

Food Applications of Berberis Plants

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The genus *Berberis* includes about 500 different species and commonly grown in Europe, the United States, South Asia, and some northern areas of Iran and Pakistan. Leaves and fruits can be prepared as food flavorings, juices, and teas. Phytochemical analysis of these species has reported alkaloids, tannins, phenolic compounds and oleanolic acid, among others. Moreover, p-cymene, limonene and ocimene as major compounds in essential oils were found by gas chromatography. *Berberis* is an important group of the plants having enormous potential in the food and pharmaceutical industry, since they possess several properties, including antioxidant, antimicrobial, anticancer activities.

Berberis

food preservative

alkaloid

antioxidant

human health

1. Introduction

Berberis species. are shrubs in the family *Berberidaceae*, native to central and southern Europe, western Asia, as well as northwest Africa ^[1]. About 500 species of these plants are found in most areas of central and southern Europe, the north-eastern region of United States, and Asia (including the northern area of Pakistan ^[2] and Iran ^[3]). The genus *Berberis* consists of spiny deciduous evergreen shrubs which are characterized by yellow wood and flowers ^[2], dimorphic long and short shoots (1–2 mm). Some *Berberis* fruits are small oblong berries 7–10 mm long and 3–5 mm broad and turn blue or red upon ripening during the late summer or autumn ^[1].

Berberis spp. are mainly consumed fresh, dried or used in juice production ^[4]. The fruits are very popular, known as *zereshk* in Iran where they are commonly used for cooking and in jam production, thus, encouraging the production of fresh edible seedless barberries fruits reaching about 22,000 tons per annum ^[5]. The fruits are also processed into beverages, drinks, syrups, candy and other confectionary products which are popular Iran. Furthermore, the leaves and fruits have also found applications in the production of food flavorings and teas. *Berberis* are popular due to their nutritional importance; however, they have found most usefulness in folk and traditional medicine where various parts, including roots, bark, leaves and fruits serve as major ingredients of herbal remedies in Ayurvedic, Iranian and Chinese medicine dating back at least 3000 years ^[6]. Currently, this species flower is popularly used amongst Tibetan speaking population in areas, such as Litang, China ^[7].

The effect of cold-pressed filtered oil of *Berberis* spp. seeds in delaying soybean oil oxidation in comparison to commercial antioxidants were carried out, and the study reported that *Berberis* oil contributed to oxidative stability of soybean oil comparably to commercial antioxidants ^[8]. Antioxidant and antibacterial activity of water extract of barberry has suggested their possible application as preservatives in food industries ^[9].

Isoquinoline alkaloids are the major bioactive constituents in *Berberis* [10]. Protoberberines and bisbenzyl-isoquinoline alkaloids, such as berbamine, tetrandrine and chondocurine, which have been known for their anti-inflammatory and immunosuppressive properties, have been detected by phytochemical analysis of the root and stem bark extracts of *B. vulgaris*. Berberine (an isoquinoline alkaloid) and berbamine are the most abundant phytochemicals of *Berberis* species [2]. The fruits contain a high amount of alkaloids, tannins, phenolic compounds and oleanolic acid [3][11], gum, pectin, oleoresins, organic acids, anthocyanins and carotenoids. In addition, palmitine [10], stigmasterol and its glycoside [12] have all been detected in various species of the *Berberis* plant.

Some *Berberis* fruits have been employed in the treatment of guts [13] kidney stones [14] and liver [15] and gall bladder [10] conditions. The root bark and stem of the *Berberis* have found usage as a diuretic, febrifuge, cathartic and antiseptic. Furthermore, preparations of the stem and root bark have been used to treat mouth and stomach ulcers [16]. Several parts of the plant have been reported to possess astringent and antiseptic properties, while the stem bark and flowers were found to be anti-rheumatic [17]. The alkaloid rich root bark of the plant has also been used as purgative and treatment for both diarrhea and rheumatism [18]. The berberine-rich rhizomes of *Berberis* species possess marked antibacterial and antitumor properties, with reported efficacies in treatment of various eye conditions [10][19]. Furthermore, the anti-inflammatory activity of berberine has been extensively studied amongst other pharmacological actions [10][20].

Berberine sulphate which is an alkaloid extracted from the roots and bark of various *Berberis* spp. Have been reported to possess antibacterial, antifungal and antiprotozoal activities. Reported the bacteriostatic activity of berberine against streptococci, and that the sub-minimum inhibitory concentrations (MICs) of the compound blocked the adherence of streptococci to host cells, immobilized fibronectin, and hexadecane in epithelial cells [21]. Furthermore, blood glucose and lipid regulatory properties of *Berberis* have been demonstrated [3][22][23][24]; and this was due to berberine-induced improvement in insulin sensitivity through regulation of adipokine secretion [25][26][27]. Effectiveness of *Berberis* species in the maintenance of heart health has been demonstrated in their ability to improve hypertension, ischemic heart disease, cardiac arrhythmias and cardiomyopathy [2][28].

