Phytochemical and biological activities of some Iranian medicinal plants

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**ABSTRACT**

**Context:** Due to adverse effects of synthetic compounds, there is a growing interest in utilization of plant-derived natural products in the pharmaceutical and food industries. Iranian endemic medicinal plants widely used in traditional practice have attracted much attention as antibacterial and antioxidant agents.

**Objective:** This review attempts to compile the accessible scientific research pertaining to phytochemical compounds, antibacterial and antioxidant effects of essential oils obtained from some of the most widely used and distributed medicinal plants in Iran.

**Methods:** This review has been compiled using references via reliable databases (Google Scholar, SID and Science Direct) from 2010 to 2020. This literature review was limited to references published in English and Persian languages.

**Results:** Based on studies heretofore carried out, essential oils isolated from mentioned medicinal plants exhibited strong antioxidant activity which is attributed to their main phytochemical compounds; thymol, carvacrol, p-cymene and \textgamma-terpinene. In addition, the antibacterial activities of essential oils of most plant species from Apiaceae and Asteraceae families were more susceptible against Gram-positive bacteria; \textit{Staphylococcus aureus} and \textit{Bacillus cereus} than Gram-negative bacteria; however, essential oils of other studied plant species manifested similar behaviours against both Gram-positive and -negative bacteria.

**Conclusions:** As there is rich ethnobotanical knowledge behind Iranian endemic medicinal plants, further scientific research is required to prove their safety and efficacy. This review revealed that there are numerous valuable medicinal plants adoptable in food and pharmaceutical industries in the near future.

**Introduction**

Traditional or complementary medicine is an important and often underestimated segment of health services. Nevertheless, this kind of medicine is to date acknowledged, as preferred primary health care system in many rural communities, particularly due to its affordability and effectiveness. Moreover, not only does it have a long history of use in health maintenance and disease prevention, but also an effective remedy for chronic diseases. It is estimated that over 75% of globe population rely on traditional medicines to treat various diseases, viz., diarrhoea, malaria, stomach-ache, cough, bilharzia and dysentery (Ghasemi Pirbalouti et al. 2010a; Rakotoarivelo et al. 2011; Mahomoodally and Chintamunnee 2012; Pan et al. 2014; Arumugam et al. 2016). It is even estimated that almost 25% of modern and 60% of antibiotic drugs be derived from natural products (Newman and Cragg 2012; Veeresham 2012; Iqbal et al. 2017). The popularity of plant usage in Traditional Iranian Medicine (Persian Medicine) goes back to Babylonian-Assyrian civilization era (Amirmohammadi et al. 2014; Buso et al. 2020).

In spite of modern medicine development, medicinal plants still play an important role in Iran as curatives for various health problems (Akbarzadeh et al. 2015; Buso et al. 2020). Iran with different climatic and geographical zones is a habitat to at least 2300 species having aromatic and medicinal properties, wherein 7.9% are endemic (Owfi and Safaian 2017; Sheibani et al. 2018; Karim et al. 2020). Almost all parts of these plants (e.g., leaves, flowers, stems, seeds, fruits and roots) (Najafi et al. 2010; Hariri et al. 2018) produce essential oils as secondary metabolites for varied purposes; plant defence against pests or pathogens, pollinator attraction and seed dispersers (Dhifi et al. 2016). Currently, essential oils are in high demand in pharmaceutical, cosmetic, sanitary and food industries, as well as agriculture due to flavour, fragrances and versatile biological properties like antimicrobial, anticancer and antioxidant (Kumar et al. 2018). These characteristics are accredited to the presence of a complex mixture of aromatic compounds; terpenes, phenolic and phenylpropanoid compounds (Bakkali et al. 2008; Dhifi et al. 2016).

Over the past few years, antimicrobial resistance has become one of the most serious international public health concerns that threatens the effective prevention and treatment of infections resulting from a wide range of pathogens, viz., bacteria, fungi and viruses (Avaei et al. 2015; Prestinaci et al. 2015). Additionally, reducing the popularity of synthetic compounds among consumers has caused a higher discovery of natural antimicrobial agents. Generally, the mechanism of essential oil inhibiting pathogens growth is associated with essential oil type and microbial strains tested (Pauli and Kubeczka 2010). Gram-positive bacteria are generally more susceptible to essential oils than...
Gram-negative bacteria (Borges et al. 2013, 2014), because they are surrounded by an outer membrane which has a more complex and assisting penetration of hydrophobic compounds through it. In other words, minute antimicrobial agents can easily access the cell membrane of Gram-positive bacterial strains (Zinoviadou et al. 2009; Hyldgaard et al. 2012). Furthermore, Gram-positive bacteria may ease the infiltration of essential oils of hydrophobic compounds due to lipophilic ends of lipoteichoic acid present in the cell membrane (Gox et al. 2000). The antimicrobial activity of essential oils is commonly evaluated via minimum bactericidal concentration (MBC) or minimum inhibitory concentration (MIC) (Baloui et al. 2016), and agar well diffusion (Rao et al. 2019).

In addition, we have noted a rise in research on the substitution of synthetic or artificial antioxidants with natural compounds since butylated hydroxyanisole and butylated hydroxytoluene (BHT) were suspected to induce carcinogenesis and liver toxicity (Caleja et al. 2017). Sequentially, adoption of essential oils as natural antioxidants in food and pharmaceutical industries has increased (Chrysargyris et al. 2020). These compounds shield human body against oxidative stress disrupt by maintaining the balance between free radicals and antioxidant defense system (Alfadda and Sallam 2012). Free radicals through oxidative stress are involved in several health disorders; cardiovascular, inflammatory, age-related diseases, cataracts and cancer (Puljsak et al. 2013). These free radicals are collectively termed reactive oxygen species (ROS) and reactive nitrogen species including highly reactive species; hydroxyl (OH·) and nitric oxide (NO·) radicals (Li et al. 2016). They are produced when our cells create energy from food and oxygen or are exposed to microbial infections, extensive exercise or pollutants/toxins, i.e., cigarette smoke, alcohol, ionizing UV radiations, pesticides and ozone (Gilca et al. 2007). Excessive ROS generated under abiotic stress causes significant damage to biomolecules; lipids, proteins and deoxyribonucleic acid (Sharma et al. 2012) leading to different chronic diseases (Ighodaro and Akinloye 2018). The most common methods to investigate antioxidant efficacy of essential oils are ferric reducing antioxidant power (FRAP) (Benzie and Strain 1996), 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) (Bondet et al. 1997), β-carotene-linoleic acid (linoleate) (Miller 1971) and 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) assays (Bertrand et al. 2005).

Several authors have reviewed the beneficial uses of essential oils (Amorati et al. 2013; Chouhan et al. 2017). Swamy et al. (2016) reviewed selected essential oils from different countries that have great antimicrobial properties. However, few comprehensive reviews have been published on phytochemical compounds and pharmaceutical effects of Iranian endemic plants. Therefore, this review aimed to focus on 23 medicinal plants native to Iran, which are widely distributed and used in Iranian traditional medicine and among locals. The entire data were classified in three tables; traditional uses (Table 1), antioxidant effects (Table 2) and antimicrobial potential (Table 3) of essential oils from the selected medicinal plants. All the available information was compiled via reliable electronic databases; ‘Google Scholar’, ‘Science Direct’ and ‘SID’ from 2010 to 2020 to provide a foundational knowledge guide for its subsequent research and utilization.

Bunium persicum (Boiss.) B. Fedtsc. (Apiaceae)

B. persicum (Figure 1(A)) is traditionally used to improve digestion, besides a flavouring and carminative agent and to treat varied ailments, viz., toothache, stomach-ache and dyspnoea (Pezhmanmehr et al. 2009; Amiri et al. 2012). The essential oil of B. persicum exhibited significant antioxidant activity using DPPH and β-carotene-linoleic acid (Nickavar et al. 2014) methods in presence of major compounds: β-pinene, p-cymene, cumin aldehyde and γ-terpinene. In previous studies, the antioxidant capacity of B. persicum essential oil isolated by two different methods: microwave (MAE) and hydro-distillation (HD) techniques were compared and no significant difference in the antioxidant activities was reported. Consequently, MAE method was recommended due to shorter extraction time and faster energy transfer (Mazidi et al. 2012; Majidi et al. 2020). The DPPH and ABTS radical scavenging assays results indicated that the antioxidant activity of Zataria multiflora Boiss. (Lamiaceae) essential oil was greater than B. persicum essential oil (Aminzare et al. 2017). The antimicrobial properties of B. persicum essential oil with the main chemical compounds: cumin aldehyde, γ-terpinene, β-pinene and p-cymene against Listeria monocytogenes, as multi-drug-resistant bacteria, have been confirmed (Sharafati Chaleshtori et al. 2018). Likewise, B. persicum essential oil inhibited the growth of Candida albicans, with considerable antibacterial potential against Staphylococcus aureus and Escherichia coli (Rustaei et al. 2016). Additionally, the synergistic antibacterial activity of B. persicum and Cuminum cyminum L. (Apiaceae) essential oils against Gram-positive bacteria (S. aureus, B. cereus and L. monocytogenes) has been recorded (Oroojalian et al. 2010).

Carum carvi L. (Apiaceae)

Caraway seeds (C. carvi) (Figure 1(B)) are used medicinally as a laxative, carminative, appetite stimulant, besides increasing lactation in pregnant women and alleviating menstrual pain (Haidari et al. 2011; Keshavarz et al. 2012). The in vitro antioxidant property of C. carvi essential oil measured by β-carotene bleaching and DPPH assays was reported by Fatemi et al. (2011). Moreover, other studies determined the antioxidant activity of C. carvi essential oil on liver and lung tissue changes histopathologically and indicated that C. carvi essential oil retained the balance via oxidants and antioxidants (Fatemi et al. 2010; Daddkhah et al. 2011, 2018). In a study on antibacterial activity of caraway essential oil, the Gram-positive bacteria; Bacillus subtilis and S. aureus exhibited more sensitivity in relation to Gram-negative pathogens; E. coli and Pseudomonas aeruginosa (Sayhoon et al. 2013).

Chaerophyllum macropodum Boiss. (Apiaceae)

