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Bioactivities of *Prunus mahaleb*: A Mini Review

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Abstract

The mahaleb cherry, which has the scientific name *Prunus mahaleb* L., is a fragrant shrub plant belonging to the Rosaceae family. The plant is commonly cultivated in the Mediterranean area. The people cultivated it for its essential oil and seeds, which have great therapeutic and nutritional value. It is widely distributed over North Africa, Central Asia, and Central-South Europe. The plant contains a variety of active constituents like coumarins, vital oils, polyphonic ingredients, and other phytochemical compounds that possess many pharmacological activities capable of improving people's health. These activities include antioxidant, antimicrobial, anti-inflammatory, gastro-protective, neuroprotective, and diabetic management actions. Overall data for this literature review was collected from online sources such as Google Scholar, Science Direct, Scopus, Research Gate, Elsevier, PubMed, and Web Science. In addition to that, the library of the pharmacognosy department was utilized to collect supplementary information on photochemical constituents, pharmacognosy, and pharmacological applications of mahaleb cherry. The gathered data was carefully examined and authenticated. The main aim of this review article is to uncover potential therapeutic activities of this plant that could be valuable in the future for therapeutic nutrition, as well as food and pharmaceutical industries.

Keywords

Antioxidant; Bioactivity; Edible oil; Polyphenol; *Prunus mahaleb*

Introduction

The small tree of *Prunus mahaleb* L. grows and reaches 10 meters in height. This deciduous shrub plant has white blooms and dark brown bark. The original distribution of Prunus mahaleb was in Central-South Europe, North Africa, and up to Central Asia (1,2). *Prunus mahaleb* L. seeds are widely known by local names as mahaleb, endulus, mahlep, or mistaka, and having a special taste and odor, the seeds are commonly used in bakery (3). Mahaleb cherries have historically been used as diuretics, tonics, digestive aids, sedatives, and antidiabetics; they are also used as a spice in food (3). The plant is abundant in polyphenolic compounds (phenolic acid, flavonoids, and anthocyanins), organic acids, volatile compounds (aldehydes were the predominant amount), and poly-unsaturated fatty acids in addition to minerals, including iron, copper, and zinc. Additionally, cherry fruit pulp contains the original forms of the distinctive fragrance chemicals coumarin and hydrocoumarin (4). The most beneficial effects of this herb are its analgesic and anti-inflammatory properties (5). In addition, several articles have demonstrated the antibacterial, antioxidant, and antiviral capabilities of *Prunus mahaleb* (6 -8), and more recent phytochemical research has identified several compounds having neuroprotective effects (5). The information for this literature review was taken from reputable online sources like Scopus, Google Scholar, Research Gate, Science Direct, Elsevier, PubMed, and Web of Science. Additional data were also received from the library's college pharmacy to find the light and notarize the morphology, distribution, and ethnobotanical importance of *Prunus mahaleb* (*P. mahaleb*), phytochemical ingredients, and pharmacological activities to reveal other rational therapeutic actions. The review aims to highlight *Prunus mahaleb* L's bioactivities that may promote fresh innovation in pharmaceuticals, foods, and industrial applicants.

Methodology

The data for this literature review were sourced from trustworthy internet platforms such as Scopus, Google Scholar, Research Gate, Science Direct, Elsevier, PubMed, and Web of Science. The search terms used for the medical subheading included "*Prunus mahaleb*", "Anti-bacterial", "Anti-viral", "Anti-fungal", "Antioxidant", "Bioactive compounds", and "Edible oil". The relevant publications were identified based on the titles and abstracts and subsequently retrieved in their entirety. These articles were then checked to ensure their inclusion in this study.

Morphology of the plant

Prunus mahaleb L. is a shrub or small tree that belongs to the Rosaceae family and grows in temperate regions all over the world. Its height ranges from 2 to 10 meters (9). The fruits are typically tiny, spherical, juicy, and flat; they also exhibit a high amount of anthocyanins. When these fruits are fully ripe, their color changes from green to red to black (3, 10).The leaves are wide, alternate, clustered at the ends of twigs that are placed alternately, oblong to cordate, and pointed. Flowers are white, fragrant, and grouped in upright racemes with 3 to 12 flowers that resemble corms (11, 12). The *Prunus mahaleb* seed has a pointed egg form, which serves as a beneficial source of fatty acids (40.40% w/w) and proteins (30.98% w/w) (13), as shown in Figure 1.

