabassum S, Mudrikah. 2015. Traditional uses and pharmacological properties of *Alhagi maurorum* Medik. Asian Pacific Journal of Tropical Disease 5(11):856-861. doi: 10.1016/S2222-1808(15)60945-8

Akhgar MR, Ebrahimi M, Taban A. 2012. A comparative study on the chemical composition of Iranian orange blossom, rosewater, and mint hydrosols. Journal of Essential Oil-Bearing Plants 15(6):942-949.

Al-Asmari AK, Athar MT, Kadasah SG. 2017. An updated phytopharmacological review on medicinal plant of Arab region: *Apium graveolens* L. Pharmacognosy Reviews 11(21):13-18.

Ali SI, Gopalakrishnan B, Venkatesalu V. 2017. Pharmacognosy, phytochemistry and pharmacological properties of *Achillea millefolium* L.: A review. Phytotherapy Research 31(8):1140-1161. doi: 10.1002/ptr.5840

Al-Snafi AE. 2016. A review on chemical constituents and pharmacological activities of *Coriandrum sativum*. IOSR Journal of Pharmacy 6(7:3):17-42. doi: 10.9790/3013-067031742

Ashrafi B, Ramak P, Ezatpour B, Talei GR. 2017. Investigation on chemical composition, antimicrobial, antioxidant, and cytotoxic properties of essential oil from *Dracocephalum kotschyi* Boiss. African Journal of Traditional, Complementary and Alternative Medicines 14(3):209-217. doi: 10.21010/ajtcam.v14i3.23

Babaei A, Tabaei-Aghdaei SR, Khosh-Khui M, Omidbaigi R, Naghavi MR, Esselink GD, Smulders MJM. 2007. Microsatellite analysis of Damask rose (*Rosa damascena* Mill.) accessions from various regions in Iran reveals multiple genotypes. BMC Plant Biology 7:12.

Batiha GE, Tene ST, Teibo JO, Shaheen HM, Oluwatoba OS, Teibo TKA, Al-Kuraishy HM, Al-Garbee AI, Alexiou A, Papadakis M. 2023. The phytochemical profiling, pharmacological activities, and safety of *Malva sylvestris*: A review. Naunyn-Schmiedeberg's Archives of Pharmacology 396(3):421-440. doi: 10.1007/s00210-022-02329-w

Blažeković B, Čiča L, Kindl M, Vladimir-Knežević S. 2025. Content and chemical composition of essential oil from *Elettaria cardamomum* (L.) Maton. Croatica Chemica Acta 98(3):1-9. doi: 10.5562/cca4178

Blumenthal M, Goldberg A, Brinckmann J. (eds) 2000. Herbal Medicine: Expanded Commission E Monographs. American Botanical Council.

Borugă O, Jianu C, Mişcă C, Goleţ I, Gruia AT, Horhat FG. 2014. *Thymus vulgaris* essential oil: Chemical composition and antimicrobial activity. Journal of Medicine and Life 7(3): 56-60.

Bouyahya A, Zengin G, Belmehdi O, Bourais I, Chamkhi I, Taha D, Benali T, Dakka N, Bakri Y. 2020. *Origanum compactum* Benth., from traditional use to biotechnological applications. Journal of Food Biochemistry 44(8): e13251. doi: 10.1111/jfbc.13251

Chahal KK, Dhaiwal K, Kumar A, Kataria D, Singla N. 2017. Chemical composition of *Trachyspermum ammi* L. and its biological properties: A review. Journal of Pharmacognosy and Phytochemistry 6(3): 131-140.

Chauhan RS, Kaul MK, Shahi AK, Kumar A, Ram G, Tawa A. 2009. Chemical composition of essential oils in *Mentha spicata* L. accession [IIIM(J)26]. Industrial Crops and Products 29(2-3): 654-656. doi: 10.1016/j.indcrop.2008.12.003

Dąbrowski G, Czaplicki S, Konopka I. 2024. Variation in the composition and quality of *Nigella sativa* L. seed oils. Molecules 29(6): 1360. doi: 10.3390/molecules29061360

El-Saber Batiha G, Beshbishy AM, Wasef LG, Elewa YHA, Al-Sagan A, Abd El-Hack ME, Taha AE, Abd-Elhakim Y, Devkota HP. 2020. Chemical constituents and pharmacological activities of garlic (*Allium sativum* L.). Nutrients 12(3): 872.