C. macropodum (Figure 1(C)) is distributed in Iran and Turkey, while other species are detectable in other areas particularly Europe and central Asia (Mozafarian 1996). This plant is not only used in traditional healing practices to treat cold and stomach, but also in culinary (Jahantab et al. 2018; Moazzami Farida et al. 2018). The antioxidant activity of essential oil from C. macropodum aerial parts was determined by DPPH radical scavenging and β-carotene bleaching tests. The results indicated that essential oil containing the most prominent bioactive compounds: trans-octimene, cis-octimene and γ-terpinene possessed low antioxidant activity as compared to BHT (Haghi et al. 2010). Additionally, the chemical composition and antioxidant properties of C. macropodum essential oil isolated by HD and microwave-assisted hydrodistillation (MAHD) methods were measured and compared. The main constituents of both essential oils obtained by HD and MAHD, were (E, Z)-β-ocimene, myrcene
| Scientific name                      | Family        | Local name          | Used parts of the plant | Local names/regions          | Traditional uses                                                                 | Ref.                        |
|--------------------------------------|---------------|---------------------|-------------------------|------------------------------|----------------------------------------------------------------------------------|-----------------------------|
| *Bunium persicum*                    | Apiaceae      | Gharah zireh, Black zira, Zireh Kermani | Aerial parts/ Fruits     | Qazvin, Semnan, Kerman, Khorasan, Isfahan | Indigestion, flavouring, carminative, diuretic, digestive disorders, asthma, anticonvulsant, antihelminthic, stomach disorders, liver and kidney toxic, appetite, carminatives, antidiarrhoeal, colic pain, dysmenorrhoeia, urinary tract disorders, emmenagogue, anticonvulsant, antihelminthic, anti-flatulent, analgesic, curing geophagy, hiccup, asphyxia, dyspnoea, spleen oedema, nasal bleeding, eye diseases, toothache | Amiri et al. (2012); Ghasemi et al. (2018); Bagherifar et al. (2019) |
| *Carum carvi*                        | Apiaceae      | Zeerah Siyah        | Fruits                  | Kermanshah, Kurdestan, Kohgiluyeh va Boyer Ahmad | Obesity, facilitate digestion, sour stomach, blood pressure, diarrhoea, lactic, carminative, appetite stimulant, lactation enhancer, menstrual pain reliever | Amiri and Joharchi (2016); Keshavarz et al. (2012); Haidari et al. (2011); Jahantab et al. (2018) |
| *Chaerophyllum macropodum*           | Apiaceae      | Garkava, Chelghaba   | Aerial parts             | Kohgiluyeh va Boyer Ahmad | Cold, stomachic, culinary uses | Amiri et al. (2016); Gachkar et al. (2007); Johri (2011); Srinivasan (2018) |
| *Cuminum cyminum*                    | Apiaceae      | Zireh-Sabz          | Fruits                  | Kerman | Carminative, obesity, digestive disorders, favouring, epilepsy, diabetes, pains | Amiri and Joharchi (2016); Ghasemi et al. (2013); Bagherifar et al. (2019); Mozafarian (1996) |
| *Ferulago angulata*                  | Apiaceae      | Chavil-eshevidi, Chavil | Aerial parts/ Seeds     | Khuzestan, Kermanshah, Kurdestan, Kohgiluyeh va Boyer Ahmad, Ilam, Lorestan, Fars, Markazi, Hamadan, Khorasan | Anti-septic, space and air freshers, sedative, digestive, intestinal, worms, toxic, food-digestive, antiparasitic | Amiri and Joharchi (2016); Ghasemi et al. (2013); Bagherifar et al. (2019); Mozafarian (1996) |
| *Heracleum persicum*                 | Apiaceae      | Golpar              | Fruit/ Flowers          | Mazandaran, Tehran, Qazvin | Hiccup, appetite, flavouring, carminative, anthelmintic, stomach tonic, tremor, migraine, headache | Amiri and Joharchi (2016); Ghasemi et al. (2013); Bagherifar et al. (2019); Mozafarian (1996) |
| *Prangos ferulacea*                  | Apiaceae      | Djashir, Jashir     | Roots/ Leaves           | Khuzestan | Wound healing, laxative, antihypertensive, carminative, digestive disorders, flavouring, animal fodder | Yousefi et al. (2017) |
| *Achillea millefolium*               | Asteraceae    | Gurtgharan, Boomadaran | Inflorescence/ Aerial parts | Golestan, Ilam | Anthelmintic, anti-infections, wounds, antihymorrhage, stomach ache and meningal, anti-inflammation, antidiabetic, pains, dysmenorrhoea, diarrhoea, stomach cramps, flatulence, gastritis and gastrointestinal disturbances | Mirdelami et al. (2011); Bahmani et al. (2014); Mazandarani et al. (2013) |
| *Seriphidium kermanense*             | Asteraceae    | Dermaneh            | Aerial parts           | Kerman | Decrease blood pressure, appetite, spice, skin disease | Dolatkhahi et al. (2014); Mozafarian (1996) |
| *Dracocephalum kotschyi*             | Lamiaceae     | Bardashiboie-Dennaie | Zarin-Giah            | Mazandaran, Tehran, Isfahan, North Khorasan, Lorestan, Azerbaijan, Fars | Stomach, liver disorders, headache, congestion, painkillers, kidney complications, toothaches, colds, antispasmodic | Heydari et al. (2019) |
| *Hymenocrater calycinus*             | Lamiaceae     | Gol-e-Arvaneh       | Aerial parts           | Mazandaran, Golestan, Mazandaran, Semnan, Khorasan, Tehran, Alborz, Isfahan | Analgesic drug, skin antiallergenic, burns | Asri et al. (2017) |
| Scientific name | Family | Local name | Used parts of the plant | Local names/regions | Traditional uses | Ref. |
|-----------------|--------|------------|-------------------------|---------------------|-------------------|-----|
| *Hymenocrater longiflorus* Benth. | Lamiaceae | Gole Arvaneh-Avarmani Soor Sanduo | Aerial parts | Kurdestan, Kermanshah | Anti-inflammatory, sedative, anti-skin allergic reaction | Taherpour et al. (2011) |
| *Mentha piperita* L. | Lamiaceae | Nana felfeli | Aerial parts | Kermanshah, Khorasan, Fars | Carminative, anti-inflammatory, cold, diaphoretic, analgesic, stimulant, anti-inflammatory, cold, diaphoretic | Taherpour et al. (2017); Mikaili et al. (2012) |
| *Salvia mirzayanii* Rech.f. & Esfand. | Lamiaceae | Salvii, Moor, Talkh | Aerial parts | Kerman, Hormozgan | Alzheimer, stomach ache, infections, spasms, gastrointestinal disorders, astringent, carminative, antiseptic, anti-diabetic, anti-inflammatory, spasmolytic, carminative, antiseptic, astringent, stomach pain | Sadat-Hosseini et al. (2017); Asadollahi et al. (2019) |
| *Saturreja spp.* | Lamiaceae | Marzeh | Aerial parts | Khorasan, Lorestan, Ilam, Khuzestan, Fars | Indigestion, anti-inflammatory, appetite, antacid, anti-diarrheal, stomach-ache | Buso et al. (2020); Razzaghi-Abyaneh et al. (2013); Jamzad (1996) |
| *Thymus daenensis* Celak. | Lamiaceae | Avishan-e-denaee | Aerial parts | Isfahan, Fars, Chaharmahal and Bakhtiari, Lorestan, Kohgiluyeh and Boyer-Ahmad, Tehran, Isfahan, Markazi | Flavouring agents, tonic, carminative, digestive, antispasmodic, anti-inflammatory, expectorant, cold, cough, anti-bacterial, carminative | Rahimimalek et al. (2009); Emami Bistgani and Sefidkon (2019) |
| *Thymus kotschyanus* Boiss. & Hohen | Lamiaceae | Avishan | Aerial parts | Fars, Ardabil, The East Azerbaijan, Tehran, Yazd, Mazandaran, Hamedan | Gastrodynia, joints pain common cold, flatulence, bone pain, redness eyes, blood depurative, stomach tonic, antiseptic coughing, appetizer, kidney stones, diuretic, analgesic, high blood pressure uterine pains, headache, vomiting, heartburn, asthma, catarrh, inflammation, irritation of urinary organs, expectorant, emmenagogue, spasm, vermifuge, sedative, diaphoretic | Naghibi et al. (2005) |
| *Zataria multiflora* Boiss. | Lamiaceae | Avishan-e-Shirazi | Leaves | Kerman, Fars, Isfahan, Yazd, Hormozgan, Khorasan | Constipation, stomach pain menstrual cramps, cold, diarrhea, stomach-ache, carminative, chest pain, headache, toothache, wound healing, fatigue, anti-pyretic, bone pain, earache, measles, reducing blood lipid and glucose | Nasab and Khosravi (2014); Safa et al. (2013) |
| *Zhumeria majdae* Rech.f. & Wendelbo | Lamiaceae | Moorkhosh | Leaves | Hormozgan | Stomach-ache antiseptic, carminative painful menstruation | Sajed et al. (2013); Rechinger (1982); Rechinger and Wendelbo (1967); Safa et al. (2013) |
| *Ziziphora clinopodioides* Lam. | Lamiaceae | Kakuti-e kuhi | Aerial parts | Yazd, Isfahan, Khorasan | Digestive system, toothache, spice | Amiri et al. (2019) |
| *Rosa damascena* P. Mill. | Rosaceae | Gole mohammadi | Flowers | Kashanm, Kerman | Burns and wounds healing, sedative, stomach and reflux, laxative, anti-haemorrhoid, calmative | Amiri and Joharchi (2013) |
and terpinolene, respectively. There was no significant difference in the antioxidant activity of both essential oils (Khajehie et al. 2017). Moreover, MIC concentrations of essential oils obtained from C. macropodum leaves and flowers were evaluated against 12 bacterial strains using the micro-well dilution assay. Thirty constituents were identified and their main classes were oxygenated, non-oxygenated monoterpenes and sesquiterpenes (trans-β-farnesene and trans-β-ocimene). Salmonella paratyphi-A serotype, Proteus vulgaris, Staphylococcus epidermidis and Klebsiella pneumoniae were the most susceptible species with MIC ranging from 125 to 250 μg/mL (Ebrahimabadi et al. 2010). Khajehie et al. (2017) evaluated the antifungal activities of C. macropodum aerial parts essential oil through HD and MAHD techniques by MIC or minimum fungicidal concentrations (MFCs) methods and reported that MAHD had no adverse effects on inhibitory effects of the essential oil, besides

Table 2. Antioxidant activity of Iranian essential oils; part used, major chemical compounds and activity.

| Scientific name | Part used | Major compounds | Activity | Ref. |
|-----------------|-----------|-----------------|----------|-----|
| Bunium persicum Boiss. | Seeds | Cuminaldehyde, carvacrol, anisole | Lower than BHT | Aminzare et al. (2017) |
| Fruits | p-Cymene, cuminaldehyde, γ-terpinene | Much lower than vitamin C | Nickavar et al. (2014) |
| Carum carvi L. | Seeds | Cumin aldehyde | Higher than BHT | Fatemi et al. (2011) |
| Aerial parts | γ-terpinene-7-al cumin aldehyde | Higher than BHT | Haghhi et al. (2010) |
| Chaerophyllum macrodum Boiss. | Aerial parts | Trans-ocimene, cis-ocimene, γ-terpinene | Much lower than BHT | Khajehie et al. (2017) |
| | Aerial parts | Myrcene, (e)-β-ocimene, terpinolene, (α)-β-ocimene, β-Pinene, γ-terpinene, cumin aldehyde, p-cymene | Higher than vitamin C | Fatemi et al. (2013) |
| Cumrum cyminum L. | Seeds | Thymol, γ-terpinene, β-pinene | Higher than Trolox | Ladan Moghadam (2016) |
| Ferula angulata (Schlecht.) Boiss. | Aerial parts | α-Pinene, z-β-ocimene | Much lower than quercetin | Shahbazi et al. (2016) |
| | Aerial parts | α-Pinene, cis-β-caryophyllene | Lower than BHT | Ghasemi Pirbalouti et al. (2016) |
| Heracleum persicum Desf. | Aerial parts | (e)-Anethole, octyl-2-methyl butanoate, octyl-2-methyl butanoate, hexyl butanoate | Much lower than quercetin | Firuzi et al. (2010) |
| Prangos ferula L. (Lindl | Leaves | p-Cymene, limonene, (e)-β-ocimene, terpinolene, 2,3,6-trimethylbenzaldehyde | Much lower than BHT | Seidi Damyeh and Niakousari (2016) |
| | Flowers leaves | α-Pinene, camphene, bornylacetate | Lower than BHT | Bazdar et al. (2018) |
| Achillea millefolium L. | Aerial parts | Limonene, α-pinene, borneol, thymol, carvacrol | Higher than Trolox | Kazemi (2015) |
| Seriphidium kermanense (D. Podl.) Y. R. Ling [syn: Artemisia kermanensis Podl.] | Aerial parts | Thymol, carvacrol | Higher than Trolox | Sahari Moghadam et al. (2017) |
| | Aerial parts | Isoborneol, camphor, cis-thujone | Lower than BHT | Kazemi et al. (2011) |
| Dracaenum kotschyi Boiss. | Aerial parts | α-Pinene, geranial, geranyl acetate | Higher than vitamin C | Ashrafi et al. (2017) |
| Hymenocratr longiflorus Benth. | Stems | α-Pinene, 1,8-cineole linalool p-menth-1-en-8-ol, l-bourbonene, trans-caryophyllene | Equivalent to vitamin C | Ahmadi et al. (2010) |
| Mentha piperita L. | Aerial parts | Menthol, menthofuran, 1s-neomenthyl acetate | A bit lower than BHT | Yazdani et al. (2019) |
| Salvia mizayyanii Rech.f. & Esfand. | Aerial parts | Menthol, menthone | Much lower than BHT | Fatemi et al. (2014) |
| Satnureja bachtiaria Bunge. | Aerial parts | β-Thujone, 1,8-cineole, camphor | Comparable to trolox | Izadi and Mirazi (2020) |
| | Aerial parts | p-Cymene, γ-terpinene, carvacrol, thymol | Much lower than BHT | Omidpanah et al. (2015) |
| Satureja khuzistanica Jamzad. | Aerial parts | Carvacrol, thymol | A bit lower than BHT | Saei-Dehkordi et al. (2012) |
| Satureja rechingeri Jamzad. | Aerial parts | Carvacrol | Lower than equivalent | Alizadeh (2015) |
| Thymus daenensis Celak. | Aerial parts | Thymol, thymoquinone, carvacrol | Comparable to vitamin C | Golkar et al. (2020) |
| | Aerial parts | Thymol, γ-terpine, p-cymene, carvacrol | A bit lower than BHT | Alavi et al. (2010) |
| Thymus kotschyanus Boiss. & Hohen | Leaves | Carvacrol, β-caryophyllene, γ-terpinene | A bit lower than BHT | Shafagh & Shafaghationba (2011) |
| Zataria multiflora Boiss. | Aerial parts | γ-terpinene, thymol, carvacrol | Much lower than BHT | Amiri (2012) |
| | Aerial parts | Thymol, carvacrol, p-cymene, γ-terpinene | Much lower than BHT | Dini et al. (2015); Fatemi et al. (2011) |
| Zhumera majdae Rech.f. & Wendelboe | Aerial parts | Thymol, carvacrol, p-cymene | Lower than BHA and BHT | Heidari et al. (2019) |
| Zaithora clinopodioides Lam. | Flowering tops | Pulegone, menthone, limonene | Much lower than BHT and vitamin C | Ghasemi Pirbalouti et al. (2016) |
| Rosa damascena P. Mill. | Flowers | Nonadecane, 9-nonadecane, eicosane | Higher than BHT | Saeid et al. (2019) |

and terpinolene, respectively. There was no significant difference in the antioxidant activity of both essential oils (Khajehie et al. 2017). Moreover, MIC concentrations of essential oils obtained from C. macropodum leaves and flowers were evaluated against 12 bacterial strains using the micro-well dilution assay. Thirty constituents were identified and their main classes were oxygenated, non-oxygenated monoterpenes and sesquiterpenes (trans-β-farnesene and trans-β-ocimene). Salmonella paratyphi-A serotype, Proteus vulgaris, Staphylococcus epidermidis and Klebsiella pneumoniae were the most susceptible species with MIC ranging from 125 to 250 μg/mL (Ebrahimabadi et al. 2010). Khajehie et al. (2017) evaluated the antifungal activities of C. macropodum aerial parts essential oil through HD and MAHD techniques by MIC or minimum fungicidal concentrations (MFCs) methods and reported that MAHD had no adverse effects on inhibitory effects of the essential oil, besides
Table 3. Antimicrobial activity of Iranian essential oils; part used, major chemical compounds and MIC values.