Distribution of the plant

The plant is native to the continents and is grown in temperate and tropical climates with well-drained soils. It can withstand hot, dry weather. *Prunus mahaleb* L. is a type of cherry tree that has white blooms and produces amazing dark red plums. It is also known as the mahaleb cherry, white mahaleb, English cherry, or wild cherry. Originally found in North Africa, Central Asia, and Central-South Europe, it is native to Iran, India, Central and Southern Europe, North Africa, Sudan, Syria, Turkey, Armenia, and Azerbaijan (12 -15). It is primarily found in the north and northeast of Iraq, where it can be found in regions that are higher than 600 meters above sea level. Most studies about mahaleb indicate that *Prunus mahaleb* grows in mountain areas, especially in the Zewe-Sulymaniya region of Iraqi Kurdistan (16), As shown in Figure 2.

Ethnobotanical importance of *Prunus mahaleb*

Humans depend on plants to meet their basic needs for food, clothing, medicine, and housing. The study of medicinal plants and their traditional usage has drawn more attention in recent years across the globe (17). *P. mahaleb* cherry trees are often used as rootstock to strengthen and vigor the sweet cherry; this practice is especially widespread in Southern Italy, particularly in the Apulia region (18). Traditional scents, lotions, and liqueurs are also made from the plant (19). Because the kernels of crushed seeds have a distinctive bitter taste, they are employed as flavoring agents in bagels, cakes, and muffins, as well as in traditional medicine as diuretic, antidiabetic, tonic, aphrodisiac, and expectorant agents (7), as shown in Table 1.

Phytochemistry

The main categories of phytoconstituents, including terpenoids (essential oil), polyphenolic compounds (phenolic acids and flavonoids), coumarins, and others, are assembled to form the phytochemical composition of *Prunus mahaleb* L. (18, 27). Table 2 and Figure 3 summarize several phytoconstituents in *Prunus mahaleb* L.

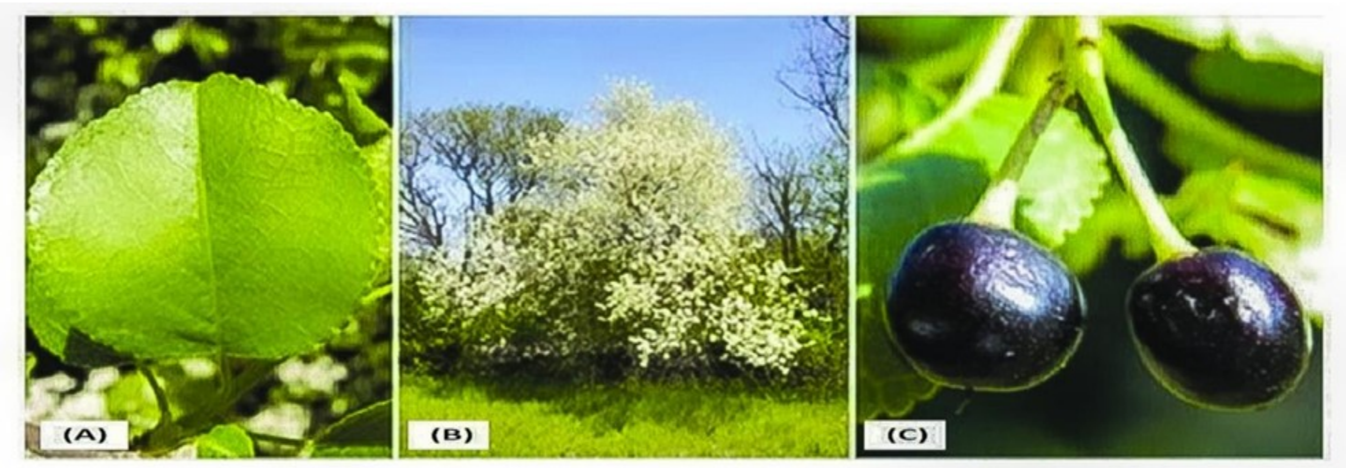

Figure 1. *Prunus mahaleb* L. A: Leaves of *Prunus mahaleb,* B: Tree of *Prunus mahaleb, C:* Fruits of *Prunus mahaleb (10)*