The health-promoting effect of *Berberis* spp. cannot be overemphasized, as well as its popularity; however, this is restricted to central and southern Europe, western Asia, as well as northwest Africa. Hence, efforts should be geared towards making the *Berberis* plant also available to other regions of the world. Furthermore, most studies on *Berberis* spp. have been on berberine; therefore, efforts should be made towards researching possible therapeutic benefits of all other important phytoconstituents of the plant. Furthermore, the synergistic or additive effect of these phytoconstituents should be studied so as to elucidate the complex molecular interaction amongst various phytochemicals leading to the observed therapeutic properties. In addition, the modulatory effect of the plant/plant materials on gene expression should be prioritized.

2. *Berberis* Plants Essential Oils and Phytochemical Composition

Essential oils (EO) are volatile, complex natural compounds, which formed in aromatic plants as secondary metabolites. They are used in pharmaceutical, agricultural, and food industries, as well as are associated with antibacterial, anti-inflammatory, antioxidant, and insecticidal potential [29][30][31].

The gas chromatography coupled to mass spectrometry (GC-MS) analysis of various parts of *B. vulgaris* revealed that benzaldehyde, benzyl alcohol, 1-hexanol and 1-2-hexenal [32] were major compounds of the EOs from fruit, while *p*-cymene, limonene and ocimene were identified as major compounds of the EOs (Figure 1) from leaves and flowers [33].

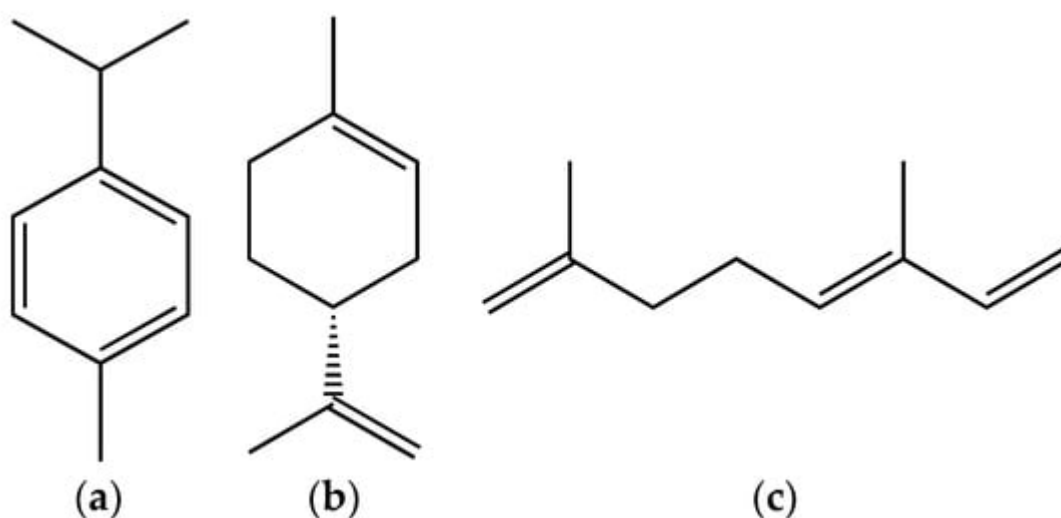


Figure 1. Major compounds of the essential oils (EOs) of *Berberis vulgaris* leaves and flowers. (a) *p*-cymene; (b) limonene; (c) ocimene.

Turkish *B. crataegina* fruit berry has 22 volatile compounds which are aldehydes had the highest concentration (5382 µg/kg), followed by alcohols (2487 µg/kg) and lactone (2422 µg/kg).

Major volatile compounds of the *B. crataegina* fruit are γ -butyrolactone, 3-hexanal and 2,6-dimethylphenol. Moreover, the olfactometric analysis of dry *B. crataegina* resulted eight aroma active compounds [34].

EOs of the roots of *B. integerrima* were analyzed by using modified microwave-assisted hydrodistillation (MAHD). Chemical diversity of 10 and 18 compounds were obtained from MAHD, MAHD with modified anyl, and with modified phenyl magnetic nanoparticles, the yields of the EOs were 0.16, 0.61 and 0.71 w/w %, respectively. Hexadecanoic acid was identified as a major compound for MAHD and modified MAHD methods [35].