| Scientific names | Part used | Major phytochemical compounds | Inhibited pathogens | MIC values | Ref. |
|------------------|-----------|-------------------------------|---------------------|------------|-----|
| *Bunium persicum* Boiss. | Fruits | γ-Terpinene | *Staphylococcus aureus* (ATCC 6538) | > 10 μg/mL | Rustaie et al. (2016) |
| | | p-Cymene | *Escherichia coli* (ATCC 8739) | > 10 μg/mL | |
| | | β-Pinene | *Candida albicans* (ATCC 10231) | 2.5–5 μg/mL | |
| | | p-Cymene | *Listeria monocytogenes* | 0.351 mg/mL | Sharafati Chaleshtori et al. (2018) |
| | | γ-Terpinene | *L. grayi* | 2.812 mg/mL | |
| | | cuminaldehyde | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | 4-Dien-7-al | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
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| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
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| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
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| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| | | Cumin aldehyde | |
| | | p-Cymene | |
| | | γ-Terpinene | |
| | | safranal | |
| | | p-Menta-1,3-dien-7-al | |
| | | p-Menta-1 | |
| | | 4-Dien-7-al | |
| Scientific names | Part used | Major phytochemical compounds | Inhibited pathogens | MIC values | Ref. |
|------------------|-----------|-------------------------------|--------------------|------------|-----|
| cis-β-Ocimene    | Seeds     | α-pinene                      | E. coli            | 4 mg/mL    |     |
|                  |           | α-Phellandrene                | P. aeruginosa      | 8 mg/mL    |     |
| (Z)-β-Ocimene    |           | p-Cymene                      | Erwinia amylovora  | 12.5 µL/mL |     |
| α-pinene         |           | Sabine                      | Xanthomonas oryzae | 12 µL/mL   |     |
| β-Phellandrene   |           | P. Phellandrene               | Pseudomonas syringae | 17.5 µL/mL |     |
| α-Phellandrene   |           |                               | Pectobacterium carotovorum | 20 µL/mL |     |
|                  |           |                               | Ralstonia solanacearum | 20 µL/mL |     |
|                  |           |                               | Bacillus thuringiensis | 8 µL/mL |     |
|                  |           |                               | Alternaria alternata | 35.40 ± 3.07 | Moz |   |
|                  |           |                               | Curvularia fallax   | 75.50 ± 4.05 |     |
|                  |           |                               | Macrophomina phaseolina | 22.73 ± 5.10 |     |
|                  |           |                               | Fusarium oxysporum  | 75.83 ± 4.29 |     |
|                  |           |                               | Cytospora sacchari  | 30.64 ± 6.65 |     |
|                  |           |                               | Colletotrichum trichellum | 76.94 ± 4.75 |     |
|                  |           |                               | R. solanacearum     | 61.80 ± 4.60 |     |
|                  |           |                               | B. thuringiensis     | 30.64 ± 6.65 |     |
|                  |           |                               | E. coli             | 17.60 ± 2.50 |     |
|                  |           |                               | L. monocytogenes    | 58.80 ± 3.10 |     |
|                  |           |                               | E. coli             | 62–500 µg/mL |     |
|                  |           |                               | L. monocytogenes    | 11%        |     |
|                  |           |                               | B. subtilis         | 30%        |     |
|                  |           |                               | S. aureus           | 3%         |     |
|                  |           |                               | E. coli             | 11%        |     |
|                  |           |                               | L. monocytogenes    | 32%        |     |
|                  |           |                               | B. cereus           | 8%         |     |
|                  |           |                               | S. typhimurium      | 18%        |     |
| (Z)-Beta-ocimene | Aerial    | Bornyl acetate                | S. aureus          | >500 µg/mL |     |
| Bornyl acetate   | parts     | p-Cymene                     | E. coli            | >500 µg/mL |     |
| α-Pinene         |           | Subtilis                     | L. monocytogenes   | >500 µg/mL |     |
| γ-Terpinene      |           | Germacrene D                 | S. aureus          | >500 µg/mL |     |
| Germacrene D     |           | Myrcene                      | S. typhimurium     | >500 µg/mL |     |
| Terpinene        |           |                               | E. coli            | >500 µg/mL |     |
| Germacrene D     |           |                               | L. monocytogenes   | >500 µg/mL |     |
| 2,3,6-trimethylbenzaldehyde | Aerial parts | Hexyl butanoate octyl isobutyrate octyl 2-methylbutyrate, pentylcyclopropane | L. monocytogenes | 2.5 mg/mL |     |
| 2,3,6-trimethylbenzaldehyde |           |                               | E. coli            | 5 mg/mL    |     |
| p-Cymene         | Prangos   | Limonene                      | B. cereus          | 6.25 mg/mL |     |
| Desf. Seeds      | ferulacea | (E)-Ocimene terpinolene      | L. innocua         | 6.25 mg/mL |     |
| Lindl. Leaves    |           | 2,3,6-trimethylbenzaldehyde  | S. aureus          | 4.30 mg/mL |     |
| (E)-Ocimene      |           | Limonene terpinolene         | E. coli            | 12.50 mg/mL |     |
| terpinolene      |           |                               | S. aureus          | 12.50 mg/mL |     |
| 2,3,6-trimethylbenzaldehyde |          |                               | E. coli            | 25.00 mg/mL |     |
| (E)-Ocimene      |           |                               | L. innocua         | 6.25 mg/mL |     |
| terpinolene      |           |                               | S. aureus          | 12.5 mg/mL |     |
| 2,3,6-trimethylbenzaldehyde |          |                               | E. coli            | 25.00 mg/mL |     |
| (E)-Ocimene      |           |                               | E. coli            | 4.3 and 5.5 mg/mL |     |
| terpinolene      |           |                               | L. innocua         | 12.5 and 25 mg/mL |     |
| (E)-Ocimene      |           |                               | E. coli            | 6.25 mg/mL |     |
| terpinolene      |           |                               | L. innocua         | 12.5 mg/mL |     |

(continued)
| Scientific names          | Part used         | Major phytochemical compounds | Inhibited pathogens                     | MIC values          | Ref.                          |
|--------------------------|-------------------|-------------------------------|-----------------------------------------|---------------------|-------------------------------|
| *Achillea millefolium* L. | Aerial parts      | Borneol                       | *S. typhimurium* (ATCC202026)           | 25 mg/mL            | Ahmadi-Dastgerdi et al. (2017) |
|                          |                   | α-Pinene                      | *Enterobacter aerogenes* (ATCC 13048)   | 25 mg/mL            |                               |
|                          |                   | β-Pinene                      | *S. aureus* (ATCC 25923)                | 4.5 and 6.53 mg/mL  |                               |
|                          |                   | 1,8-Cineole                   | *S. enteritidis* (ATCC 4933)            | 7.2 mg/mL           |                               |
|                          |                   |                               | *E. coli* (ATCC 25922)                  | 7.2 mg/mL           |                               |
|                          |                   |                               | *Penicillium glaucum* (ATCC 9849P)      | 0.46 and 1.67 mg/mL |                               |
|                          |                   |                               | *Saccharomyces cerevisiae* (ATCC 60782) | 0.46 and 2.41 mg/mL |                               |
| *Seriphidium kermanense* | Aerial parts      | α-Thujone                     | *P. aeruginosa*                        | 62 μg/mL            | Gavanji et al. (2014)         |
| (D. Podl.) Y. R. Ling [syn: |                   | camphor                       |                                            |                     |                               |
| *Artemisia kermanensis* Podl. |                   | β-Thujone                     | *S. aureus*                            | 48 μg/mL            |                               |
|                          |                   | p-Mentha-1                    | *K. pneumonia*                          | 54 μg/mL            |                               |
|                          |                   | S-Dien-8-ol                   |                                            |                     |                               |
| *Dracocephalum kotschyi* | Aerial parts      | α-Pinene                      | *B. cereus* (ATCC 6633)                 | 5.0 mg/mL           | Kazemi et al. (2011)          |
| Boiss.                   |                   | geranial                      | *B. subtilis* (ATCC 9372)               | 1.25 mg/mL          |                               |
|                          |                   | geranyl acetate               |                                            | 2.5 mg/mL           |                               |
|                          |                   | geraniol                      |                                            |                     |                               |
|                          |                   | limonene                      |                                            |                     |                               |
|                          |                   | neral                         |                                            |                     |                               |
|                          |                   |                               | *S. aureus* (ATCC 12600)                | 160 μg/mL           | Ashrafi et al. (2017)         |
|                          |                   |                               | *S. epidermidis* (PTCC 1435)            | 80 μg/mL            |                               |
|                          |                   |                               | *Streptococcus agalactiae* (PTCC 1768)  | 80 μg/mL            |                               |
|                          |                   |                               | *Streptococcus mutans* (PTCC 1683)      | 80 μg/mL            |                               |
|                          |                   |                               | *E. faecalis* (ATCC 29219)              | 640 μg/mL           |                               |
|                          |                   |                               | *L. monocytogenes* (ATCC13932)          | 160 μg/mL           |                               |
|                          |                   |                               | *E. coli* (ATCC11775)                   | 640 μg/mL           |                               |
|                          |                   |                               | *S. typhi* (PTCC 1609)                  | 80 μg/mL            |                               |
|                          |                   |                               | *S. paratyphi A* (PTCC 1230)            | 160 μg/mL           |                               |
|                          |                   |                               | *S. enterica* (PTCC 1709)               | 160 μg/mL           |                               |
|                          |                   |                               | *P. aeruginosa* (ATCC 27853)            | 320 μg/mL           |                               |
|                          |                   |                               | *K. pneumoniae* (ATCC 700603)           | 320 μg/mL           |                               |
|                          |                   |                               |                                            |                     |                               |
|                          |                   |                               |                                            | 2–4 mg/mL           | Moridi Farimani et al. (2017) |
|                          |                   |                               |                                            | 4–16 mg/mL          | Ghabam et al. (2021)          |
|                          | Aerial parts      | Limonene                      | *S. aureus* (ATCC 29523)                | 125–250 μg/mL       |                               |
|                          |                   |                               |                                            | 125–500 μg/mL       |                               |
|                          |                   |                               |                                            | 31.25–125 μg/mL     |                               |
|                          |                   |                               |                                            | 125 μg/mL           |                               |
|                          |                   |                               |                                            | 125–500 μg/mL       |                               |
|                          |                   |                               |                                            | 500–1000 μg/mL      |                               |
|                          |                   |                               |                                            | 125–250 μg/mL       |                               |
|                          |                   |                               |                                            | 250–500 μg/mL       |                               |
|                          |                   |                               |                                            | 1000 μg/mL          |                               |
|                          |                   |                               |                                            | 500–2000 μg/mL      |                               |
|                          |                   |                               |                                            | 500–2000 μg/mL      |                               |
|                          | Flowering fragments | α-Pinene                      | *Aspergillus brasiliensis* (PTCC 5011)  | 62.5 μg/mL          | Shakib et al. (2018)          |
|                          |                   | geraniol                      |                                            |                     |                               |
|                          |                   | geranial                      |                                            |                     |                               |
|                          |                   | limonene                      |                                            |                     |                               |
|                          | Aerial parts      |                               |                                            |                     | Khodaie et al. (2018)         |

(continued)
| Scientific names | Part used | Major phytochemical compounds | Inhibited pathogens | MIC values | Ref. |
|------------------|-----------|-------------------------------|---------------------|------------|-----|
| Limonene         |           | S. aureus (ATCC 6538)         | 200 μg/mL           |            |     |
| Perilla aldehyde |           | S. epidermidis (ATCC 12228)   | 200 μg/mL           |            |     |
|                  |           | E. coli (ATCC 8739)           | 500 μg/mL           |            |     |
|                  |           | P. aeruginosa (ATCC 9027)     | 900 μg/mL           |            |     |
| **Hymenocrater calycinus** (Boiss.) Benth. | Aerial parts | 1,8-Cineole | B. subtilis (PTCC 1023) | 1.6 mg/mL |     |
|                  |           | β-Pinene                      | S. aureus (PTCC 1112) | 0.8 mg/mL |     |
|                  |           | α-Pinene                      | E. coli (PTCC 1330)  | 1.6 mg/mL |     |
|                  |           |                               | S. typhi (PTCC 1639) | 1.6 mg/mL |     |
|                  |           |                               | P. aeruginosa (PTCC 1074) | – | Morteza-Semnani et al. (2012) |
|                  |           |                               | A. niger (PTCC5011)  | –          |     |
|                  |           |                               | C. albicans (PTCC 5027) | – |     |
| **Hymenocrater longiflorus** Benth. | Stems | α-Pinene | E. faecalis (ATCC 29122) | > 480 μg/mL |     |
|                  |           | 1,8-Cineole                   | S. aureus (ATCC 11522) | 120 μg/mL | Ahmadi et al. (2010) |
|                  |           | p-Menth-1-en-8-ol             | K. pneumonia (ATCC 13183) | > 480 μg/mL |     |
|                  |           | β-Bourbonene                  | P. aeruginosa (ATCC 27853) | > 480 μg/mL |     |
|                  |           | trans-caryophyllene           | S. flexneri 2a (L53) | > 480 μg/mL |     |
|                  |           |                               | Salmonella typhimurium (ATCC 19430) | > 480 μg/mL |     |
|                  |           |                               | E. coli (PTCC 11522)  | > 480 μg/mL |     |
|                  |           |                               | A. niger             | 480 μg/mL  |     |
|                  |           |                               | C. albicans         | 240 μg/mL  |     |
| **Mentha piperita** L. | Aerial parts | Menthol | C. albicans | 1.5 μL/mL | Saharkhiz et al. (2012) |
|                  |           | methyl acetate               | Candida tropicalis  | 1.0 μL/mL |     |
|                  |           |                               | Candida krusei      | 0.5 μL/mL |     |
|                  |           |                               | Candida glabrata    | 1.2 μL/mL |     |
|                  |           |                               | Candida dublinensis | 2.4 μL/mL |     |
|                  |           |                               | Candida parapsilosis| 4.0 μL/mL |     |
|                  |           |                               | Cryptococcus neoformans | 4.0 μL/mL |     |
|                  |           |                               | A. flavus (ATCC 64025) | 4.0 μL/mL |     |
|                  |           |                               | Aspergillus fumatus (ATCC 14110) | 0.5 μL/mL |     |
|                  |           |                               | Aspergillus fumatus (CBS 14489) | 2.0 μL/mL |     |
|                  |           |                               | Aspergillus clavatus (CBS 514.65) | 0.5 μL/mL |     |
|                  |           |                               | A. oryzae (CBS 818.72) | 2.0 μL/mL |     |
| **Salvia mirzayanii** Rech.f. & Esfand. | Aerial parts | Menthofuran menthol | S. epidermidis | 31.25 μg/mL | Yazdani et al. (2019) |
|                  |           | 1s-neomenthyl acetate         | S. aureus          | 31.25 μg/mL |     |
|                  |           |                               | S. dysenteriae     | 62.50 μg/mL |     |
|                  |           |                               | K. pneumonia       | 62.50 μg/mL |     |
|                  |           |                               | B. subtilis        | 1.87 mg/mL | Armana et al. (2012) |
|                  |           |                               | Bacillus pumilus   | 1.87 mg/mL |     |
|                  |           |                               | E. faecalis        | –          |     |
|                  |           |                               | S. aureus          | 7.5 mg/mL |     |
|                  |           |                               | S. epidermidis     | 7.5 mg/mL |     |
|                  |           |                               | E. coli            | 15 mg/mL |     |
|                  |           |                               | K. pneumonia       | –          |     |
| **Aerial parts** |         | α-Terpinyl acetate geranial   | S. aureus          | 40.6 ± 2.1 to | Ghasemi et al. (2020) |
|                  |         | 1,8-Cineole                   | E. coli            | 62.5 ± 2.4 μg/mL |     |
|                  |         |                               | C. albicans        | 22.4 ± 1.8 to |     |
|                  |         |                               |                   | 33.6 ± 1.2 μg/mL |     |
|                  |         |                               |                   | 28.5 ± 1.7 to |     |
|                  |         |                               |                   | 42.4 ± 1.8 μg/mL |     |
| **Aerial parts** |         | Cineol                        | Streptococcus mutants (ATCC 35668) | 0.062-0.125 μL/mL | Zomorodian et al. (2015) |
|                  |         | linalyl acetate               | Streptococcus sanguinis (ATCC 10556) | 0.125 μL/mL |     |