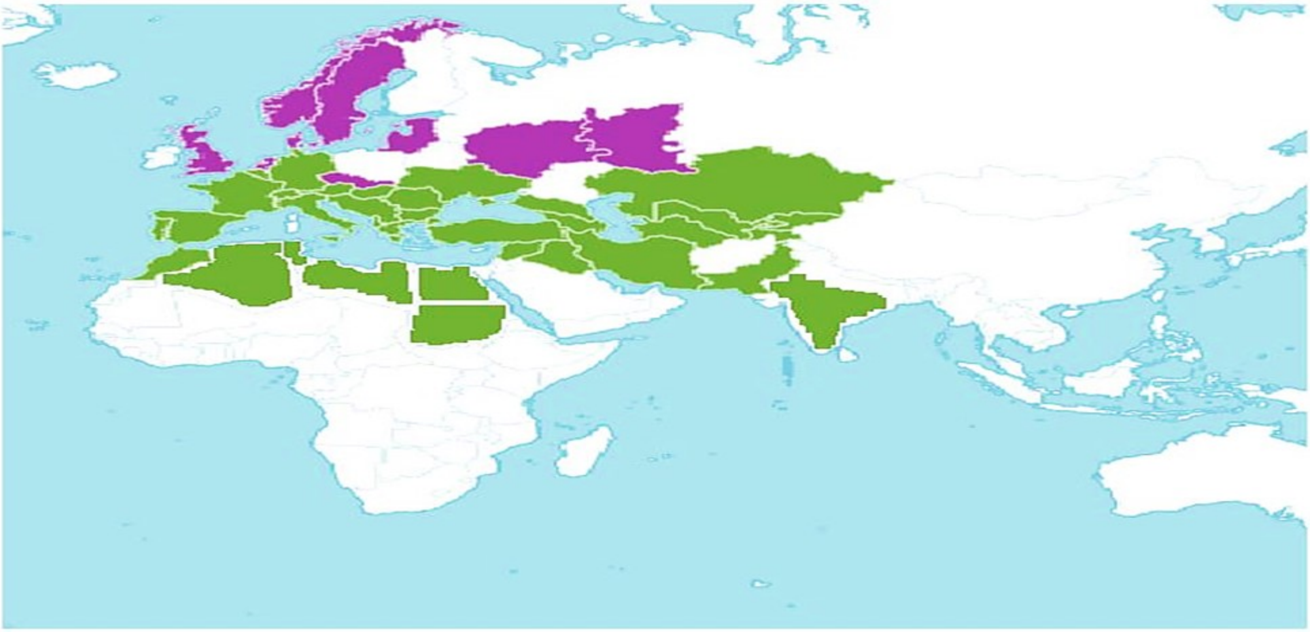

Figure 2. Geographical distribution of *Prunus mahaleb*. All the regions where mahaleb plants are most common are highlighted in green, while the violet color is related to other species of Prunus (12,13).

Table 1. Ethnobotanical uses of *Prunus mahaleb*

S.No.	Regions	Part used	Form of use	Ethnobotanical use	References
1.	Middle East and North Africa	Seeds	Powder	An aromatic spice and flavor	20
2.	Sudan	Kernels, seeds	Lotion	Hair nourishing, diarrhea treatment, flavoring agent	6,2,8
3.	Iran	Seed	Extract	kidney stones and respiratory tract infections	21
4	Turkey	Seeds	Powder	flavoring agent	3
5	Egypt	Kernels	Powder	Used as tonics, diuretics, digestive aids, sedatives, and antidiabetics	6
6	Turkey	Kernels	Powder	Improve the quality of bread	22
7	India	Fruit Kernels	Powder	Reduce hyperpigmentation	8
8	Iran	Fruit, Wood, Seed	Poultice	Edible as wild fruit, diaphoretic, laxative, culinary and spice, and wild fruit stomachic	23-26
9	Iraq	Fruit	Powder	Flavor and spice	16

Table 2. The main categories of phytoconstituents in the *Prunus mahaleb* L. plant

S No.	Plant part	Type of compound	Isolated chemical compound	Method of isolation/ detection	References
1.	Seeds	Volatile oils	linolenic acid, oleic acid, and linoleic acid	GC-MS	28
2.	Fruits	Phenolic acids	chlorogenic acid, coumaric acid, and ferulic acid	HPLC-DAD-MS	29
4.	Fruits	flavonoids	Rutin, naringenin	HPLC-DAD-MS	8
5.	Fruits, seedcake	Flavan -3-ols	Gallic acid ,catechin and epicatechin	HPLC-DAD-MS	30
	Seeds	Fatty acids & Phthalate esters	phthalate derivatives, six saturated fatty acids, five monounsaturated fatty acids (MUFAs), and three polyunsaturated fatty acids (PUFAs)	GC-MS	27

HPLC-DAD: High-performance liquid chromatograpgy- Diod array detector- Mass spectrometry, **GC-MS**: Gas chromatography – Mass Spectrometry.