Moreover, the GC/MS study on hexane extracts of the *B. aetnensis* and *B. libanotica* roots was showed that *B. aetnensis* have twenty-six and *B. libanotica* have thirty-seven non-polar compounds. Stigmasterol (Figure 2) is the major compound of both species [36].

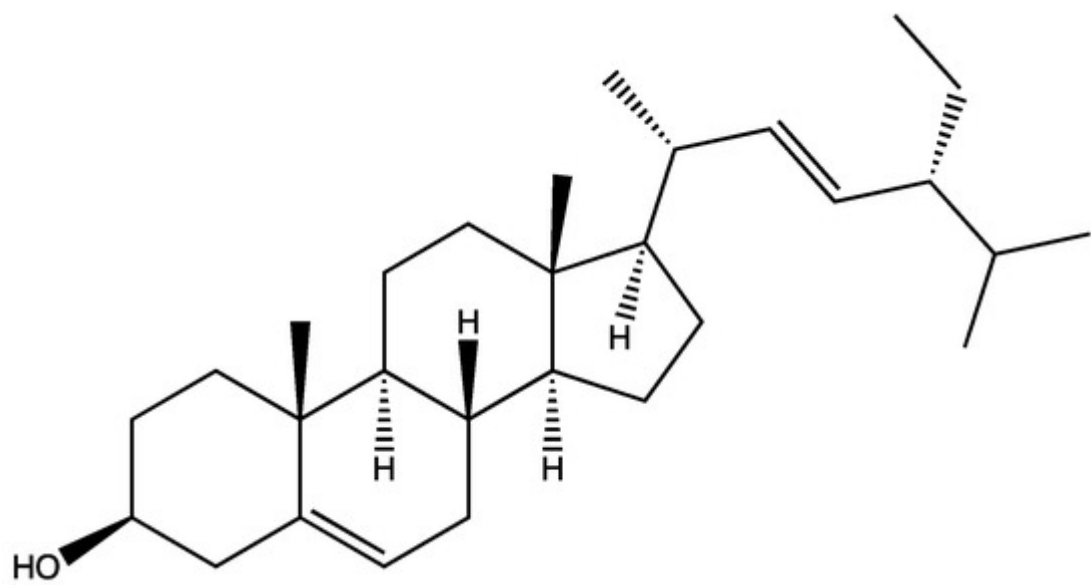
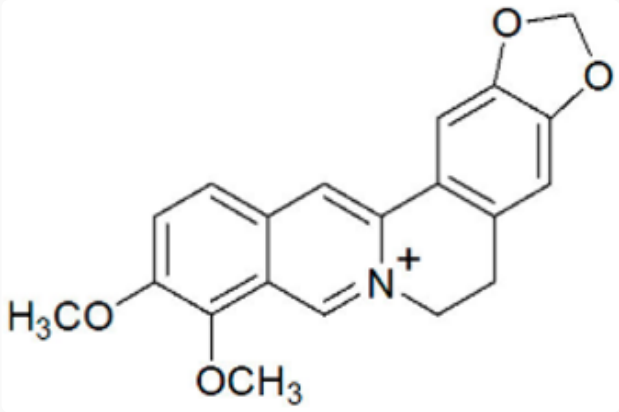
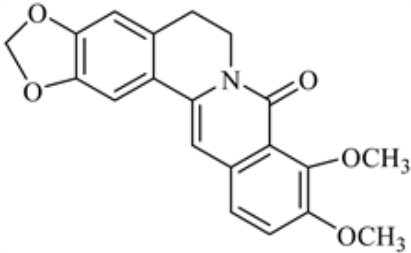
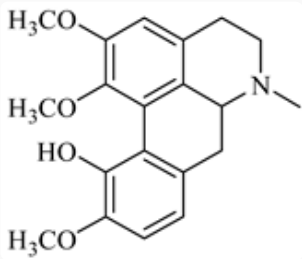
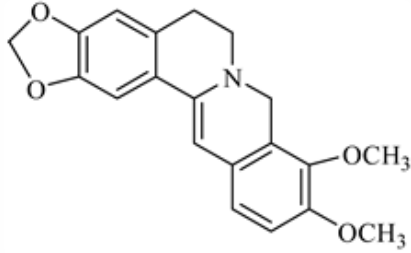


Figure 2. Stigmasterol.