(continued)
| Scientific names          | Part used | Major phytochemical compounds | Inhibited pathogens                                  | MIC values                  | Ref.               |
|--------------------------|-----------|-------------------------------|------------------------------------------------------|-----------------------------|--------------------|
| Satureja bachtiarica     | Aerial parts | Carvacrol, thymol, p-Cymene   | **S. aureus** (PTCC1311)                              | 1.0 mg/mL                   | Falsafi et al. (2015) |
|                          | Aerial parts | carvacrol                    | B. cereus (PTCC 1015)                                | 1.0 mg/mL                   |                    |
|                          | Aerial parts | thymol                       | **E. coli** (PTCC 1399)                              | 0.5 mg/mL                   |                    |
|                          | Aerial parts | p-Cymene                     | **P. aeruginosa** (PTCC1430)                         | >64 mg/mL                   |                    |
|                          | Aerial parts | thymol                       | **B. cereus**                                       | 62.5–500 μg/mL              |                    |
|                          | Aerial parts | p-Cymene                     | **S. aureus**                                       | 62.5–500 μg/mL              |                    |
|                          | Aerial parts | thymol                       | **S. agalactiae**                                   | 31.2–125 μg/mL              |                    |
|                          | Aerial parts | p-Cymene                     | **P. vulgaris**                                     | 31.2–500 μg/mL              |                    |
|                          | Aerial parts | thymol                       | **L. monocytogenes**                                | 16–250 μg/mL                |                    |
|                          | Aerial parts | p-Cymene                     | **L. monocytogenes**                                | 5 mg/mL                     |                    |
|                          | Aerial parts | thymol                       | **E. coli**                                         | 0.14 ± 0.08 μg/mL           |                    |
| Satureja khuzistanica    | Aerial parts | Carvacrol, thymol, p-Cymene   | **S. aureus**                                       | 62 μg/mL                    | Ghasemi Pirbalouti et al. (2014) |
| Jamzad                   | Aerial parts | carvacrol, borneol, linalool | Lactobacillus plantarum LUS                         | 12.5 μg/mL                  | Mahboubi and Kazempour (2016) |
|                          | Aerial parts |                 | **S. flexneri**                                     | 3.125 μg/mL                 |                    |
|                          | Aerial parts | Carvacrol                     | **E. coli**                                         | 12.5 μg/mL                  |                    |
|                          | Aerial parts |                | **S. aureus**                                       | 0.062–0.125 μg/mL           |                    |

(continued)
| Scientific names | Part used | Major phytochemical compounds | Inhibited pathogens | MIC values | Ref. |
|-----------------|-----------|-------------------------------|---------------------|------------|-----|
| Carvacrol       | Aerial parts | Carvacrol γ-Terpinene p-Cymene | S. aureus (ATCC 25923) | 0.16–7.8 mg/mL | Rashidipour et al. (2016) |
|                 |           |                               | S. MRSA (ATCC 20413) | 0.125–0.625 mg/mL | |
|                 |           |                               | P. aeruginosa (ATCC 27853) | 20–80 mg/mL | |
|                 |           |                               | L. monocytogenes (ATCC 35152) | 0.31–1.25 mg/mL | |
|                 |           |                               | C. albicans (ATCC 10231) | 360 μg/mL | |
|                 | Aerial parts | Carvacrol | S. aureus (ATCC 2228) | 30 μg/mL | Saei-Dehkordi et al. (2012) |
|                 |           | thymol carvacrol | L. monocytogenes (ATCC 19118) | 20 μg/mL | |
|                 |           |                               | B. cereus (ATCC 1778) | 5 μg/mL | |
|                 |           |                               | E. coli (ATCC 15701) | 0.25 μg/mL | Hadian et al. (2012) |
| Satureja rechingeri Jamzad | Aerial parts | Carvacrol γ-Terpinene linalool p-Cymene thymol | C. albicans (ATCC 10231) | 0.19 mg/mL | Alizadeh (2015) |
|                 |           |                               | S. aureus (ATCC 6538) | 0.39 mg/mL | |
|                 |           |                               | S. epidermidis (ATCC 1435) | 0.39 mg/mL | |
|                 |           |                               | E. coli (ATCC 25922) | 0.19 and 0.39 mg/mL | |
| Thymus daenensis Celák. | Aerial parts | Thymol carvacrol p-Cymene thymol | S. aureus (PTCC1431) | 0.5 mg/mL | Hadian et al. (2012) |
|                 |           |                               | B. cereus (PTCC 1015) | 0.25 mg/mL | |
|                 |           |                               | E. coli (PTCC1399) | 0.25 mg/mL | |
|                 |           |                               | P. aeruginosa (PTCC1430) | >64 mg/mL | |
|                 |           |                               | Rhodotorula mucilaginosa (ATCC 2503) | 90 μg/mL | |
|                 |           |                               | Rhodotorula rubra (PTCC 5076) | 135 μg/mL | |
| Aerial parts | Thymol carvacrol p-Cymene thymol | C. albicans (ATCC 10231) | 0.19 mg/mL | |
| Aerial parts | Thymol carvacrol | A. fumigatus A. niger | 0.5 ± 0/05 mg/mL | Mohammad et al. (2018) |
| Aerial parts | Thymol carvacrol | E. coli (ATCC35218)  | 1 ± 0/1 mg/mL | Golkar et al. (2020) |
| Aerial parts | Thymol carvacrol | S. typhimurium (ATCC14028) | 20 μg/mL | |
| Aerial parts | Thymol carvacrol | S. aureus (ATCC29213) | 20 μg/mL | |
| Aerial parts | Thymol carvacrol | B. cereus (ATCC14579) | 20 μg/mL | |
| Aerial parts | Thymol carvacrol | B. subtilis (PTCC-1156) | 7.5 μg/mL | Alamholo (2020) |
| Aerial parts | Thymol carvacrol | B. cereus (PTCC-1247) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | S. pyogenes (PTCC-1447) | 7.5 μg/mL | |
| Aerial parts | Thymol carvacrol | M. luteus (ATCC 10987) | 7.5 μg/mL | |
| Aerial parts | Thymol carvacrol | E. faecalis (PTCC-1195) | 3.75 μg/mL | |
| Aerial parts | Thymol carvacrol | S. aureus (PTCC-1189) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | S. typhi (PTCC-1609) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | P. aeruginosa (PTCC-1181) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | E. coli (PTCC-2922) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | Shigella boydii (PTCC1744) | – | |
| Aerial parts | Thymol carvacrol | Enterobacter aerogenes (PTCC-1221) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | Acinetobacter baumanni (PTCC-4413) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | Proteus mirabilis (ATCC-1287) | – | |
| Aerial parts | Thymol carvacrol | Neisseria meningitidis (PTCC-4578) | 15 μg/mL | |
| Aerial parts | Thymol carvacrol | K. pneumoniae (ATCC-1129) | 15 μg/mL | |

(continued)
| Scientific names              | Part used          | Major phytochemical compounds | Inhibited pathogens                  | MIC values       | Ref.         |
|------------------------------|--------------------|-------------------------------|--------------------------------------|-----------------|--------------|
| *Thymus kotschyanus* Boiss. & Hohen | Aerial parts       | Carvacrol                     | *C. albicans* (ATCC 10231 BBL)       | 3.645 μg/mL     | Ahmadi et al. (2015) |
|                              |                    | 1,8-Cineole                   | *S. aureus* (ATCC 6538)              | 1.562 μg/mL     |              |
|                              |                    | thymol                        | *S. epidermidis* (PTCC1435)          | 0.097 μg/mL     |              |
|                              |                    | borneol                       | *B. cereus* (PTCC1247)              | 1.562 μg/mL     |              |
|                              |                    | *E-*Caryophyllene             | *E. coli* (PTCC1399)                | 6.25 μg/mL      |              |
|                              | Aerial parts       | Carvacrol                     | *S. faecalis*                       | 1.562 μg/mL     |              |
|                              |                    | β-Caryophyllene               | *S. typhi*                           | 50 μg/mL        |              |
|                              |                    | γ-Terpine                     | *S. aureus*                         | 100 μg/mL       |              |
|                              |                    | α-Phellandrene                | *C. albicans*                       | –               |              |
|                              |                    | thymol                        | *E. coli*                           | –               |              |
|                              |                    | *E*-Caryophyllene             | *S. faecalis*                       | –               |              |
|                              |                    | *S. typhi*                    | *S. aureus*                         | –               |              |
|                              | Zataria multiflora Boiss. | Thymol                        | *E. coli* (ATCC 25922)              | 1.3 ± 0.4 mg/mL | Fatemi et al. (2015) |
|                              | Aerial parts       | thymol                        | *P. aeruginosa* (ATCC 27853)        | 2.6 ± 0.9 mg/mL |              |
|                              |                    | *B. cereus*                   | *E. coli*                           | 1.3 ± 0.4 mg/mL |              |
|                              |                    | *S. aureus* (ATCC 25923)      | *E. coli*                           | 1.2 ± 0.7 mg/mL |              |
|                              | Aerial parts       | Carvacrol                     | *E. coli* O157:H7                   | 0.015–0.03% (v/v) | Khatibi et al. (2017) |
|                              |                    | thymol                        | *S. typhimurium* (ATCC14028)        | 500 ppm         | Javan (2016)  |
|                              |                    | *L. monocytogenes* (ATCC19118) | *B. cereus* (ATCC 11778)           | 500 ppm         |              |
|                              |                    | *S. aureus* (ATCC 6538)       | *B. cereus* (ATCC 11778)           | 500 ppm         |              |
|                              | Aerial parts       | Carvacrol                     | *L. monocytogenes* (ATCC19111)      | 1.2–9.5 μg/mL   | Rahnama et al. (2012) |
| |                    |                    | thymol                        | *Aspergillus* spp.                  | 200 ppm         | Nasser et al. (2016) |
|                              |                    | *Rhizoctonia solani*          | *Rhizopus stolonifer*               | 300 ppm         |              |
|                              |                    | *L. monocytogenes* (ATCC1911) | *L. monocytogenes* (ATCC19111)      | 1.2–9.5 μg/mL   |              |
|                              | Aerial parts       | Carvacrol                     | *P. aeruginosa* (ATCC 27853)        | 12.5 mg/mL      | Sheikholeslami et al. (2016) |
|                              |                    | thymol                        | *L. monocytogenes* (ATCC 9027)      | 7.8 μg/mL       | Mahmoodi et al. (2012) |
|                              | Aerial parts       | Carvacrol                     | *Lactococcus garvieae*              | 3.125 mg/mL     | Mahboubi et al. (2017) |
|                              |                    | γ-Terpine                     | *P. aeruginosa* (ATCC 27853)        | 2 μg/mL         |              |
|                              |                    | α-Pinene                      | *S. aureus* MRSA (ATCC 33591)       | 3.125 mg/mL     |              |
|                              |                    | Thymol                        | *S. aureus* (ATCC 14990)            | 3.125 mg/mL     |              |
|                              |                    | carvacrol                     | *P. aeruginosa* (ATCC 27853)        | 6.25 mg/mL      |              |
|                              |                    | p-Cymene                      | *P. aeruginosa* (ATCC 9027)         | 12.5 mg/mL      |              |
|                              |                    | thymol                        | *S. typhi* (ATCC 10031)             | 2.65 ± 0.7 μg/mL | Mahammadi Purfard and Kavoosi (2012) |
|                              |                    | *K. pneumonia* (PTCC 1053)    | *E. coli* (ATCC 8739)               | 2.85 ± 0.5 μg/mL |              |
|                              |                    | *S. aureus* (PTCC 1112)       | *E. coli* (ATCC 8739)               | 2.72 ± 0.8 μg/mL |              |
|                              |                    | *S. epidermidis* (ATCC 12228) | *S. aerues* (PTCC 1112)             | 3.02 ± 0.8 μg/mL |              |
| |                    |                    | *S. epidermidis* (ATCC 12228) | *S. epidermidis* (ATCC 14990)       | 3.53 ± 1 μg/mL  |              |
| Scientific names          | Part used        | Major phytochemical compounds | Inhibited pathogens                   | MIC values          | Ref.                                      |
|---------------------------|------------------|-------------------------------|----------------------------------------|---------------------|-------------------------------------------|
| *B. subtilis* (ATCC 6033) |                  |                               |                                        | 3.65 ± 0.9 µg/mL    |                                            |
| *A. niger* (PTCC 5010)    |                  |                               |                                        | 2.2 ± 0.5 µg/mL     |                                            |
| *C. albicans* (PTCC 5027) |                  |                               |                                        | 2.8 ± 0.8 µg/mL     |                                            |
| *S. typhimurium* (ATCC 14028) |              |                               |                                        | 0.625 mg/mL         |                                           |
| *L. monocytogenes* (ATCC 19117) |          |                               |                                        | 1.25 mg/mL          | Mojaddar Langroodi et al. (2019)          |
| *B. cereus* (PTCC 1012)   |                  |                               |                                        | 50 µg/mL            |                                            |
| *P. aeruginosa* (PTCC 1310) |              |                               |                                        | 25 µg/mL            |                                            |
| *P. vulgaris* (PTCC 1449)  |                  |                               |                                        | 25 µg/mL            |                                            |
| *S. cerevisiae* (PTCC 24860) |             |                               |                                        | 200 µg/mL           |                                            |
| *C. utilis* (PTCC 5052)    |                  |                               |                                        | 100 µg/mL           |                                            |
| *P. digitatum* (ATCC 201167) |             |                               |                                        | 200 µg/mL           |                                            |
| *A. niger* (PTCC 5011)    |                  |                               |                                        | 200 µg/mL           |                                            |
| *S. typhimurium* (ATCC 14028) |             |                               |                                        | 0.93 mg/mL          | Mirzakhani et al. (2018)                   |
| *L. monocytogenes* (ATCC 19118) |            |                               |                                        | 0.93 mg/mL          |                                            |
| *B. cereus* (ATCC 1015)   |                  |                               |                                        | 7.5 mg/mL           |                                            |
| *S. epidermidis*          |                  |                               |                                        | 5 mg/mL             |                                            |
| *S. typhimurium*          |                  |                               |                                        | 10 mg/mL            |                                            |
| *Campylobacter jejuni*    |                  |                               |                                        | 15 mg/mL            |                                            |
| *K. pneumoniae*           |                  |                               |                                        | 10 mg/mL            |                                            |
| *P. fluorescens*          |                  |                               |                                        | 15 mg/mL            |                                            |
| *B. cereus* (PTCC 1015)   |                  |                               |                                        | 7.5 mg/mL           |                                            |
| *Aspergillus parasiticus* |                  |                               |                                        | 0.37 ± 0.1 mg/mL    | Khosravi et al. (2011)                    |
| *S. aureus* (ATCC 6538)   |                  |                               |                                        | 0.03 ± 0.00 to      | Shahbazi (2017)                           |
| *B. subtilis* (ATCC 6633) |                  |                               |                                        | 0.03 ± 0.00 to      |                                            |
| *B. cereus* (ATCC 11774)  |                  |                               |                                        | 0.03 ± 0.00%        |                                            |
| *L. monocytogenes* (ATCC 19118) |           |                               |                                        | 0.04 ± 0.00%        |                                            |
| *S. typhimurium* (ATCC 14028) |             |                               |                                        | 0.04 ± 0.00 to      |                                            |
| *E. coli* O157:H7         |                  |                               |                                        | 0.04 ± 0.00 to      |                                            |
| *S. epidermidis*          |                  |                               |                                        | 0.05 ± 0.00%        |                                            |
| *P. fluorescens*          |                  |                               |                                        | 0.05 ± 0.00%        |                                            |
| *B. cereus* (ATCC 1015)   |                  |                               |                                        | 0.05 ± 0.00%        |                                            |
| *S. aureus* (ATCC 25923)  |                  |                               |                                        | 1 µg/mL             | Mahboubi et al. (2011)                    |
| *Staphylococcus saprophyticus* (ATCC 15305) | | | | 0.5 µg/mL |                                            |
| *S. epidermidis* (ATCC 14490) |             |                               |                                        | 0.5 µg/mL           |                                            |
| *B. cereus* (ATCC 1247)   |                  |                               |                                        | 0.5 µg/mL           |                                            |
| *B. subtilis* (ATCC 6051) |                  |                               |                                        | 0.5 µg/mL           |                                            |
| *S. pyogenes* (ATCC 88668) |                  |                               |                                        | 0.25 µg/mL          |                                            |
| Scientific names | Part used | Major phytochemical compounds | Inhibited pathogens | MIC values | Ref. |
|------------------|-----------|-------------------------------|---------------------|------------|-----|
| S. agalactiae    |           |                               | E. faecalis (ATCC 29212) | 1 µg/mL    |     |
| Enterococcus faecium (ATCC 25778) | |                               | K. pneumonia (ATCC 10031) | 0.125 µg/mL |     |
| S. sanguis (ATCC 10556) | |                               | E. coli (ATCC 8739) | 1 µg/mL    |     |
| S. salivarius (ATCC 9222) | |                               | S. typhimurium (ATCC 14028) | 1 µg/mL |     |
| P. aeruginosa (ATCC 9027) | |                               | P. vulgaris (RI 231) | 1 µg/mL |     |
| E. aerogenes (NCTC 10009) | |                               | S. dysenteriae (RI 366) | 1 µg/mL |     |
| S. flexneri (NCTC 8516) | |                               | Serratia marcescens (ATCC 13880) | 0.5 µg/mL |     |
| S. aureus        |           |                               | C. albicans (ATCC10231) | 1 µg/mL    |     |
| E. coli          |           |                               | A. flavus            | 0.5 µg/mL  |     |
| P. aeruginosa    |           |                               | A. niger (ATCC 16404) | 0.125 µg/mL |     |
| A. parasiticus   |           |                               | A. parasiticus (ATCC 15517) | 0.25 µg/mL |     |
| Petals           | Nonadecane|                               | S. aureus       | 250 µL/mL  |     |
| 9-Nonadecane     |           |                               | E. coli          | 500 µL/mL  |     |
| Eicosane         |           |                               | S. typhi         | 1000 µL/mL |     |
| –                | Nonadecane|                               | C. albicans      | 2 µL/mL    |     |
| Heneicosane      |           |                               | C. tropicalis    | 8 µL/mL    |     |
| β-Citronellol    |           |                               | C. krusei        | 8 µL/mL    |     |
|                  |           |                               | C. glabrata      | 1 µL/mL    |     |
|                  |           |                               | C. dubliniensis  | 1 µL/mL    |     |
|                  |           |                               | A. flavus        | 2 µL/mL    |     |
|                  |           |                               | A. fumigatus      | 0.5 µL/mL  |     |
|                  |           |                               | A. clavatus (CBS 514.65) | 0.5 µL/mL |     |
|                  |           |                               | A. oryzae (CBS 818.72) | 1 µL/mL |     |
|                  |           |                               | Cryptococcus neoformans (ATCC2406) | 0.25 µL/mL |     |
|                  |           |                               | S. aureus (ATCC29213) | 8 µL/mL    |     |
|                  |           |                               | E. faecalis (ATCC 11700) | >64 µL/mL |     |
|                  |           |                               | E. coli (ATCC 25922) | 16 µL/mL |     |
|                  |           |                               | P. aeruginosa (ATCC27853) | >64 µL/mL |     |