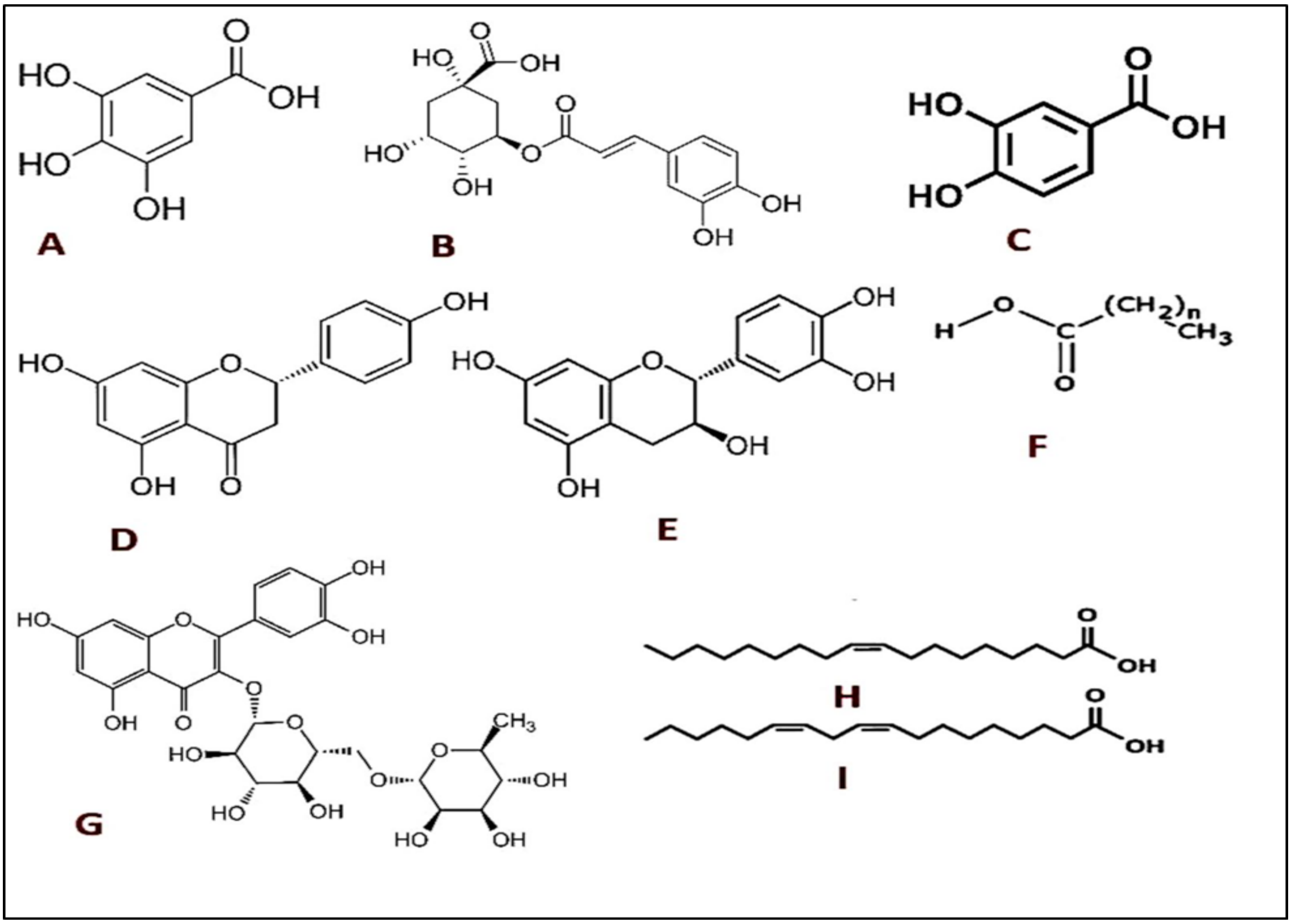

Figure 3.Chemical structure of the main active constituents of *Prunus mahaleb*: A: Gallic acid, B: Chlorogenic acid, C: Protocatechuic acid, D: Naringenin, E : catechin, F: saturated fatty acid, G: Rutin, H: Olieic acid, I: Linoleic acid (26,28, 31-33).

Pharmacological activity of *Prunus mahaleb*

Prunus mahaleb exhibits a range of pharmacological activities, including anti-inflammatory, antibacterial, antiviral, and antifungal effects. These effects can be attributed to the presence of its active constituent, Kernel oil, which contains a high percentage of unsaturated fatty acids (primarily linoleic acid), minerals oil, vitamins, phytosterols, phenolic compounds, carotenoids, and vitamin E (34).