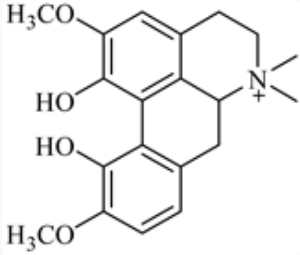
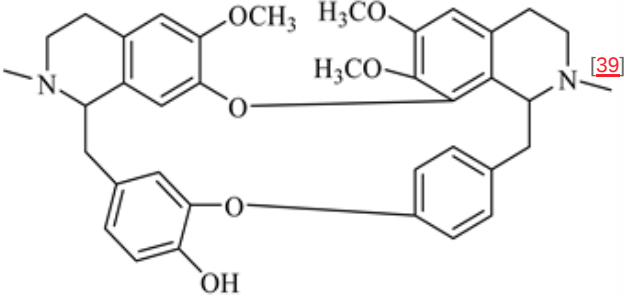
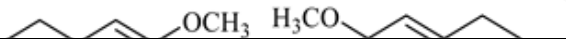
On the other hand, alkaloids (Table 1) represent the main compounds in *Berberis* species, and many of them have been identified by different spectroscopic techniques previously mentioned. The most known are berberine, berbamine, palmitine, jatrorrhizine, and isotetrandrine. They are located mainly in the cortical tissues of the roots and stems and have important biological activities. In fact, in vitro and in vivo anti-proliferative and anti-metastatic effects on various types of cancers have been reported for different alkaloids. These compounds, such as vinblastine, have already used as anticancer drugs [3].

Table 1. Alkaloids from *Berberis* species.

Chemical structure	Name	Plant
<p>The chemical structure of palmitine is a berberine alkaloid. It consists of a tetracyclic core (protoberberine). The nitrogen atom in the central ring is positively charged (N⁺). There are four methoxy groups (OCH₃) attached to the aromatic rings: one at C1, one at C3, one at C5, and one at C7. The side chains at C8 and C9 are not shown in this simplified representation.</p>	palmatine	<i>B. vulgaris</i>

Chemical structure	Name	Plant
	berberine	<i>B. vulgaris</i>
	oxyberberine	<i>B. vulgaris</i>
	isocoridine	<i>B. vulgaris</i>
	lambertine	<i>B. vulgaris</i>

Typically, the process of food preservation depends on the growth inhibition of undesirable microorganisms. Use of chemical agents with antimicrobial activity is commonly used a traditional method for food preservation [37]. However, antimicrobial agents also gain momentum, due to their fewer side effects and compatibility with the human body. Further, synthetic antimicrobials and their toxicological safety as food additives needed to be ensured by regulatory authorities. Moreover, processed foods with natural preservatives have great demand and considered safer and beneficial for public health [38]. The naturally occurring compounds demonstrated antimicrobial activity in foods as natural ingredients and can be used as additives to other foods.

Chemical structure	Name	Plant
	magniflorine	<i>B. vulgaris</i>
	oxycanthine	<i>B. vulgaris</i>
		

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
1	<i>B. aristata</i>	Stem and leaves	Nepal	Hexane, Ethyl acetate, Methanol	<i>Staphylococcus aureus</i> , <i>KleibSELLA pneumoniae</i> , <i>Salmonella typhimurium</i>	Against <i>S. aureus</i> : methanol significant zone of inhibition (21 mm), ethyl acetate extracts moderate activity, hexane extract of stem slightly active.	[40]
2	<i>B. aristata</i> , and <i>B. ligulata</i>	Bark stem Leaves	Nepal	Ethanol	<i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Pseudomona aeruginosa</i> , <i>Salmonella. typhi</i> , <i>Salmonella</i>	Ethanol extract of <i>B. aristata</i> : largest zone of inhibition (21 mm) against <i>B. subtilis</i> and the smallest MBC	[41]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
					<i>dyjenteriae</i> , <i>Salmonella cholerae</i>	value (90 mg/mL) for <i>S. aureus</i> . Gram positive bacteria more susceptible to the ethanol extract. <i>B. aristata</i> relatively broad-spectrum antibacterial activity.	
3	<i>B. vulgaris</i>	Stem	Iran	Ethanol	<i>P. aeruginosa</i> , <i>Acinetobacter baumannii</i> , <i>E. coli</i> and <i>Salmonella enteritidis</i>	MIC determination: stem extracts inhibit the growth of all the studied bacteria (3900 to 37,500 µg/mL) by synergistic effects with ciprofloxacin.	[42]
4	<i>B. asiatica</i>	Leaves	Uttarakhand, India	Methanol	<i>E. coli</i> , <i>Enterobacter aerogenes</i> , <i>Proteus vulgaris</i> , <i>P. aeruginosa</i> , <i>K. pneumoniae</i> , <i>B. subtilis</i> , <i>S. aureus</i>	Methanol extracts of leaves: high inhibitory potential on <i>S. aureus</i> , <i>K. pneumoniae</i> , <i>E. coli</i> , <i>B. subtilis</i> and <i>P. vulgaris</i> in all concentration.	[43]
<div><div></div><div>OH</div></div>							