Elsbaey M, Ibrahim MAA, Shawky AM, Miyamoto T. 2022. *Eryngium creticum* L.: Chemical characterization and SARS-CoV-2 inhibitory activity. ACS Omega 7(26): 22725-22734. doi: 10.1021/acsomega.2c02237

Fernández-Cabal J, Avilés-Betanzos KA, Cauich-Rodríguez JV, Ramírez-Sucre MO, Rodríguez-Buenfil IM. 2025. Recent developments in *Citrus* × *aurantium*: Bioactive compounds and technological applications. Processes 13(1): 120. doi: 10.3390/pr13010120

Fierascu I, Dinu-Pirvu CE, Fierascu RC, Velescu BS, Anuta V, Ortan A, Jinga V. 2018. Phytochemical profile and biological activities of *Satureja hortensis* L. Molecules 23(10): 2458. doi: 10.3390/molecules23102458

Ghahremaninejad F, Alirezaei Z, Mohammadi M, Nejad Falatoury A. 2025. Updated catalogue of Iran's endemic angiosperms. Taxonomy and Biosystematics 17(64): 23-70. doi: 10.22108/tbj.2025.146441.1314

Ghanbari R, Anwar F, Alkharfy KM, Gilani AH, Saari N. 2012. Valuable nutrients in *Olea europaea* L. International Journal of Molecular Sciences 13(3): 3291-3340. doi: 10.3390/ijms13033291

Ghorbani A. 2005. Studies on pharmaceutical ethnobotany in Turkmen Sahra, Iran. Journal of Ethnopharmacology 102(1): 58-68.

Goyal S, Gupta N, Chatterjee S. 2016. Therapeutic potential of *Trigonella foenum-graecum* L. Journal of Toxicology 2:1250387. doi: 10.1155/2016/1250387

Ibn Sina (Avicenna): 1998. The Canon of Medicine (Al-Qanun fi'l-tibb: Vol. 1 (L. Sharafkandi, Trans.). Soroush Press. (Original work published 11th century).

Jalali S, Ghahremaninejad F, Nazari H, Bussmann RW. 2025. Documentation of medicinal plant use in Karaj, Iran: An urban ethnobotanical study of herbal markets and shops. Ethnobotany Research and Applications 33:8(2026): 1-27. http://dx.doi.org/10.32859/era.33.8.1-27

Javeed A, Ahmed M, Sajid AR, … Li C. 2022. Phytoconstituents and antioxidant activity of *Silybum marianum*. Molecules 27(9): 2641. doi: 10.3390/molecules27092641

Johri RK. 2011. *Cuminum cyminum* and *Carum carvi*: An update. Pharmacognosy Review 5(9): 63-72.

Kaur GJ, Shah S. 2009. Antibacterial properties of *Anethum graveolens*. BMC Complementary and Alternative Medicine 9:30.

Leporini M, Bonesi M, Loizzo MR, Passalacqua NG, Tundis R. 2020. Essential oil of *Salvia rosmarinus*. Plants 9(6): 798.

Li H, Zou Y, Liang J, … Li C. 2023. Resource utilization of *Platanus orientalis* bark. Forests 14(10): 2002.

Maghsudi M, Parsapajouh S, 2022. A Case Study of Ethnobotany in Iran: Pas-Qaleh Village of North Tehran. In: Öztürk M, Khan SM, Altay V, Efe R, Egamberdieva D, Khassanov FO. (eds) Biodiversity, Conservation and Sustainability in Asia. Springer International Publishing, pp. 763-783. doi: 10.1007/978-3-030-73943-0_42

Mahmoudi M, Ehsani A, Jebelli Javan A. 2020. Phytochemical, antioxidant and antimicrobial activity of *Mentha pulegium* L. hydrosol and its application in ultrafiltration cheese. Journal of Food Science and Technology 57(4): 1479-1488.

Maleki M, Ariaii P, Sharifi Soltani M. 2021. Fortifying of probiotic yogurt with free and microencapsulated extract of *Tragopogon collinus* and its effect on the viability of *Lactobacillus casei* and *Lactobacillus plantarum*. Food Science and Nutrition 9(7):3436-3448. doi: 10.1002/fsn3.2250

Malekpourzadeh L, Ghahremaninejad F, Mirtajadini SM. 2023. Collection and identification of some selected medicinal plants with antimicrobial properties from Takhte-Sartashtak region, Kerman. Iranian Journal of Medicinal Plants By-Products 13:1137-1146.