The essential oils with highly inhibitory effects against Gram-positive bacteria are highlighted in grey.
Trichoderma harzianum was the most sensitive microorganism with MIC of 625 μg/mL.

**Cuminum cyminum L. (Apiaceae)**

C. cyminum (Figure 1(D)), or cumin seeds, is not only the main ingredient of different traditional cuisines, but also has been widely used to cure varied ailments; gastrointestinal diseases, tooth decay, cough, epilepsy, diabetes and aches (Gachkar et al. 2007; Johri 2011; Srivasvan 2018). The essential oil of C. cyminum seeds rich in β-pinene, γ-terpinene-7-al and γ-terpinene have considerable radical-scavenging and antioxidant activities that are comparable with Trolox and BHT (Fatemi et al. 2013). Likewise, Ladan Moghadam (2016), showed that the antioxidant activity of C. cyminum essential oil was even higher than trolox. Moreover, Zolfaghari et al. (2015), studied *in vitro* and *in vivo* antimicrobial potentiality of cumin seeds essential oil against Gram-positive and negative bacterial strains and revealed that *B. cereus* (MIC = 2.07 ± 0.51 mg/mL) was the most species. Later, the combinations of C. cyminum essential oil and standard antibiotics (sodium benzoate) were screened to determine the presence of any synergistic activities. The results demonstrated that the antimicrobial activity of C. cyminum essential oil preservatives, when used in combination with other preservatives, was higher. Moreover, the Gram-positive bacteria (MIC = 1.13 ± 0.11%) were more sensitive to C. cyminum essential oil than Gram-negative bacteria (MIC = 1.93 ± 0.11%) (Ekheltat et al. 2019). Similarly, Tavakoli et al. (2015) indicated good antimicrobial activity of C. cyminum essential oil combined with nisin (a preservative agent) against *Salmonella typhimurium* growth at 10°C and *S. aureus* growth at 10°C and 25°C, respectively, in BHI broth during study period of 43 days.

**Ferulago angulata (Schltdl.) Boiss. (Apiaceae)**

Chaval (F. angulata) (Figure 1(E)) has been traditionally used as an antiseptic, air freshener and spice in Iranian cuisine (Ghasemi et al. 2013; Bagherifar et al. 2019). The antioxidant capacity of F. angulata essential oil collected from diverse Iran provinces was compared. In DPPH assay, the strongest antioxidant effects were found in Chaval collected from Lorestan Province (IC₅₀=11.70 ± 0.217 mg/mL) attributed to its main compounds of α-pinene and Z-β-oicimen (Shahbazi et al. 2016). Chaval essential oil (α-pinene and cis-β-oicimen) from the southwestern regions of Iran also presented an excellent antioxidant activity comparable with BHT (Ghasemi Pirbalouti et al. 2016). The phytochemical composition and antibacterial activity of F. angulata essential oil collected from different parts of Iran were assessed by agar dilution and disc diffusion methods. The results showed that the essential oil from F. angulata grown in Kurdestan Province containing high amount of α-pinene and Z-β-oicimen exhibited highest antibacterial activity against all the tested bacteria particularly *E. faecalis* (MIC and MBC = 33.3 and 40 μg/mL) (Shahbazi et al. 2016). Mumivand et al. (2019) reported that Gram-negative pathogens (*E. coli* and *P. aeruginosa*) were more resistant to essential oil of F. angulata aerial parts. Likewise, Moghaddam et al. (2018) studied the antibacterial and antifungal activities of essential oil from *F. angulata* seeds against six bacterial and fungal species and revealed that Bacillus thuringiensis, Fusarium oxysporum and Colletotrichum trichellum were sensitive to essential oil containing high content of cis-β-oicimen, α-pinene and α-phemllandrene. Similarly, the findings of Ghasemi Pirbalouti et al. (2016) indicated that Chaval essential oil extracted from *F. angulata* had very strong activity against *L. monocytogenes* (Gram-positive bacterium). Similarly, Shahbazi et al. (2015) reported that the two Gram-positive bacteria (*L. monocytogenes* and *B. cereus*) were more sensitive to *F. angulata* essential oil.

**Heracleum persicum Desf. (Apiaceae)**

Golpar (*H. persicum*) (Figure 1(F)) distributed in Alborz regions has been widely used in traditional medicine and food in different parts of Iran and Middle Eastern countries (Amin 1991; Kousha and Bayat 2012; Roshanaei et al. 2017). In traditional Iranian medicine, fruits and stems of this plant are used as a spice, in pickling (Shariatifar et al. 2017), and as an analgesic, antiseptic, anti-flatulence and digestive aid, as well as remedy for stomach pains and infections (Hemati et al. 2010; Bahadori et al. 2016). In the comparative antioxidant activities of 10 selected herbs via DPPH method, *H. persicum* extract did not show a significant result (Dehghan et al. 2016), contrastingly, comparative study on antioxidant activity of essential oils from four *Heracleum* species; *H. patinacifolium* C. Koch and *H. persicum* essential oils showed the highest activities which could probably be due to the presence of myristicin and (*E*)-anethole (Firuzi et al. 2010). The data (Shariatifar et al. 2017) obtained from disc diffusion and broth micro-dilution methods demonstrated a notable antimicrobial activity of *H. persicum* essential oil against the selected bacterial strains; *S. aureus* (MIC = 11%), *Salmonella enterica* (MIC = 32%), *E. coli* (MIC = 30%), Vibrio cholerae (MIC = 8%) and Yersinia enterocolitica (MIC = 18%). Rezayan and Ehsani (2015) reported that the antibacterial effects of *H. persicum* essential oil with principal compounds; hexyl butanoate, octyl isobutyrate, octyl 2-methylbutyrate and pентylcyclopropane, were more significant on *L. monocytogenes* (PTCC 1165) as a Gram-positive bacterium. The highest antimicrobial potentials were reported for essential oil of *H. persicum* on *B. subtilis* (Noudeh et al. 2010). In a study by Ehsani et al. (2019) evaluated *H. persicum* essential oil, nisin and *Lactobacillus acidophilus* (as a probiotic agent) to inhibit the growth of *L. monocytogenes* and reported that a combined formulation containing low concentration of *H. persicum* essential oil, nisin and probiotic agent signified a synergistic effect.

**Prangos ferulacea (L.) Lindl. (Apiaceae)**

*P. ferulacea* (Figure 1(G)) (Djashir) is used to flavour foods, for medical preparations, and animal fodder. In addition, Djashir is a laxative, wound healing, antihypertensive and carminative agent (Yousefi et al. 2017; Mottaghipisheh et al. 2020). Bazdar et al. (2018) evaluated the antioxidant potential of essential oil and extract from *P. ferulacea* flowers and leaves against DPPH radicals and reported that the hydro alcoholic flowers (*IC₅₀=8.01 ± 0.60*) containing the highest number of flavonoids showed the highest antioxidant activities compared to Djashir essential oil (*IC₅₀=23.90 ± 2.59* and 22.99 ± 2.13, respectively). A comparative study (Seidi Damyeh et al. 2016) assessed the effects of novel ohmic-assisted hydrodistillation (OAHD) on chemical compositions, besides antioxidant and antibacterial activities of essential oil from *P. ferulacea* leaves and demonstrated a significant difference in the percentage of chemical compositions percent between HD and OAHD, but antioxidant effects (*IC₅₀=488.14* and 570.52 μg/mL, respectively) were less remarkable than BHT (*IC₅₀=17.34 μg/mL*). OAHD method influence on antibacterial efficacy of *P. ferulacea* essential oil, *B. cereus*,...
Listeria innocua, S. aureus, E. coli, S. typhimurium and Enterobacter aerogenes was studied. The essential oil extracted by HD constituting mainly (E)-β-ocimene, p-cymene, 2,3,6-trimethylbenzaldehyde, germacrene D and terpinolene showed better antimicrobial activity, particularly against S. aureus. These researchers also indicated that sonication prior to extraction had no significant efficacy on antibacterial effects and chemical compounds of P. ferulacea essential oils, and the most sensitive and resistant bacterial species were S. aureus and S. typhimurium, respectively. Therefore, the ultrasonic pre-treatment of plants prior to extraction could be desirable to minimize the extraction times (Seidi Damyeh and Niakousari 2016).

*Achillea millefolium* (Boomadaran) (Figure 1(H)) is an herbaceous flowering plant with several traditional uses, viz., anti-infections, antihemorrhage, anti-inflammation and anti-diabetic (Mirdeilami et al. 2011; Mazandaran et al. 2013; Bahmani et al. 2014). A. millefolium essential oil exhibited significantly greater radical scavenging activity (IC$_{50}$ =23.11 ± 0.04 mg/mL), than trolox (IC$_{50}$ =23.51 ± 0.05 mg/mL). β-Carotene bleaching method findings also confirmed its capacity (Sahari Moghadam et al. 2017). Additionally, *A. millefolium*, *A. graveolens* and *Carum copticum* L. (Apiaceae) essential oils were tested for in vitro antioxidant activity using DPPH, FRAP and β-carotene bleaching assays. The antioxidant activity of *A. millefolium* essential oil was statistically superior to other tested plants and even trolox. The presence of high levels of phenolic substances, viz., thymol and carvacrol may attribute to the antioxidant properties of *A. millefolium* essential oil (Kazemi 2015). Comparatively, the essential oil of *A. millefolium* leaves had weaker antimicrobial effects than the essential oil from its flowers positively correlating to occurrence of camphor, borneol and α-cadinol. The highest activity of essential oils was observed against *S. aureus*, *Penicillium glaucum* and *S. cerevisiae* (Ahmadi-Dastgerdi et al. 2017).