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
5	<i>B. aristata</i> , <i>B. asiatica</i> , <i>B. lycium</i>	Stem	Bangalore, India	Methanol	<i>Nocardia</i> sp., <i>S. aureus</i> , <i>S. pneumonia</i> , <i>P. aeruginosa</i> , <i>Streptococcus viridians</i> , <i>E. coli</i>	Sensitivity to <i>Nocardia</i> sp., <i>S. pneumonia</i> and <i>E. coli</i> .	[44]
6	<i>B. glaucocarpa</i>	Root wood	Pakistan	Ethanol	SMRSA, EMRSA, <i>Mycobacterium marinum</i> , <i>E. coli</i> , <i>Trypanosoma brucei</i>	Berberine (MIC = 12.5 and 25 µg/mL), berberine chloroform (MIC = 25 and 12.5 µg/mL) and syringaresinol (12.5 µg/mL): very active against SMRSA, <i>M. marinum</i> and <i>T. brucei</i> .	[45]
7	<i>B. vulgaris</i>	Stem bark	Romania	Ethanol	<i>Botrytis cinerea</i>	<i>B. vulgaris</i> bark extract, berberine, and fluconazole significantly inhibited growth of <i>B. cinerea</i> .	[46]
8	<i>B. vulgaris</i>			Ethanol	<i>S. aureus</i> , <i>Staphylococcus epidermidis</i> , <i>K. pneumoniae</i> , <i>B. subtilis</i> , <i>E. coli</i> ,	20 mm zone of inhibition against <i>E. coli</i> . Good activity against <i>B. Subtilis</i> ,	[47]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
					<i>Aspergillus niger</i> , <i>Trichoderma</i> , <i>Alternaria solanai</i>	moderate against <i>Trichoderma</i> , insignificant against other stains.	
9	<i>B. vulgaris</i> and its active constituent, berberine	Root	Egypt	Ethanollic extract	<i>Candida albicans</i> , <i>E. coli</i>	<i>Berberis</i> ethanollic extract and berberine standard can inhibit <i>C. albicans</i> and <i>E. coli</i> growth.	[48]
10	<i>B. vulgaris</i>	Fruit	Pakistan	Distilled water	<i>S. aureus</i> , <i>Proteus</i> , <i>S. typhi</i> , <i>Salmonella</i> <i>paratyphi</i> A, <i>Salmonella paratyphi</i> <i>B</i> , <i>K. pneumoniae</i> , <i>E. coli</i> , <i>P. aeruginosa</i>	Antibacterial activity against all tested pathogens.	[49]
11	<i>B. thunbergii</i>	Fruit	Hungary	Juice; water extract and -methanol extract	<i>B. subtilis</i> , <i>Bacillus</i> <i>cereus</i> var. <i>mycoides</i> , <i>E. coli</i> , <i>Serratia</i> <i>marcescens</i>	Juice, water extract and methanol extract showed activity against all bacteria.	[50]
12	<i>B. calliobotrys</i>	Stems and branches	Pakistan	Methanol	<i>B. subtilis</i> , <i>P. aeruginosa</i> , <i>S. aureus</i> fungal strains namely <i>C. albicans</i> , <i>Penicillium notatum</i>	The methanol extract, ethyl acetate and n- butanol fractions: maximum zone of inhibition	[51]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
						against all bacterial strains especially <i>S. aureus</i> and antifungal effects.	
13	<i>B. lycium</i>	Roots	Libya	Distilled water, ethanol, isopropanol and methanol	<i>Pseudomonas</i> sp., <i>E. coli</i> , <i>Streptococcus</i> sp., <i>Staphylococcus</i> sp.	Methanolic displayed maximum inhibitory zone (16 mm), isopropanol extract (13 mm) and ethanol extract (12 mm). The aqueous extract exhibited the least inhibitory zone (10 mm). The methanolic extract: maximum inhibitory zone (12 mm), <i>Pseudomonas</i> (11 mm) and <i>Staphylococcus</i> (10 mm).	[52]
14	<i>B. hispanica</i>	Root Bark	Marocco	Ethanolic extract	<i>Mycobactérium smegmatis</i> , <i>Mycobacterium aurum</i>	The ethanolic extract from root bark displayed an important	[53]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
						antimycobacterial activity. The inhibition zones for <i>M. aurum</i> A+ were significantly larger than those for <i>M. smegmatis</i> MC2.	
15	<i>B. ruscifolia</i>	-	Argentina	Acetone, chloroform-methanol (1:1) and methanol	<i>E. coli</i> , <i>P. aeruginosa</i> , <i>Listeria monocytogenes</i> , <i>S. aureus</i>	All extracts exhibited antibacterial activity with MIC varying from 16 to 2 mg/mL. The highest inhibition with acetonic and chloroform-methanolic extracts of species against <i>S. aureus</i> (MIC = 2 mg/mL). Methanolic extracts <i>B. ruscifolia</i> showed no antibacterial activity against all tested bacteria.	[54]
16	<i>B. aristata</i>	Stem bark	India	Ethanol and aqueous extracts	<i>Shigella flexneri</i> , <i>Shigella sonnei</i> , <i>Shigella dysenteriae</i> , <i>Shigella boydii</i>	Extracts of <i>B. aristata</i> : antibacterial activity against	[55]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
						four strains of <i>Shigella</i> (8 and 23 mm).	
17	<i>B. aristata</i> , <i>B. asiatica</i> , <i>B. chitria</i> and <i>B. lycium</i>	Root and stem	India	Ethanol	<i>Micrococcus luteus</i> , <i>B. subtilis</i> , <i>B. cereus</i> , <i>Enterobacter aerogenus</i> , <i>E. coli</i> , <i>K. pneumoniae</i> , <i>Proteus mirabilis</i> , <i>P. aeruginosa</i> , <i>S. aureus</i> , <i>S. typhimurium</i> , <i>Streptococcus pneumoniae</i> , Fungal strains <i>Aspergillus nidulans</i> , <i>C. albicans</i> , <i>Aspergillus terreus</i> , <i>Trichophyton rubrum</i> , <i>Cistus albidus</i> , <i>Aspergillus flavus</i> , <i>A. niger</i>	<i>B. lycium</i> , <i>B. aristata</i> and <i>B. asiatica</i> root extract showed significant antifungal activity against <i>A. terreus</i> and <i>A. flavus</i> . <i>B. aristata</i> root and <i>B. lycium</i> (stem) extracts gave very low MIC values (0.31 µg/mL) as compared to other tested species.	[56]