Anti-Inflammatory Activity

The *Prunus mahaleb* plant shows notable anti-inflammatory properties by inhibiting the increased activation of gene expression of tumor necrosis factor-alpha (TNF-α) and cyclooxygenase-2 (COX-2), primarily in the colon of mice (29). Furthermore, the suppressive impact of the fruit extract of *P. mahaleb* on the production of endothelial adhesion molecules induced by lipopolysaccharide has been assessed in a laboratory setting. The extract exhibits a significant impact even at a concentration of 1 mg/mL, with a 50% drop observed at a concentration of 3 mg/mL. Furthermore, the extract reduces the expression of intercellular adhesion molecules -1 (ICAM-1), vascular cell adhesion molecules-1 (VCAM-1), and E-selectin in a manner that is dependent on the concentration (35).

Anti-bacterial Activity

Along with the increasing resistance of many bacteria to many types of currently available antibiotics and the high-cost production of many synthetic antibiotics, scientists are constantly searching for novel molecules with antibacterial properties. Herbal plants can be a viable alternative due to their broad safety margin, cost-effectiveness, and efficacy against numerous antibiotic-resistant pathogens. As shown in Table 3, different types of extract (ethanolic, methanolic, and even water) from other parts of the *P. mahaleb* plant (fruit, seed, leaves, branches, and flower) had potential antibacterial activity against various types of gram-positive and gram-negative bacteria like *Bacillus anthracis, Staphylococcus aureus*, *Bacillus licheniformis, Brucella melitensis, Escherichia coli*, *Pseudomonas aeruginosa, Klebsiella pneumonia, Enterococcus faecalis, Vibrio harveyi Bacillus subtilis* and *Proteus mirabilis.* The *Prunus mahaleb* contains a high percent of flavonoid depending on its genotypes with the highest level in fruit (30).

Anti-Fungal activity

The powerful anti-fungal effects of different parts of mahaleb may be related to the plant's capacity to hinder the biochemical manufacturing pathway of aflatoxin, hence impeding fungal growth (39). The methanol extracts derived from seeds, leaves, and fruits have inhibitory properties against many fungus species, including *Candida albicans, Candida parapsilosis, Candida tropicalis,* and *Candida krusei* (Table 4).

Table 3. Antibacterial activity of different parts of *P. mahlab* extracted in various solvents.

S.No.	Parts used	Type of extract	Bacteria inhibited	Inhibition value	References
1	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extract	*E. coli*	32-64 µg/ml	36
2	Fruit	Water extract	*E. coli*	31.49 µg/ml	37
3	Seed	Ethanolic extract	*E. coli*	Inhibition zone (10-13 mm)	38
4	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extract	*P. aeruginosa*	32-64 µg/ml	36
5	Fruit	Water extracts	*P. aeruginosa*	µg/ml 200<	37
6	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract. & n-hexane extract	*P. mirabilis*	16 µg µg/ml	36
7	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract. & n-hexane extract	*K. pneumonia*	32-64 µg /ml	36
8	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extract	*A. baumannii*	8-16 µg µg/ml	36
9	Leaves, seed kernels, fleshy seed coats, stalks, and resins	Methanolic extract & n-hexane extract	*S. aureus*	32 µg/ml	36
10	Flower	Methanolic extract	*S. aureus*	64 µg µg/ml	36
11	Fruit	n-hexane extract	*S. aureus*	64 µg µg/ml	36
12	Branches	n-hexane extract	*S. aureus*	64 µg µg/ml	36
13	Seed	Ethanolic extract	*S. aureus*	Inhibition zone 9 mm	36
14	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extract	*E. faecalis*	32 µg µg/ml	36
15	Leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extract	*E. faecalis*	32 µg µg/ml	36
16	Flower	Methanolic extract	*E. faecalis*	64 µg µg/ml	36
17	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extract	*B. subtilis*	16 µg µg/ml	36
18	Flower	Methanolic extract	*B. subtilis*	64 µg µg/ml	36
19	Fruit	n-hexane extract	*B. subtilis*	64 µg µg/ml	36
20	Branches	n-hexane extract	*B. subtilis*	64 µg µg/ml	36

Table 4. Antifungal activity of activity of different parts of P. mahaleb extracted in different solvents.