*Seriphidium kermanense* (D. Podl.) Y. R. Ling (Asteraceae)

*S. kermanense* [syn. *Artemisia kermanensis* D. Podl.] (Figure 1(I)) is an important herb in the south of Kerman Province, Iran (Mozafarian 1996). In folk medicine, this plant was used for to treat skin disease and high blood pressure (Dalatkhahi et al. 2014). Jamzad (1996) demonstrated that *A. kermanensis* essential oil possessed considerable antioxidant and radical scavenging activities through DPPH and β-carotene-linoleic acid assays (Jamzad 1996). The essential oil was reported to exert antibacterial effects against *B. subtilis*, *P. aeruginosa* and *S. aureus*. The MIC and MBC results demonstrated that *B. subtilis* (MIC = 1.25 mg/mL, MBC = 2.5 mg/mL), *P. aeruginosa* (MIC = 1.25 mg/mL, MBC = 2.5 mg/mL) and *S. aureus* (MIC = 1.25 mg/mL, MBC = 2.5 mg/mL) were the most sensitive microorganisms (Kazemi et al. 2011). Gavanji et al. (2014) evaluated the antimicrobial activity of *A. kermanensis* essential oil against *S. aureus* (ATCC 25923), *P. aeruginosa* (PTCC 1310) and *K. pneumonia* (PTCC 1053), with 54, 62 and 48 μg/mL MIC values, respectively.

*Dracocephalum kotschyi* Boiss. (Lamiaceae)

*D. kotschyi* (Figure 1(J)) aerial parts are used in traditional medicine to treat stomach, headache, toothache and liver disorders (Heydari et al. 2019; Fallah et al. 2020). The chemical composition and antioxidant activity of *D. kotschyi* essential oil were analysed by DPPH and GC/MS methods, respectively. The results showed that the essential oil containing neral geranial, geranyl acetate and α-pinene had good antioxidant potential (Ashrafi et al. 2017; Fallah et al. 2020). The essential oils from cultivated and wild *D. kotschyi* were tested for their inhibitory effects against 12 microbial strains by MIC and MBC tests. This activity was more marked against Gram-positive bacteria, while, essential oil from the wild was the most effective to halt *C. albicans* growth, the essential oil from crops was more marked against Gram-positive bacteria (*B. subtilis*) (Ghavam et al. 2021). Ashrafi et al. (2017) reported that *D. kotschyi* essential oil showed the greatest bactericidal activities against the highly susceptible strains of most Gram-positive organisms (except *E. faecalis*) with MIC values of 80–160 μg/mL and a few Gram-negative organisms; *Salmonella typhi*, *S. paratyphi* and *S. enterica* (80–160 μg/mL). In a comparative study, the antimicrobial activities of *D. polychaetum* Borm., *D. kotschyi* and *D. multiotula* Montbret & Aucher ex Benth. were investigated wherein *D. kotschyi* essential oil with MIC of 200 μg/mL exhibited the strongest antimicrobial activity against *S. epidermidis* (Khodaee et al. 2018). *D. kotschyi* essential oil inhibitory effects against *K. pneumonia* as the third leading cause of hospital-acquired pneumonia were reported which can be replaced with conventional antibiotics such as amoxicillin (Shakib et al. 2018). In an investigation, the chemical composition and antibacterial efficacy of *D. kotschyi* essential oil were isolated by three different techniques (HD, solvent-free microwave extraction (SFME) and MAHD). The lowest MICs (2 mg/mL) were of the essential oil extracted by MAHD and SFME against *S. aureus*. However, the maximal limonene compounds were found in the essential oil obtained by HD (Moridi Farimani et al. 2017).

*Hymenocrater spp.* (Lamiaceae)

*H. longiflorus* Benth. (Figure 1(K)) and *H. calycinus* (Boiss.) Benth. (Figure 1(L)) are termed Gol-e-Arvaneh in Persian (Morteza-Semnani et al. 2016). In Iranian traditional and folk medicine, it is optimally consumed for sedative, inflammation and skin antiallergenic (Asri et al. 2017). The antioxidant activities of essential oils besides polar and non-polar fractions of methanolic extract from *H. longiflorus* were estimated by DPPH and β-carotene-linoleic acid, respectively. According to DPPH assay results, polar extract exhibited better antioxidant activities due to lower EC$_{50}$, while oxidation of linoleic acid was effectively inhibited by non-polar extracts (Ahmadi et al. 2010). *H. calycinus* essential oil was most effective to inhibit *S. aureus* (MIC = 0.8 mg/mL) growth. While it had no antifungal activity against any tested fungal strain (Morteza-Semnani et al. 2012). Ahmadi et al. (2010) showed that *S. aureus* (MIC = 40 μg/mL) was more sensitive to essential oil, and essential oil had significant inhibitory effects on *C. albicans* (MIC = 240 μg/mL) and *A. niger* (MIC = 480 μg/mL).

*Mentha piperita* L. (Lamiaceae)

*M. piperita* (peppermint) (Figure 1(M)), a natural hybrid between spearmint (*M. spicata* L.) and water mint (*M. aquatica*...
Salvia mirzayanii Rech.f. & Esfand. (Lamiaceae)

Salvia (S. mirzayanii) (Figure 1(N)) aerial parts have long been used to cure infections, inflammatory diseases, spasms, gastrointestinal disorders and diabetes (Sadat-Hosseini et al. 2017; Asadollahi et al. 2019). Oxygenated monoterpenes including ß-thujone, 1,8-cineole and camphor (Izadi and Mirazi 2020) were the main constituents of Salvia essential oil displaying considerable antioxidant activities when compared to trolox (Omidpanah et al. 2015). Armana et al. (2012) investigated the chemical compositions and antimicrobial activity of essential oil from S. mirzayanii aerial plants against B. subtilis, B. pumilus, E. faecalis, S. aureus, S. epidermidis, E. coli and A. niger. Gram-positive bacteria (B. subtilis and B. pumilus) were the most sensitive microorganisms to Salvia essential oil (containing spathulenol, linalool and 1,8-cineole) with MIC = 1.87 mg/mL. Ghasemi et al. (2020) reported that chemical compounds and antimicrobial activities of S. mirzayanii essential oils were dependent on variety and environmental conditions. The essential oils of various plant species: S. mirzayanii, Ocimum sanctum L. (Lamiaceae), A. sieberi Besser., Satureja khuzestanica Jamzad (Lamiaceae), Satureja bachtiarica Bunge. (Lamiaceae) and Z. multiflora were tested for antimicrobial efficiency against oral bacteria: Streptococcus mutans, C. albicans and E. faecalis via broth micro-dilution method. The study revealed that O. sanctum, A. sieberi and S. mirzayanii essential oils rich in 1,8-cineole displayed strong antimicrobial effects (Zomorodian et al. 2015). Two years later, Zomorodian et al. (2017) investigated the antimicrobial effects of essential oil from S. mirzayanii leaves against some common pathogenic bacteria and fungi and found that Gram-negative (E. faecalis) bacteria were more sensitive than Gram-positive ones.

Satureja spp. (Lamiaceae)

About 16 Satureja species are grown in Iran, of which, S. bachtiarica (Figure 1(O)), S. khuzestanica (Figure 1(P)) and S. rechingeri Jamzad (Figure 1(Q)) can be easily found in different parts of Iran (Jamzad 1996; Razzaghi-Abyaneh et al. 2013). In Iranian folk medicine, they treat cramps, muscle pains, nausea indigestion, diarrhoea and infectious diseases (Senatore et al. 1998; Bezić et al. 2009; Hadian et al. 2014). The aerial parts of these plants are used in traditional medicine as antibacterial, anti-inflammation, analgesic, anti-septic besides flavouring agents (Naghibi et al. 2005; Ghasemi Pirbalouti et al. 2010b). Alizadeh (2015) evaluated the antioxidant activity of essential oil and extract from S. rechingeri using DPPH and FRAP assays and revealed that antioxidant capacity of S. rechingeri extract was stronger than its essential oil due to high concentration of phenolic contents. Similarly, antioxidant activity of S. rechingeri essential oil solely and in combination with deuterium depleted water (DDW) has been evaluated using glutathione S-transferase (GST), lipid peroxidation (LP) and glutathione (GSH) methods respectively and based on data, essential oil solely or in combination with DDW showed a high antioxidant activity level as compared to BHT (Attaran et al. 2015; Fatemi et al. 2015; Rasooli et al. 2016). The therapeutic effects of DDW on various diseases in humans mainly cancer have been previously confirmed due to its great antioxidant potentials (Basov et al. 2019). Memarzadeh et al. (2020) characterized the impact of different extraction techniques vs. HD and microwave-assisted steam hydro-diffusion (MSHD) on phytochemical analysis and antioxidant capacity of S. bachtiarica essential oil. Although there was an equal amount of two principal components (carvacrol and thymol) present in the essential oils extracted by both methods, the antioxidant activity of essential oil extracted by MSHD was higher than that of HD. A comparative study assessed the chemical compositions and antioxidant activities of four essential oils (S. khuzestanica, Oliveria decumbens Vent. (Apiaceae) and Thymus daenensis Celak. (Lamiaceae) and their components). The results showed that antioxidant activity of S. khuzestanica essential oil was weaker than other tested essential oils (Saïdi 2014). S. khuzestanica essential oil (IC50=28.71 µg/mL) exhibited the highest DPPH scavenging activity and strong antioxidant activity in ß-carotene-linoleic acid assay (Saei-Dehkordi et al. 2012). Alizadeh (2015) assessed the antimicrobial effects of S. rechingeri oil against four microorganisms: C. albicans (ATCC 10231), S. aureus (ATCC 6538), S. epidermidis (ATCC 1435) and E. coli (ATCC 25922) by recording inhibition zones and MIC and revealed that S. rechingeri essential oil had a significant potential to inactive the growth of all tested pathogens (MIC = 0.19 and 0.39 µL/mL) compared to standard antibiotics (tetracycline and amoxicillin). The in vitro antibacterial activities of S. bachtiarica essential oil were also evaluated against several bacterial species. The results indicated that S. bachtiarica essential oil containing carvacrol and thymol showed a stronger antimicrobial activity against S. typhimurium and L. monocytogenes (Ghasemi Pirbalouti et al. 2017). The inhibitory effect of S. bachtiarica essential oil against P. aeruginosa was also reported (Ghasemi Pirbalouti and Dadfar 2013). The antibacterial efficacy from S. bachtiarica and T. daenensis essential oils against S. aureus was considerably higher than that from Dracocephalum muticaule Montbr. & Auch. (Lamiaceae) and Tanacetum polychalpeum Schultz-Bip (Asteraceae) essential oils (Ghasemi Pirbalouti et al. 2014). Previous researches demonstrated that S. bachtiarica essential oil had a therapeutic potentiality to treat Helicobacter pylori and L. monocytogenes (Falsafi et al. 2015; Fathi-moghaddam et al. 2020). The antibacterial activity of essential oils from Satureja species against some Gram-positive and negative bacteria was evaluated by disc diffusion method. The strongest antibacterial activities were observed in S. khuzestanica and S. rechingeri essential oils against B. cereus with MIC of 0.25 mg/mL. Interestingly, the ability of whole essential oils to prevent tested pathogens except P. aeruginosa was comparable to, or in most cases greater than, those of their pure main constituents (Hadian et al. 2012). Similarly, both S. khuzestanica and S. rechingeri essential oils possessed stronger antibacterial potential against Gram negative bacteria (E. coli and S. flexneri) than S. bachtiarica (Saharkhiz et al. 2016). S. khuzestanica essential oil...
showed strong antibacterial activity against S. aureus which was mainly correlated to presence of carvacrol (Rashidipour et al. 2016). Mahboubi and Kazempour (2016) evaluated in vitro antibacterial activity of S. khuszestanica essential oil, carvacrol and gentamicin and their synergistic effect on E. coli. They found that antibacterial activity of carvacrol was higher than essential oil. They also reported a considerable synergistic effect while using gentamicin with carvacrol and S. khuszestanica essential oil. Likewise, Hashemi and Khodaei (2020) conducted an in vitro study to assess the inhibitory potential of S. khuszestanica and S. bacthiarica essential oils solely or in combination against Lactobacillus plantarum LUS growth as a probiotic culture or S. flexneri, and E. coli. Their results confirmed that the mixture of both essential oils had no synergic effect on probiotics while it significantly prohibited the pathogen. The antibacterial effects of S. khuszestanica essential oil alone and in combination with both synthetic (ciprofloxacin fluconazole and amphotericin B) and natural (lysozyme) agents using fractional inhibition concentration indices and MIC assays were studied against food-borne microorganisms. The results indicated that the interactive effects of combinations between essential oil and ciprofloxacin against E. coli and S. typhimurium were considerable (Saei-Dehkordi 2014). In another comparative study, Jalas et al. have been analysed against seven microorganism strains. The lowest MICs were found to be 2.46 ± 0.75 to 4.58 ± 1.4 µL/mL for Z. multiflora which was more susceptible than that of F. assa-foetida essential oil (Kavooosi and Purfard 2013). The other related study results indicated that use of Z. multiflora essential oil could considerably modulate antioxidant/oxidative stress parameters including LP and GSH, as well as antioxidant enzymes such as GST (Daddkhah et al. 2014; Attaran et al. 2018). In a study by Sharifi et al. (2011), Z. multiflora essential oil exhibited strong scavenging activity, inhibiting LP at all tested doses (100, 200 and 400 µL/kg/day). Previously, several studies proved the antibacterial activities of Z. multiflora essential oil against different bacterial species. Fatemi et al. (2015) assessed the antibacterial potency of Z. multiflora essential oil (100 and 200 mg/kg b.w.) using disc diffusion, agar well diffusion, besides MIC and MBC determination assays as well as caecal ligation and puncture model. They reported that S. aureus and B. cereus (Gram-positive bacteria) were more sensitive to Z. multiflora essential oil than E. coli and P. aeruginosa (Gram-negative bacteria). Likewise, Rahimi et al. (2019) indicated that Z. multiflora essential oil inhibited A. flavus growth at 50–400 ppm concentrations. Even, Mahboubi et al. (2017) evaluated the antimicrobial activity of Z. multiflora essential oil and its main compounds; thymol, carvacrol and p-cymene against P. aeruginosa. The MICs results showed the equal growth inhibitory effects of both essential oil and its major compositions. The antimicrobial activity of Z. multiflora essential oil collected from Khorasan Province was analysed against seven microorganism strains. The lowest MICs were against P. aeruginosa (25 µg/mL) and P. vulgaris (25 µg/mL) and S. cerevisiae, P. digitatum and A. niger were the most resistant microorganisms (Avaee et al. 2015).