18	<i>B. Lycium</i>	Root	Pakistan	Ethanol, petroleum ether	<i>S. aureus</i> , <i>S. epidermidis</i> , <i>B. subtilis</i> , <i>S. typhi</i> , <i>E. coli</i> , <i>C. albicans</i>	The ethanolic and aqueous crud root extract: most effective antifungal and antibacterial agents.	[57]
19	<i>B. integerrima</i>	Roots	Iran	Methanol	<i>Brucella abortus</i>	MIC and MBC results, jatrorrhizine	[58]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
	Syn: <i>B. densiflora</i>					exhibited higher antibacterial activity with MIC (0.78 µg/mL) and MBC (1.56 µg/mL) compared with the standard (streptomycin, 10 µg/mL).	
20	<i>B. lycium</i>	Roots	Pakistan	Hydric extract	<i>E. coli</i> , <i>Pseudomonas</i> , <i>Staphylococcus</i> , <i>Proteus</i>	Significant activity against <i>E. coli</i> and <i>Proteus</i> (80 to 100%), while it demonstrated a good activity against <i>Pseudomonas</i> and <i>Staphylococcus</i> (60 to 70%).	[59]
21	<i>B. aristata</i>	Bark and leaves	India	Methanol, ethanol and hexane	<i>B. subtilis</i> , <i>Agrobacterium tumefaciens</i> , <i>E. coli</i> , <i>Xanthomonas Phaseoli</i> , <i>Erwinia chrysanthemi</i>	All the extracts of tested plants showed variable activity against all the tested bacterial strains. Methanol extract revealed highest antibacterial activity (11 mm) recorded against	[60]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
						<i>E. chrysanthemi</i> . Hexane extract: totally inactive against all the tested strains.	
22	<i>B. aristata</i>	Roots	India	Aqueous and alcohol extracts	<i>S. aureus</i> , <i>B. subtilis</i> , <i>E. coli</i> , <i>S. typhimurium</i>	Alcoholic and aqueous extract showed antimicrobial activity against four tested bacteria. <i>B. aristata</i> exhibited highest zone of inhibition for <i>B. subtilis</i> followed by <i>S. aureus</i> , <i>E. coli</i> and <i>S. typhimurium</i> .	[61]
23	<i>B. microphylla</i>	Leaves, stems and roots	Chile	Methanol	<i>E. coli</i> , <i>S. typhimurium</i> , <i>L. monocytogenes</i> , <i>E. aerogenes</i> , <i>S. aureus</i> , <i>B. cereus</i> , <i>S. epidermidis</i> and <i>B. subtilis</i>	All extract possesses significant antibacterial activity against Gram-positive bacteria but not against Gram-negative bacteria.	[62]
24	<i>B. lycium</i>	Root bark	Pakistan		<i>E. coli</i> , <i>K. pneumoniae</i> , <i>P.</i>	Silver nanoparticles	[63]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
					<i>aeruginosa</i> , <i>S. aureus</i> , <i>B. subtilis</i>	were very active against Gram-negative and Gram-positive bacteria Aqueous bark extract (10 µg/mL) possess highest activity against <i>E. coli</i> and <i>P. aeruginosa</i> .	
25	<i>B. vulgaris</i>	Fruit	Iran		<i>L. monocytogenes</i>	Average diagonal of growing area in disk diffusion test for species: 12 mm and MIC was 125 µg/mL and MBC of <i>B. vulgaris</i> was 500 µg/mL.	[64]
26	<i>B. aristata</i>	Stem bark	Alcohol	In vivo in an animal model using Sprague Dawley rats	Carbapenem-resistant <i>E. coli</i>	An aquo-alcoholic extract of the species: effectively manage peritonitis induced by Carbapenem-resistant <i>E. coli</i> in a rat model at a single post-exposure prophylactic dose	[65]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
						of 0.5 mg/kg body weight.	
27	<i>B. aristata</i>	Roots	India	Aqueous and alcoholic extract of fresh roots, as well as aqueous extract of dried roots	<i>S. aureus</i> , <i>S. epidermidis</i> , <i>Streptococcus pyogenes</i> , <i>Streptococcus viridans</i> , <i>Enterococcus faecalis</i> , <i>B. subtilis</i> , <i>B. cereus</i> , <i>E. coli</i> , <i>K. pneumoniae</i> , <i>P. aeruginosa</i> , <i>P. vulgaris</i> , <i>P. mirabilis</i> , <i>S. typhi</i> , <i>S. paratyphi</i> A, <i>S. typhimurium</i> , <i>S. dysenteriae</i> type 1, <i>Vibrio cholerae</i>	All three extracts displayed wide antibacterial activity against Gram-positive bacteria. Among the Gram-negative bacteria tested, the antibacterial activity was limited to <i>E. coli</i> , <i>S. typhimurium</i> , <i>S. dysenteriae</i> type 1 and <i>V. cholerae</i> . All extracts also possess antifungal activity against the fungal species tested, except <i>Candida krusei</i> .	[66]
28	<i>B. aristata</i>	Root Stem Leaf	Pakistan		<i>E. coli</i> , <i>S. typhi</i> , <i>S. aureus</i> , <i>Shigella</i> , <i>Citrobacter</i> , <i>P. vulgaris</i> , <i>Enterobacter</i> , <i>Streptococcus pyogenes</i> , <i>V. cholera</i> , <i>Klebsiella</i> spp., <i>A. niger</i> ,	The extracts significantly inhibited the growth of the studied microbes, except <i>A. niger</i> , <i>Curvularia</i> ,	[67]