S.No.	Parts used	Type of extract	Fungi inhibited	Minimum inhibitory concentration	References
1	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extracts	*C. albicans*	16-32 µg µg/ml	36
2	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extracts	*C. parapsilosis*	32 µg µg/ml	36
3	Leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract & n-hexane extracts	*C. tropicalis*	32 µg µg/ml	36
4	Flower	Methanolic extract	*C. tropicalis*	64 µg µg/ml	36
5	Flower, leaves, seed kernels, fleshy seed coats, fruit stalks, branches, and resins	Methanolic extract and n-hexane extracts	*C. krusei*	64 µg µg/ml	36

Neuroprotective activity

The neuroprotective efficacy of the aqueous extract derived from *P. mahaleb* was assessed by employing hypothalamic HypoE22 cells. The MTT viability test revealed that the aqueous extract of *P. mahaleb* can enhance cell viability by over 70% when administered at concentrations ranging from 100 to 1000 µg/ml. In addition, when cells were subjected to a pro-oxidant stimulus of hydrogen peroxide at a concentration of 300 µM, the extract successfully prevented the degradation of dopamine, as indicated by the DOPAC/DA ratio (30). The main reason for the neuroprotective effect of *P. mahaleb* is the strong interaction between chicoric acid and monoamines oxidase-B (MAO-B) enzyme, which leads to improved survival of neuronal cells and subsequently reduced memory impairment. This finding has been shown by animal models of neuroinflammation (40). Moreover, another study demonstrated that the potential micromolar affinity of chicoric acid towards MAO-B caused enhancement in the neuroprotective prosperity and anti-neuroinflammatory actions exerted by other species of *P. mahaleb* (41). Additionally, it underscores the ability of chicoric acid in isolation to increase the viability of neuronal cells and decrease memory decline in diverse experimental models utilized in the induction of neuroinflammation (42). An experimental trial has been done to explore the analgesic properties of *P. mahaleb* water extract when administered orally at 12 and 24 mg/kg doses. This suggests that it could be a novel option for management of pain (5).

Anti-viral activity

Two studies have examined the antiviral efficacy of the aqueous extract of *P. mahaleb*. The first one was against the COVID-19 virus (30). The second study concluded that the aqueous extract possesses the capacity to inhibit the gene expression of two proteins, mainly angiotensin-converting enzyme 2 (ACE2) and transmembrane protease serine 2 (TMPRSS2), which play an important role in facilitating the entry of SARS-CoV-2 into the human host (43).

Antioxidants activity

Antioxidants are substances that aid the body in protecting itself against oxidative stress, which occurs when there is an imbalance between the body's antioxidants and free radicals (44). Free radicals are extremely reactive substances that can harm cells and have a role in the development of certain chronic illnesses, such as cancer, heart disease, and neurological disorders (45-47). The seeds and fruits of *P. mahaleb* contain bioactive components, including flavonoid and phenolic compounds, which possess antioxidant activity (3,10). These chemicals can reduce oxidative stress and its harmful consequences by removing and counteracting free radicals (30). *Prunus mahaleb* extract has been the subject of several studies that have investigated their antioxidant effects using various in-vitro approaches, as indicated by literature analysis. The results of this research are summarized in Table 5. The ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) assay are frequently used in-vitro techniques to assess the antioxidant properties of extracts.

Table 5. The total antioxidant capacity of the extract from the stem, bark, and fruit of *P. mahaleb* was measured by different techniques.

Part of the plant	Extract's type	Antioxidant techniques	Antioxidant capacity	References
Stem bark	Methanolic extract	2,2-diphenyl-1-picrylhydrazyl radical (DPPH)	80.9%	30
Stem bark	Methanolic extract	Reducing power assay (RPA	89.30%	30
Seed	Methanolic extract	DPPH	44.3 %	48
Seed	Hexane extract	DPPH	26.8 %	48
Seed	Methanolic extract	Ferric reducing antioxidant power	51.P9 %	48
Seed	Hexane extract	Ferric reducing antioxidant power	32.8 %	48
Fruit	Ethanolic extract	Oxygen Radical Absorbance Capacity (ORAC)	450.550 ± 18.447 µmol /mL	3
Fruit	Ethanolic extract	Folin–Ciocalteu reducing capacity assay	22.734 ± 0.253 mg GAE/mL	3
Fruit	Methanolic extract	Cupric ion reducing antioxidant capacity (CUPRAC) assay	3.92 ± 0.26 mg Trolox/100g	49
Fruit	Methanolic extract	Ce(IV)⌧Based reducing capacity (CERAC) assay	15.64 mg Trolox/100g	49