A comparative study on antibacterial activities of different essential oils against Lactobacillus garvieae, as the causative agent of lactococcosis, indicated that the inhibitory effect of Z. multiflora essential oil (MIC = 7.8 µg/mL) were far stronger than

### Thymus spp. (Lamiaceae)

*Thymus* contains 18 species in Iran, wherein *T. daenensis* (Figure 1(R)) and *T. kotschyanus* Boiss. & Hohen. (Figure 1(S)) are widely distributed in the central and southern parts of Iran (Jalas 1982; Mozafarian 1996). They treat common cold, high blood pressure, vomiting, heartburn, asthma and cough (Naghibi et al. 2005; Rahimmalek et al. 2009; Emami Bistgani and Sefidkon 2019). The antioxidant activities of *Thymus* species including *T. kotschyanus*, *T. daenensis* and *T. eriocalyx* Jalas have been addressed by various model systems; DPPH and β-carotene/linoleic acid. Their main phytochemical compositions were thymol, carvacrol and γ-terpinene. While the antioxidant effect of *T. daenensis* essential oil was higher than the other essential oils in DPPH assay and *T. eriocalyx* Jalas exerted the greatest antioxidant activity in β-carotene/linoleic acid test (Amiri et al. 2012) and even greater than that of reference antioxidant (Alavi et al. 2010). In another comparative study, *T. vulgaris* L. exhibited the highest antioxidant activity as compared to other *Thymus* species (*T. daenensis* and *T. kotschyanus*) due to high thymol constituent (Mehran et al. 2016). However, the activity of *T. kotschyanus* leaves essential oil was lower than the positive control (BHT) (Shafaghat and Shafaghatlomba 2011). *T. kotschyanus* essential oil exerted notable antimicrobial effects on *C. albicans* and *B. cereus* (Ahmadi et al. 2015). Golkar et al. (2020) compared the antibacterial activities and chemical compositions of *Thymus* species and *Z. multiflora* through disk diffusion and broth microdilution assays against both Gram-positive and negative bacteria. They reported that *T. kotschyanus* and *Z. multiflora* had considerable antibacterial effects (MIC ≥ 20 µg/mL) which might be attributed to high thymol and carvacrol levels. The antifungal activities and phytochemical compounds of *T. daenensis* essential oil were tested against two fungi. GC/MS analysis identified the major components: thymol, carvacrol and p-cymene, as well as the potent inhibitory effects at very broad spectrum against *A. fumigatus*, *A. niger* and *C. albicans* (Hadipanah and Khorami 2016; Mohammadi Gholami et al. 2018). Asbaghian et al. (2011) compared the antimicrobial activities of *Thymus* species (*T. caucasicus* Wild., *T. kotschyanus* and *T. vulgaris*) and showed that *T. vulgaris* with the highest thymol concentration (43.8%) had the highest antimicrobial activity on *E. coli* (MIC = 12.5 µg/mL), followed by *S. faecalis* (MIC = 25 µg/mL). According to Alamholo (2020), *T. daenensis* essential oil had the moderate antibacterial activity against Streptococcus pyogenes, Micrococcus luteus and *B. subtilis*, with MIC = 7.5 µg/mL and high-level activity against *E. faecalis* (MIC = 3.75 µg/mL), however, showed no activity against *S. typhi*, *P. aeruginosa*, *E. coli*, *Proteus mirabilis* and *S. boydii*.

**Zataria multiflora Boiss. (Lamiaceae)**

*Z. multiflora* (Figure 1(T)), (Avishan-e-Shirazi), has been used for many decades as a flavouring ingredient in a number of Iranian cuisines (Gandomi et al. 2009; Basti et al. 2016). It has several traditional uses as an infusion, decoction or vapour to treat digestive problems, headache, common cold, migraine and bone pain (Safa et al. 2013; Nasab and Khosravi 2014). *Z. multiflora* essential oil containing the phenolic compounds particularly carvacrol and thymol demonstrated a high antioxidant activity through β-carotene/linoleic acid and DPPH assays (Fatemi et al. 2012; Dini et al. 2015), but lower than BHT (Hashemi et al. 2011). A number of different methods have been used to compare the radical-scavenging/antioxidant activity of essential oils isolated from *Z. multiflora* leaves and *Ferula assa-foetida* L. latex. The free radical scavenging activity estimated by inhibitory concentration ranged from 2.46 ± 0.75 to 4.58 ± 1.4 µg/mL for *Z. multiflora* which was more susceptible than that of *F. assa-foetida* essential oil (Kavooosi and Purfard 2013). The other related study results indicated that use of *Z. multiflora* essential oil could considerably modulate antioxidant/oxidative stress parameters including LP and GSH, as well as antioxidant enzymes such as GST (Daddkhah et al. 2014; Attaran et al. 2018). In a study by Sharifi et al. (2011), *Z. multiflora* essential oil exhibited strong scavenging activity, inhibiting LP at all tested doses (100, 200 and 400 µL/kg/day). Previously, several studies proved the antibacterial activities of *Z. multiflora* essential oil against different bacterial species. Fatemi et al. (2015) assessed the antibacterial potency of *Z. multiflora* essential oil (100 and 200 mg/kg b.w.) using disc diffusion, agar well diffusion, besides MIC and MBC determination assays as well as caecal ligation and puncture model. They reported that *S. aureus* and *B. cereus* (Gram-positive bacteria) were more sensitive to *Z. multiflora* essential oil than *E. coli* and *P. aeruginosa* (Gram-negative bacteria). Likewise, Rahimi et al. (2019) indicated that *Z. multiflora* essential oil inhibited *A. flavus* growth at 50–400 ppm concentrations. Even, Mahboubi et al. (2017) evaluated the antimicrobial activity of *Z. multiflora* essential oil and its main compounds; thymol, carvacrol and p-cymene against *P. aeruginosa*. The MICs results showed the equal growth inhibitory effects of both essential oil and its major compositions. The antimicrobial activity of *Z. multiflora* essential oil collected from Khorasan Province was analysed against seven microorganism strains. The lowest MICs were against *P. aeruginosa* (25 µg/mL) and *P. vulgaris* (25 µg/mL) and *S. cerevisiae*, *P. digitatum* and *A. niger* were the most resistant microorganisms (Avaee et al. 2015).
Rosmarinus officinalis L. (Lamiaceae) (MIC = 15.6 μg/mL), Anethum graveolens L. (Apiaceae) (MIC = 62.4 μg/mL) and Eucalyptus globulus Labill. (Myrtaceae) (MIC = 250 μg/mL) (Mahmoodi et al. 2012). Similarly, the antibacterial property of Z. multiflora essential oil was superior to Berberis vulgaris L. (Berberidaceae) extract (Langroodi et al. 2018). Recently, Mahammedi Purfard and Kavoosi (2012) compared the effect of Z. multiflora essential oil and aqueous extract on inhibition of P. aeruginosa, S. typhi, E. coli, K. pneumoniae, S. aureus, S. epidermidis, B. subtilis, A. niger and C. albicans and demonstrated that Z. multiflora essential oil significantly inhibited the growth of all tested pathogens except P. aeruginosa, while, Z. multiflora extract was unable to inhibit the growth of all tested pathogens. Furthermore, the synergistic antibacterial activity of Z. multiflora essential oil in combination with monolaurin as a non-traditional antimicrobial agent was investigated. Consequently, the combination of these components revealed a more potent inhibitor against L. monocytogenes (Raeisi et al. 2016). In addition, the antibacterial property of Z. multiflora essential oil in combination with other antimicrobials has been well investigated. Rahnama et al. (2012) reported the enhanced synergistic antibacterial effect of Z. multiflora essential oil and nisin on L.
monocytes through decrease in MIC and MBC values. Likewise, Javan (2016) indicated that the combination of Z. multiflora and Trachyspermum ammi L. (Apiaceae) essential oils exhibited a synergistic effect on the bacterial inhibition, and B. cereus was the most sensitive pathogen. For the first time, the application of silver nanoparticles as an antimicrobial agent in combination with Z. multiflora essential oil against a variety of pathogens S. aureus, methicillin-resistant S. aureus (MRSA), S. epidermidis and P. aeruginosa was investigated by Sheikholeslami et al. (2016). They confirmed that these compounds exerted additive effects against S. epidermidis and S. aureus. Moreover, Nasser et al. (2016) demonstrated that Z. multiflora essential oil loaded with nanoliposomes showed higher antifungal effect on Aspergillus spp., Rhizoctonia solani and Rhizopus stolonifer than non-capсуlated essential oil. Khatibi et al. (2017) also reported a significant increase in inhibitory effect of Z. multiflora essential oil against E. coli O157:H7 after encapsulation into nanoliposomess. Moreover, Shahabi et al. (2017) reported that although conversion of Z. multiflora essential oil to nanoemulsion could not significantly improve its antibacterial activity, but it enhanced its antibiofilm activity.

Zhumeria majdae Rechinger f. & Wendelbo (Lamiaceae)

Mohrehkosh (Z. majdae) (Figure 1(U)) has been traditionally used as antiseptic, carminative and painkiller (Rechinger and Wendelbo 1967; Rechinger 1982; Safa et al. 2013). Z. majdae essential oils collected from different locations of Iran showed high antioxidant activity in vitro with DPPH (IC_{50}=8.801) and β-carotene/linoeleic assays (11.77 mg/mL). This study revealed a direct relationship between the geographical location and the antioxidant activity of Z. majdae essential oils (Saeidi et al. 2019). Mirzakhan et al. (2018) reported the inhibition effects of Z. majdae essential oil on some food-borne pathogenic bacteria; B. cereus, E. faecalis and S. typhimurium. They also signified that Z. majdae essential oil had inhibiting effects on all tested Gram-positive strains except E. faecalis.

Ziziphora clinopodioides Lam. (Lamiaceae)

In Iranian folklore, different parts of kakuti-e kuhi (Z. clinopodioides) (Figure 1(V)), i.e., from leaves to roots were commonly used as spice and treatment of digestive system, cold and tooth-ache (Asgharipour et al. 2016; Amiri et al. 2019). In the present study, antioxidant compounds (total phenol and flavonoid contents) and antioxidant activities of Z. tenuior L. and Z. clinopodioides essential oils were compared. The antioxidant analysis revealed that both essential oils considerably reduced the value of DPPH free radicals. The total phenolic compounds content in Z. clinopodioides essential oil (49 ± 1.4 mg quercetin/100 g oil) was higher than Z. tenuior essential oil (30.3 ± 0.1 mg gallic acid/100 g oil) (Hazrati et al. 2020). Shahbazi (2017) determined antioxidant activity of Z. clinopodioides essential oil was determined by four different tests; TBA and FRAP assays and revealed that the antioxidant effects of essential oils harvested from Kermanshah Province were highest. Z. clinopodioides essential oil exhibited a considerable antibacterial activity against food-borne pathogens, with MIC and MBC values ranging from 0.0012 to 0.0025 μg/mL, respectively, even much higher than records of tetracycline as a positive control, 2–2.5 μg/mL. Generally, Gram-negative bacteria are more resistant than Gram-positive ones (Shahbazi 2015). An in vitro study evaluated the antifungal properties of C. cymum, Z. clinopodioides and Nigella sativa L. (Ranunculaceae) essential oils on Aspergillus parasiticus, which is able to produce aflatoxin as a toxic and carcinogenic metabolite. The findings from broth microdilution method, revealed that the tested fungi were most sensitive to C. cymum (MIC_{90}=1.6 mg/mL; MFC = 3.5 mg/mL) and Z. clinopodioides (MIC_{90}=2.1 mg/mL; MFC = 5.5 mg/mL) (Khosravi et al. 2011). Furthermore, the comparative study on compositions and antibacterial activity of essential oils from leaf, flower and stem of Z. clinopodioides collected from four natural habitats in the western provinces of Iran was conducted. No significant difference was observed in antibacterial potential of essential oils isolated from different parts of the plant. The Gram-negative bacteria (S. typhimurium and E. coli) were more resistance to Gram-positive bacteria (S. aureus, B. cereus, B. subtilis and L. monocytogenes) in relation to essential oils. The main constituent of all essential oils except the essential oils collected from Kurdestan was carvacrol (Shahbazi 2017).

Rosa damascene P. Mill. (Rosaceae)

Damask (R. damascena) (Figure 1(W)) is a hybrid between R. gallica L. and R. phoenicia Boiss. and was brought to European countries from Iran (Mabhoubi 2016). This plant is widely used in varied industries; cosmetic, pharmaceutical and food for centuries (Georgiev and Stoyanova 2006). R. damascena essential oil exhibited a strong antioxidant activity as compared to BHT and trolox (Dadkhah et al. 2019; Kheirkhahan et al. 2020). Fatemi et al. (2020) revealed the positive treatment of animals with synthetic antioxidant effects of R. damascena essential oil and DDW due to regulation of oxidative stress/antioxidant parameters mainly; GSH, LP, GST and FRAP. Moreover, Afarsi Sardari et al. (2019) showed that essential oil of fresh flowers had more antioxidant activity as compared to the spent flower essential oil. Damask essential oil exhibited antimicrobial activity against 20 microorganisms selected from both Gram-negative and positive bacteria. The essential oil exhibited the highest antimicrobial activity against P. vulgaris and K. pneumonia (Mabhoubi et al. 2011). In a study, R. damascena essential oil with high alcoholic monoterpenes content; β-citronellol, geraniol, farnesol and geranyl acetate had the best antifungal and antibacterial effects (Moein et al. 2017). Kheirkhahan et al. (2020) studied antibacterial effect of R. damascena essential oil using the disc diffusion method against S. aureus, E. coli and S. typhi bacterial strains and reported that volatile oil obtained from Damask was effective against the three tested bacteria with MICs ranging from 500 to 1000 μL/mL.