Michalak M, Stryjecka M, Żarnowiec P, Zagórska-Dziok M, Kiełtyka-Dadasiewicz A. 2024. Chemical Composition of Extracts from Various Parts of Feverfew (*Tanacetum parthenium* L.) and Their Antioxidant, Protective, and Antimicrobial Activities. International Journal of Molecular Sciences 25:2212179. doi: 10.3390/ijms252212179

Mohammed HA. 2022. Phytochemical characterization, antioxidant and cytotoxicity evaluation of traditionally used *Artemisia absinthium* L. (Wormwood). Plants 11:81028. doi: 10.3390/plants11081028

Nalimu F, Oloro J, Kahwa I, Ogwang PE. 2021. Review on the phytochemistry and toxicological profiles of *Aloe vera* (L.) Burm.f. and *Aloe ferox*. Future Journal of Pharmaceutical Science 7:145. doi: 10.1186/s43094-021-00296-2

Nănescu V, Tănasie ȘE, Biță A, Ciocîlteu MV, Bejenaru C, Bejenaru LE, Oancea CN, Nicolaescu OE, Rău G, Chirigiu L, Mocanu AG. 2023. Polyphenol Quantification on *Dipsacus laciniatus* and *Armoracia rusticana* from Romanian Flora. Farmacia 71 (5). doi: 10.31925/farmacia.2023.5.5

Negi N, Upadhyay S, Rana M, 2023. Phytochemical Investigation, Antioxidant and Anti-inflammatory activity of *Nasturtium officinale* W.T. Aiton. Journal of Chemistry and Health Risks 13:4913-919.

Okut N, Yagmur M, Yildirim B. 2017. Chemical composition of essential oil of *Mentha longifolia* L. subsp. longifolia growing wild. Pakistan Journal of Botany 49:2525-529.

Păltinean R, Toiu A, Wauters JN, Frédérich M, Tits M, Angenot L, Tămaş M, Crişan G. 2016. Phytochemical Analysis of *Fumaria officinalis* L. (Fumariaceae). Farmacia 64 (3).

Patočka J, Jakl J. 2010. Biomedically relevant chemical constituents of *Valeriana officinal*is. Journal of Applied Biomedicine 8:111-118. doi: 10.2478/v10136-009-0002-z

Petrisor G, Motelica L, Craciun LN, Oprea OC, Ficai D, Ficai A. 2022. *Melissa officinalis*: composition, pharmacological effects and derived release systems-A review. International Journal of Molecular Sciences 23:73591. doi: 10.3390/ijms23073591

Piątczak E, Dybowska M, Płuciennik E, Kośla K, Kolniak-Ostek J, Kalinowska-Lis U. 2020. Identification and accumulation of phenolic compounds in the leaves and bark of *Salix alba* (L.) and their biological potential. Biomolecules 10 (10):1391. doi: 10.3390/biom10101391

Roman I, Stănilă A, Stănilă S. 2013. Bioactive compounds and antioxidant activity of *Rosa canina* L. biotypes from spontaneous flora of Transylvania. Chemistry Central Journal 7:173. doi: 10.1186/1752-153X-7-73

Safari M, Ahmady-Asbchin S, Rezaei Z. 2019. Evaluation of antioxidant and antimicrobial activities of *Rosa damascena* hydrosol and its synergistic effect with nisin in food model system. Journal of Food Measurement and Characteristics 13:2933-2941.

Sajjadi SE, Shokoohinia Y, Moayedi NS. 2015. A review on the phytochemistry and pharmacology of *Rosa damascena* Mill. Journal of Islamic Iranian Traditional Medicine 6:111-124.

Sanchez M, Lozano LJ, Garcia A. 2020. Potential applications of hydrolates from aromatic plants as natural food preservatives. Foods 9:121750.

Sarikurkcu C, Kakouri E, Sarikurkcu RT, Tarantilis PA. 2019. Study on the chemical composition, enzyme inhibition and antioxidant activity of *Ziziphora taurica* subsp. *cleonioides*. Applied Science 9:245515. doi: 10.3390/app9245515

Savage GP. 2001. Chemical composition of walnuts (*Juglans regia* L.) grown in New Zealand. Plant Foods and Human Nutrition 56:175-182. doi: 10.1023/a:1008175606698

Sefidkon F, Abbasi K, Khaniki GB. 2006. Influence of drying and distillation methods on oil content and composition of *Rosa damascena*. Flavour and Fragrance Journal 21 (2):305-310.

Shahsavari S, Derikvand Z. 2022. Extraction and identification of compounds of *Althaea officinalis* L. and *Anchusa italica* Retz. native to Ilam Province by using HS-SPME, GC-MS, and FTIR, and study of their antioxidant capacity. Progress in Chemistry and Biochemistry Research 5:338-350. doi: 10.22034/pcbr.2022.351031.1228

Shojaii A, Abdollahi Fard M. 2012. Review of pharmacological properties and chemical constituents of *Pimpinella anisum*. ISRN Pharmacy 510795. doi: 10.5402/2012/510795

Singh N, Rao AS, Nandal A, Kumar S, Yadav SS, Ganaie SA, Narasimhan B. 2021. Phytochemical and pharmacological review of *Cinnamomum veru*m J. Presl. -a versatile spice used in food and nutrition. Food Chemistry 338:127773. doi: 10.1016/j.foodchem.2020.127773