Discussion

Prunus mahaleb is believed to have originated from the northern region of Iraq, as shown by its seeds, fruits, and other parts that are specifically utilized in traditional medicine, as a food additive (flavoring agent), and for aromatic uses. In Turkish traditional medicine, plant parts have been used as a tonic to treat several diseases. The fruits and seeds of the mahaleb tree, known for their bitter taste, have long been used as a remedy for the treatment of gastrointestinal problems and diabetes mellitus, as well as a heart tonic. The resins obtained from the external surface of wood have been utilized for the treatment of gastritis for many generations. Locally, herbal teas derived from stems, fruit stalks, leaves, and flowers have conventionally been employed to remedy colds and asthma in the winter season. The oil derived from the kernels by extraction has been employed in the production of liqueurs, varnished, and specialty wines due to its aromatic taste (50). The seed kernels have also been used for the management of diarrhea in children in Sudan, as well as for their sedative and vasodilator effects in Arabic countries (51).

Most of these applications have been verified through in vitro and in vivo investigations for biological assessment. The purpose of this research is to gather and analyze the existing literature on *P mahaleb*, focusing on its botanical, ethnobotanical, phytochemical, and pharmacological aspects. *Prunus mahaleb* exhibited diverse pharmacological actions, as indicated by the literature survey. Nevertheless, a thorough examination and meticulous evaluation of the provided data allow us to deduce that the plant exhibited encouraging antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, and neuroprotective properties. Inflammation is intricately linked to a range of disorders, including atherosclerosis, cardiovascular disease, stroke, cancer, diabetes mellitus, osteoarthritis, asthma, migraine, periodontitis, irritable bowel syndrome, and chronic fatigue syndrome. Presently, the primary pharmacological agents employed for the treatment of chronic inflammatory disorders mostly consist of diverse nonsteroidal medications, which have the potential to induce adverse effects (52). Consequently, there has been a growing focus on creating efficient and organic sources of anti-inflammatory substances. Recent evidence has indicated that several types of wild fruits exhibit anti-inflammatory properties through diverse modes of action. Nitric oxide (NO) is a biomarker that indicates the presence of inflammation that occurs later in the process, specifically when inducible nitric oxide synthase (iNOS) is activated (53). Hence, the suppression of NO serves as an indication of potential anti-inflammatory characteristics. The study conducted by A. Oskoueian et al. examined the in vitro anti-inflammatory properties of methanol extracts derived from the seeds of *P. mahaleb*. The study showcased the seed extract's capacity to hinder the activity of inducible nitric oxide synthase (iNOS) while preserving cell viability (48). Cyclooxygenase -2 (COX-2) expression has a crucial role in promoting inflammation. Multiple investigations have verified the close association between COX-2, a significant mediator of inflammation, and the onset and progression of diabetes mellitus and diabetic nephropathy (54). Therefore, the suppression of COX-2 serves as an indication of potential anti-inflammatory characteristics. A study examined the anti-inflammatory properties of a water extract derived from the fruit of *P. mahaleb*. In the ex vivo experimental paradigm, the extract successfully inhibited the up-regulation of gene expression of TNFα and COX-2 (29), which play a significant role in colon inflammation. This suggests the extract has anti-inflammatory actions in the colon, aligning with existing research (55). Tumor necrosis factor-alpha is a cytokine that plays a role in systemic inflammation. It can change the expression of adhesion molecules on cultured endothelial cells, namely human umbilical vein endothelial cells (HUVECs) (56). The response of cellular adhesion molecules to pathophysiological stimuli can impact the advancement of atherosclerosis by facilitating the interaction between blood cells, such as leukocytes and endothelial cells (57). Tumor necrosis factor-alpha can enhance the production of adhesion molecules, including intercellular cell adhesion molecule-1 (ICAM-1), vascular cell adhesion molecule 1 (VCAM-1), and E-selectin, hence promoting inflammation (58). Flavonoids, which are polyphenolic substances found widely in plants, negatively correlate with cardiovascular disorders. They have preventative benefits against atherosclerosis (59). Anthocyanins, the primary flavonoid found in fruits and vegetables of *P. mahaleb*, are accountable for the vibrant red, blue, and purple hues observed in several plant-based items. The concentrated extract of *P mahaleb* contains a significant amount of anthocyanins, flavonols, and coumarin (3). The fruit extract can reduce the expression of endothelial adhesion molecules (ICAM-1, VCAM-1, and E-selectin) in cultured HUVEC, which may result in an anti-inflammatory action (35). The majority of the studies utilized in vitro assays to examine the pharmacological activities of the extracts, such as antiproliferative, antiplatelet aggregation, and cytotoxicity. This approach was chosen because cell lines offer a more efficient and cost-effective means of screening for chemotherapeutic activity compared to in vivo assay systems (60). While the data obtained from in vitro experiments is restricted and cannot be relied upon to anticipate the results of in vivo testing, they do have the advantage of delivering high-throughput preliminary data in a more efficient manner (61). Additionally, in vitro research can be utilized to gather information that can help limit the focus of subsequent investigations, which may involve more extensive and time-consuming approaches that are also more costly (62). Antibiotics eliminate bacteria in many ways, including disrupting cell wall synthesis, inhibiting protein and nucleic acid synthesis, or functioning as anti-metabolites. Nevertheless, there has been a rise in resistance to antibiotics. While the degree and rate at which bacteria acquire resistance to antimicrobial medications may differ, resistance has emerged against all antimicrobial drugs. Furthermore, there has been a rise in the prevalence of documented clinical issues resulting from bacterial resistance to several antimicrobial agents.