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
					<i>Cladosporium</i> , <i>Rhizoctonia</i> , <i>Alternaria</i> , <i>Trichoderma</i> , <i>Penicillium</i> , <i>Curvularia</i> , <i>Paecilomyces</i> and <i>Rhizopus</i>	<i>Paecilomyces</i> and <i>Rhizopus</i> .	
29	<i>B. aristata</i>		India		<i>V. cholerae</i> , <i>S. aureus</i>	All the strains of <i>V. cholerae</i> are susceptible. All the <i>Salmonella</i> sp., <i>Pseudomonas</i> sp., and some of the <i>E. coli</i> strains are highly resistant, except some strains of <i>E. coli</i> as AL26, and <i>Shigella</i> sp. are susceptible. All <i>Xanthomonas</i> sp. were highly susceptible. Berberine sulfate showed antifungal action against <i>C. albicans</i> , <i>Candida tropicalis</i> , <i>Trichophyton mentagrophytes</i> , <i>Microsporum</i>	[68]

References

S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
						<i>gypseum</i> , <i>Cryptococcus neoformans</i> and <i>Sporothrix schenkii</i> , <i>Mycobacterium tuberculosis</i> var. <i>hominis</i> H ₃₇ RV and <i>Entamoeba histolytica</i> .	n. J. and ect of d
30	<i>B. heterophylla</i>	Leaves, stems and roots berberine	Argentina		<i>S. aureus</i> , <i>E. faecali</i> , <i>P.aeruginosa</i> , <i>E. coli</i> , <i>C. albicans</i> , <i>Candida glabrata</i> , <i>Candida haemulonii</i> , <i>Candida lusitanae</i> , <i>C. krusei</i> , <i>Candida parapsilosis</i>	The aqueous extracts of <i>B. heterophylla</i> do not possess significant antimicrobial activity. Berberine displayed a significant antibacterial and antifungal activity against <i>S. aureus</i> and different <i>Candida</i> spp., some of them obtained from the clinical isolated.	[69] r of edicinal ild food ansu, as a 14– Activity 3, 38,
31	<i>B. amurensis</i>	Branches and leaves	Korea		<i>Bacillus atrophaeus</i> , <i>Kocuria rhizophila</i> , <i>M. luteus</i> , <i>S. epidermidis</i> , <i>B.</i>	No significant activity against gram-negative bacteria.	[70] ction