Singh O, Khanam Z, Misra N, Srivastava MK. 2011. Chamomile (*Matricaria chamomilla* L.): An overview. Pharmacognosy Review 5 (9): 82-95. doi: 10.4103/0973-7847.79103

Slama M, Slougui N, Benaissa A, Nekkaa A, Sellam F, Canabady-Rochelle L. 2024. *Borago officinalis* L.: A review on extraction processes, phytochemistry, pharmacology and toxicity. Chemistry and Biodiversity 21(5):e202301822. doi: 10.1002/cbdv.202301822

Street RA, Sidana J, Prinsloo G. 2013. *Cichorium intybus* L.: Traditional uses, phytochemistry and pharmacology. Evidence-Based Complementary and Alternative Medicine 579319. doi: 10.1155/2013/579319

Tajkarimi MM, Ibrahim SA, Cliver DO. 2010. Antimicrobial herb and spice compounds in food. Food Control 21 (9):1199-1218.

Toplan GG, Göger F, Taşkın T, Genç GE, Civaş A, İşcan G, Kürkçüoğlu M, Mat A, Başer KH. 2022. Phytochemical composition and pharmacological activities of *Teucrium polium* L. collected from eastern Turkey. Turkish Journal of Chemistry 46 (1):269-282. doi: 10.3906/kim-2107-13

Tundis R, Xiao J, Silva AS, Carreiró F, Loizzo MR. 2023. Health-Promoting properties and potential application in the food industry of *Citrus medica* L. and *Citrus* × *clementina* Hort. ex Tan. essential oils and their main constituents. Plants 12:991. doi: 10.3390/plants12050991

Urović S, Kojić I, Radić D, Smyatskaya YA, Bazarnova JG, Filip S, Tosti T. 2024. Chemical constituents of Stinging Nettle (*Urtica dioica* L.): A comprehensive review on phenolic and polyphenolic compounds and their bioactivity. International Journal of Molecular Sciences 25(6):3430. doi: 10.3390/ijms25063430

Usai M, Marchetti M, Culeddu N, Mulas M. 2018. Chemical composition of Myrtle (*Myrtus communis* L.) berries essential oils as observed in a collection of genotypes. Molecules 23:102502. doi: 10.3390/molecules23102502

Uysal S, Senkardes I, József Jekő J, Cziáky Z, Zengin G. 2023. Chemical characterization and pharmacological profile of *Tribulus terrestris* extracts: A novel source of cosmeceuticals and pharmaceuticals. Biochemistry Systematics and Ecology 107:104600. doi: 10.1016/j.bse.2023.104600

Vukic MD, Vukovic NL, Obradovic AD, Galovičová L, Čmiková N, Kačániová M, Matic MM. 2022. Chemical composition and biological activity of *Tanacetum balsamita* essential oils obtained from different plant organs. Plants 11:243474. doi: 10.3390/plants11243474

Wang C, Han J, Pu Y, Wang X. 2022. Tea (*Camellia sinensis*): A review of nutritional composition, potential applications, and omics research. Applied Science 12:125874. doi: 10.3390/app12125874

Wrona O, Rafińska K, Walczak-Skierska J, Możeński C, Buszewski B. 2019. Extraction and determination of polar bioactive compounds from Alfalfa (*Medicago sativa* L.) Using supercritical techniques. Molecules 24:244608. doi: 10.3390/molecules24244608

Yosri N, Alsharif SM, Xiao J, Musharraf SG, Zhao C, Saeed A, Gao R, Said NS, Di Minno A, Daglia M, Guo Z, Khalifa, SAM, El-Seedi HR. 2023. (Burdock): Insights from ethnopharmacology, chemical constituents, clinical studies and pharmacological utility — a review. Biomedicine and Pharmacotherapy 158:114104. doi: 10.1016/j.biopha.2022.114104

Zargari A, 1990. Medicinal plants, vol. 1-5. University of Tehran Publications, Tehran.

Zengin G, Yagi S, Selvi S, Cziáky Z, Jeko J, Sinan KI, Topcu AA, Erci F, Boczkaj G. 2023. Elucidation of chemical compounds in different extracts of two *Lavandula* taxa and their biological potentials: Walking with versatile agents on the road from nature to functional applications. Industrial Crops Production 204:117366. doi: 10.1016/j.indcrop.2023.117366

Zhou H, Zhang J, Ba L, Liu J, Li H, Hua J, Luo, S, 2023. Chemical structure diversity and extensive biological functions of specialized metabolites in Rice. International Journal of Molecular Sciences 24 (23):17053. doi: 10.3390/ijms242317053