Utilizing medicinal plants, potentially as part of the diet, presents a viable substitute for antimicrobial medications because of their safety, minimal side effects, lower cost, and efficacy against a broad spectrum of antibiotic-resistant microorganisms (63). Flavonoids are polyphenolic compounds that demonstrate antibacterial activity through various mechanisms of action. Multiple studies have shown that flavonoids can impede energy metabolism, cytoplasmic membrane function, and nucleic acid synthesis. Furthermore, studies have revealed that flavonoids can reduce the permeability of cell membranes, the ability of pathogens to cause disease, the presence of porin on cell membranes, the adherence of bacteria, and the creation of biofilms, all of which are crucial for bacterial growth and development (64-69). Candida species are currently the most prevalent and dangerous fungal pathogens, accountable for most invasive and non-invasive fungal illnesses. Currently, only four categories of antifungal medications (polyene macrolides, azoles, flucytosine, and echinocandins) can be used to treat systemic mycoses. Regrettably, none are optimal in terms of effectiveness, the range of fungi they can combat, or their safety. The n-Hexane and methanol extracts obtained from several parts of the mahaleb plant, including flowers, leaves, seed kernels, fleshy seed coats, fruit stalks, and branches, exhibited antifungal properties against *C. krusei*. However, they did not show any action against *C. albicans, C. parapsilosis, or C. tropicalis* (56). As of now, no research has been conducted to elucidate the antifungal properties of *P. mahaleb* extracts. Nevertheless, numerous phenolic compounds can serve as a defense mechanism against fungal attack and aflatoxin synthesis by inhibiting the α-amylase enzyme or exerting an antioxidant impact (70). The α-amylase enzyme plays a crucial role in the growth of microorganisms. Inhibiting this enzyme strengthens the idea that there is a connection between phenolic compounds and susceptibility to fungal infections. Previous research has demonstrated that the combined action of different compounds can help protect against contamination by harmful fungal species (71,72).The antioxidant qualities can inhibit the oxidative effects on the toxigenic fungi, preventing mycotoxins' development. Flavonoids are a wide-ranging collection of polyphenolic chemicals found in plants with antioxidant properties (73). The flavonoid composition of mahaleb exhibits variation across different genotypes and various regions of the mahaleb tree (74). Fruits exhibited the greatest overall flavonoid concentration compared to leaves and bark (75). Phenolic compounds exhibit antioxidant action by effectively neutralizing free radicals, by scavenging them, donating hydrogen atoms or electrons, or chelating metal cations (76).

Conclusion

The review above highlights that *Prunus mahaleb* L. is a noteworthy medicinal plant due to its diverse array of biological activities, which can be attributed to its rich composition of phytochemical components such as coumarins (coumarin, dihydrocoumarin, herniarin), polyphenolic compounds (phenolic acids, flavonoids, and anthocyanins), glycosides, tannins, and Proanthocyanidins. Because of their effectiveness, these chemicals possess anti-inflammatory, analgesic, antibacterial, and antioxidant properties, which are utilized in conventional, pharmaceutical, and therapeutic applications. The objective of the review is to ascertain the specific active components accountable for the bioactivities of *Prunus mahaleb* L, which could stimulate advancements in medications, food products, and industrial applications.

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Authors' contributions

NMI participated in the design of the study and wrote the phytochemical study of the plants. TZA conceived of the study and participated in its design and coordination. ASM wrote the pharmacological activity and discussion part of the study review and participated in the sequence alignment and drafted the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest : Authors do not have any conflict of interest to declare.

Ethical issues: None.

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