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S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
1					<i>subtilis</i> subsp. <i>Spizizenii</i> , <i>K. pneumoniae</i> , <i>Enterobacter cloacae</i> , <i>Salmonella enterica</i> subsp. <i>enterica</i> , <i>P. aeruginosa</i>		berberis 2010, M.; bon plants 015, 5,
32	<i>B. croatica</i> and <i>B. vulgaris</i>	Roots, leaves, and twigs	Croatia	Ethanol	<i>B. subtilis</i> , <i>S. aureus</i> , <i>E. coli</i> , <i>P. aeruginosa</i> , <i>C. albicans</i>	Extracts of both species: significant antibacterial activity against the Gram-positive bacteria. Root extracts of <i>B. croatica</i> : activity against <i>P. aeruginosa</i> , and leaf extracts against <i>B. subtilis</i> . Neither species possessed antifungal activity. Leaf extracts of <i>B. croatica</i> : antibacterial activity against <i>B. subtilis</i> . Likewise, neither of the species extracts showed activity against <i>E. coli</i>	[74]

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S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
22						and <i>C. albicans</i> , except when were diluted. Ethanolic extracts of twigs of both species: inactive against <i>B. subtilis</i> and against <i>S. aureus</i> , with the exception of <i>B. croatica</i> twig from Kiza locality.	n. B hyther. lgaris dless 6–287.
33	<i>B. lycium</i>	Roots	India	Hexane extract, Methanolic extract, aqueous extract and berberine	<i>K. pneumonia</i> , <i>E. coli</i> , <i>P. aeruginosa</i> , <i>S. aureus</i> , <i>B. subtilis</i> , <i>C. albicans</i> , <i>A. niger</i> , <i>Aspergillus fumigates</i>	Methanolic extract of species was highly effective against <i>E. coli</i> , <i>S. aureus</i> , <i>B. subtilis</i> , <i>C. albicans</i> , <i>A. fumigates</i> . Pure berberine was effective against <i>E. coli</i> and <i>C. albicans</i> .	[72] rages ditions. erberis al oils
34	<i>B. aetnensis</i>	Roots	Italy	Ethanol ether and chloroform	<i>S. aureus</i> , <i>B. subtilis</i> , <i>E. faecalis</i> , <i>E. coli</i> , <i>P. aeruginosa</i> , <i>Stenotrophomonas maltophilia</i> , against 14 strains of nosocomial origin:	The root and leaf extracts showed a greater activity against Gram-positive bacteria and yeasts than against Gram-	[73] R. inhibitory SBN

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S. No.	Species	Part	Country	Extract/Model/Compound	Tested Micro-Organism	Results	Reference
34					two strains of <i>S. aureus</i> (1 Met-S, 1 Met-R); four strains of <i>S. epidermidis</i> (2 Met-S, 2 Met-R); three strains of <i>E. coli</i> ; four strains of <i>P. aeruginosa</i> , <i>Hafnia alvei</i> and <i>C. albicans</i> , <i>C. parapsilosis</i> , <i>C. krusei</i>	negative bacteria, except for <i>P. aeruginosa</i> . The chloroform extract of leaves was more active than the ethanol.	ic me .2, 4, l. Int. J.
35	<i>B. thunbergii</i> , <i>B. vulgaris</i>	Roots	USA		<i>E. coli</i> , <i>P. aeruginosa</i> , <i>S. aureus</i> , <i>S. mutans</i> , and <i>S. pyogenes</i>	Ethanollic extracts more active against studied bacteria, strongest activity against <i>S. pyogenes</i> and <i>S. aureus</i> .	, 7, n, O.;
36	<i>B. vulgaris</i>	Root bark	Algeria	Methanol and water	<i>S. aureus</i> , <i>E. faecalis</i> , <i>E. coli</i> , <i>E. cloacae</i> , <i>K. pneumoniae</i> , <i>P. aeruginosa</i>	The extracts of species root barks presented a strong activity against <i>S. aureus</i> (23.0 mm), a weak activity against <i>E. faecalis</i> (13.0 mm) and no activity toward other strains.	ected rm. ed. ivity of f ace

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