Conclusions and future perspectives

This review discussed the antioxidant and antimicrobial potencies of essential oils of some indigenous plant species from Iran commonly used in Iranian traditional medicine for a wide range of applications (Table 1). The 23 studied essential oils showed high antioxidant activity particularly, C. carvi, C. cymum, A. millefolium and T. daenensis essential oils which exerted even greater effects than synthetic antioxidants; Trolox and BHT (Table 2). The antioxidant activity of these essential oils is related to their main chemical composition; primarily to the presence of polyphenolic compounds (carvacrol and thymol). These natural antioxidants could be effectually used as an adjuvant to shield our body against oxidative stress-related disorders including cardiovascular diseases, dementia, neurodegenerative diseases and cancer. However, it mandates a detailed study to
explore their efficacy, safety and exact mechanism in vivo and in clinical trials.

Furthermore, this review revealed that essential oils isolated from the selected endemic medicinal plants possessed strong antibacterial activities against various bacterial and fungal pathogens. As depicted in Table 3, Gram-positive bacteria, Staphylococcus spp., Bacillus spp. and Listeria monocytogenes are more sensitive to C. carvi, C. macropodum, C. cymum, P. f progressa, A. canadensis, Hymenocrater spp., Z. majdae and Z. clinopodioides essential oils than Gram-negative bacteria such as E. coli and S. enterica. Likewise, the essential oils have similar effects on inhibition of both Gram-negative and positive bacteria. Therefore, it can be safely concluded that antimicrobial activity of essential oils is highly dependent upon some parameters mainly essential oil type and microbial strains tested. Perhaps, the difference in antimicrobial potential of these plant species might stem from varying their phytochemical compounds. In addition, future studies should be focussed to determine antimicrobial activity mechanisms of these pure essential oils and their individual major compounds as well as activity enhancement in combination with other antimicrobial agents.

Unfortunately, the commercial use of these essential oils as antimicrobials is still a challenging scenario because of their poor solubility and stability. Moreover, the antimicrobial effects of essential oil can be reduced via exposure to light, heat and oxidation (Khatibi et al. 2017). Nevertheless, encapsulation of essential oils and their constituents seems to be an efficient solution to overcome such problems due to improvement in their oxidative-stability, thermo-stability, photo-stability, shelf-life and even biological activity as well as increasing their solubility (Stevanovic et al. 2020). Encapsulated Z. multiflora essential oil mentioned in this review is a good example. Thus, it is expected that this review would be helpful to adopt more efficient natural anti-microbial and antioxidant agents for pharmaceutical and food purposes.

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References
Alavi I, Barzegar M, Jabari A, Naghdi BH. 2010. Effect of heat treatment on chemical composition and antioxidant property of Thymus daenensis essential oil. J Med Plants. 9(35):129–138.
Amorati R, Foti MC, Valgimigli L. 2013. Antioxidant activity of essential oils. J Agric Food Chem. 61(46):10835–10847.
Ahmadi F, Sadrizadeh S, Moghadam M, Arbib R, Mikeali A. 2010. Chemical composition, in vitro anti-microbial, antifungal and antioxidant activities of the essential oil and methanolic extract of Hymenocrater longiflorus Benth., of Iran. Food Chem Toxicol. 48(5):1137–1144.
Ahmadi R, Alizadeh A, Ketabchi S. 2015. Antimicrobial activity of the essential oil of Thymus kotschyanus grown wild in Iran. Int J Biol Sci. 6: 239–248.
Ahmadi-Dastgerdi A, Ezzatpanah H, Asgary S, Dokhani S, Rahimi E. 2017. Phytochemical, antioxidant and antimicrobial activity of the essential oil from flowers and leaves of Achillea millefolium subsp. millefolium. J Essent Oil-Bear Plants. 20(2):395–409.
Asgharipour MR, Abjahan AA, Dahmarde M. 2016. Variability in essential oil and methanolic extract of Z. majdae – Z. commutata var. persica from wild growing populations from Iran. Chem Biodivers. 13(10):1903–1906.
Asadollahi M, Firouzeh A, Jafari A. 2013. Antimicrobial and antioxidant activities of the essential oil of Thymus daenensis and Thymus eriocalyx essential oils against human pathogenic bacteria. J Med Microbiol. 8:148–154.
Alldaffa AA, Sallam RM. 2012. Reactive oxygen species in health and disease. J Biomed Biotechnol. 2012:936486.
Amiri H. 2012. Essential oils composition and antioxidant properties of three Thymus species. Evid Based Complement Alternat Med. 2012. 728065–728103.
Amiri MS, Jabbarzadeh P, Akhondi M. 2012. An ethnobotanical survey of medicinal plants used by indigenous people in Zangelan district, Northeast Iran. J Med Plants Res. 6:749–753.
Amiri MS, Joharchi MR. 2013. Ethnobotanical investigation of traditional medicinal plants commercialized in the markets of Mashhad, Iran. Avicenna J Phytomed. 3(3):254–271.
Amiri MS, Joharchi MR. 2016. Ethnobotanical knowledge of Apiaceae family in Iran: a review. Avicenna J Phytomed. 6(6):621–635.
Amirmohammadi M, Khajoeini S, Bahmani M, Rafieian-Kopaei M, Eftekhar Z, Qorbani M. 2014. In vivo evaluation of antiparasitic effects of Artemisia abrotanum and Salvia officinalis extracts on Sphyacia obvelata, Aspiculuris tetraptera and Hymenolepisis nana parasites. Asian Pac J Trop Dis. 4: S250–S254.
Armanna M, Azizi N, Yousufzadai M. 2012. Cytotoxicity, antimicrobial activity and composition of the essential oil from Salvia mizayani Rech. f. & Esfand from Iran. J Biol Active Prod Nat. 2:54–58.
Arumugam G, Swamy MK, Sainih JJ, 2016. Plectranthus amboinicus (Lour.) Spreng. botanical, phytochemical, pharmacological and nutritional significance. Molecules. 21(4):369–395.
Asadollahi M, Firuzi O, Jamezobori FH, Alizadeh M, Jassbi AR. 2019. Ethnopharmacological studies, chemical composition, antioxidant and cytotoxic activities of essential oils of eleven Salvia in Iran. J Herb Med. 17:100250–100302.
Asghari S, Shafaghat A, Zaree K, Kasimov F, Salimi F. 2011. Comparison of volatile constituents, and antioxidant and antibacterial activities of the essential oils of Thymus caucasicus, T. kotschyanus and T. vulgaris. Nat Prod Commun. 6:137–140.
Asgharipour MR, Abjahan AA, Dahmarde M. 2016. Variability in Ziziphora clinopodioides subsp. bungeana (Juz.) based on morphological traits and essential oils profile. Not Bot Horti Agrobot. 41(1):189–194.
Ashrafi B, Ramak P, Ezzatpour B, Talei GR. 2017. Investigation on chemical composition, antimicrobial, antioxidant, and cytotoxic properties of essential oil from Dracaenophalum kotschyi Boiss. Afr J Tradit Complement Altern Med. 14(3):209–217.
Asri Y, Sadeh-Hoseinabadi Ghaini F, Vaziri A, Akbarzadeh M. 2017. Essential oil composition from Hymenocorater calycinus (Boiss.) Benth. in Iran. J Essent Oil-Bear Plants. 20(3):712–719.
Attaran HR, Diri S, Fatemi P, Hosseini, S, Parhizkarie M, Dadkhan A. 2015. Hepatoprotective evaluation of Iranian Saturaea Rechingeri essential oils against oxidative injuries induced by acetaminophen in Wistar rats. Int J Rev Life Sci. 5:204–210.
Attaran HR, Fatemi R, Rasooli A, Dadkhan A, Mohammadi Malayeri MR, Dini S. 2018. Zataria multiflora essential oil prevent iron oxide nanoparticles-induced liver toxicity in rat model. J Med Plants By Prod. 7:15–24.
Avaei A, Mohammadi Sanj, M, Mohammadi Sanj Z, Vaziri B. 2015. Chemical composition and antimicrobial effect of the essential oil of Zataria multiflora Boiss. endemic in Khorasan-Iran. Asian Pac J Trop Dis. 5:181–185.
Bagherifar S, Sourestani MM, Zolfaghari M, Mottaghishぱ, Jesh, Zomborski ZP, Czupor D. 2019. Variation of chemical constituents and antiradical capacity of nine Parula angula populations from Iran. Chem Biodivers. 16(10):1903062.
Bahadori MB, Dinparast L, Zengin G. 2016. The genus Hernolepis: a comprehensive review on its phytochemistry, pharmacology, and ethnobotanical
Ghasemi PA, Momeni M, Bahmani M. 2013. Ethnobotanical study of medicinal plants used by Kurd tribe in Dehloran and Abadan districts, Ilam Province, Iran. Probl Medicol. 10(2):368–385.

Ghasemi PA, Alirezaual, Ghosta Y, Jarrahi A, Safavi SA, Abbas-Mohammadi M, Barba FJ, Munekata PE, Domínguez R, Lorenzo JM. 2020. Composition, antifungal, phytotoxic, and insecticidal activities of *Thymus kotschyanus* essential oil. Molecules. 25(5):1152–1170.

Ghasemi Pirbalouti A, Izadi A, Malek Poor F, Hamedi B. 2018. Chemical composition, antioxidant and antibacterial activities of essential oils from *Cuminum cyminum* L. Pharm Biol. 50(14):3943–3946.

Izadi Z, Mirzai N. 2020. Identification of chemical compounds and evaluation of antioxidant and antimicrobial properties of *salvia officinalis* L. essential oil at different harvest times. Qom Univ Med Sci J. 14(9):1–5.

Jahantab E, Hatami E, Sayyadian M, Salahi Ardakani A. 2018. Ethnobotanical study of medicinal plants of Boyer Ahmad and Dena regions in Kohgiluyeh and Boyer Ahmad province. Iran Adv Herb. 3:12–22.

Jalas J. 1982. Flora Iranica No. 150. New York: Springer; p. 536–538.

Jamzad Z. 1996. *Satyrea rechingeri* (Labiatae)—a new species from Iran. Ann Herb. 5:249–254.

Javan A. 2016. Combining effects of *Trachyspermum ammi* and *Zataria multiflora* Boiss essential oils on some pathogenic food-borne bacteria. Koomesh. 17:374–383.

Johri RK. 2011. *Cuminum cyminum* and *Carum carvi*: an update. Pharmacogn Rev. 5(9):63–72.

Kamal MH, Karbasi A, Mohamadzadeh SH. 2020. Marketing strategies and export of Iranian medicinal plants. J Med Plants Prod. 9:101–104.

Kavovit G, Purfard AM. 2013. Essential oil of *Ziziphora clinopodioides* – a new species from Iran. Ann Herb. 5:25–30.

Kazemi M, Dakhili M, Dadkhah A, Yasrebifar Z, Larijani K. 2011. Composition, antimicrobial and antioxidant activities of the essential oil of *Artemisia kermanensis* as a potential source of antioxidant and antimicrobial activities. J Agric Food Chem. 59(15):7150–7156.

Kazemi M. 2015. Chemical composition and antimicrobial, antioxidant activities and anti-inflammatory potential of *Aycaea millefolium* L., *Anethum graveolens* L., and *Carum cypoticum* L. essential oils. J Herb Med. 5(4):217–222.

Keshavarz A, Minaiyan M, Ghanadri A, Mahzoumi P. 2012. Effects of *Carum carvi* L. (caraway) extract and essential oil on TNBS-induced colitis in rats. Res Pharmac Sci. 8:1–10.

Khajehie N, Golmakani MT, Elbaghi M, Eskandari MH. 2017. Evaluating the effects of microwave-assisted hydrodistillation on antifungal and radical scavenging activities of *Oliveria decumbens* and *Chaerophyllum asiaticum* as antifungal agents. J Essent Oil-Bear Plants. 20(2):47–53.

Khajehie N, Golmakani MT, Elbaghi M, Eskandari MH. 2017. Evaluating the effects of microwave-assisted hydrodistillation on antifungal and radical scavenging activities of *Oliveria decumbens* and *Chaerophyllum asiaticum* as antifungal agents. J Essent Oil-Bear Plants. 20(2):47–53.

Khajehie N, Golmakani MT, Elbaghi M, Eskandari MH. 2017. Evaluating the effects of microwave-assisted hydrodistillation on antifungal and radical scavenging activities of *Oliveria decumbens* and *Chaerophyllum asiaticum* as antifungal agents. J Essent Oil-Bear Plants. 20(2):47–53.

Khajehie N, Golmakani MT, Elbaghi M, Eskandari MH. 2017. Evaluating the effects of microwave-assisted hydrodistillation on antifungal and radical scavenging activities of *Oliveria decumbens* and *Chaerophyllum asiaticum* as antifungal agents. J Essent Oil-Bear Plants. 20(2):47–53.
of barberry and Zataria multiflora Boiss. essential oil against some foodborne bacteria. J Kermanshah Univ Med Sci. 22(2):e83087–e83094.

Ji R, Zangi A, Amoli MA. 2016. Defining ROS in biology and medicine. React Oxygen Species (Apex). 1(1):9–21.

Mahmoudi S, Rezaei K, Golmakani MT, Sharifan A, Rezazadeh S. 2012. Pseudomonas aeruginosa. Herba Polonica. 63(3):18–24.

Mahboubi M, Kazempour N, Khameneh T, Fallah MH, Kermani MM. 2011. Chemical composition and antimicrobial activity of Rosca damascena Mill. essential oil. J Biol Active Prod Nat. 1(1):19–26.

Mahboubi M, Kazempour N. 2016. The antibacterial activity of Satureja khus-zestanica essential oil against clinical isolates of E. coli. Jundishapur J Nat Pharm Prod. 11(2):e30034–e30040.

Mahboubi M. 2016. Rosa damascena as holy ancient herb with novel applica-

Moazzami Farida SH, Ajani Y, Sadr M, Mozaffarian V. 2018. Ethnobotanical studies and their correspondence with phylogeny in Apiaceae–Apoideae. Res J Pharmacogn. 5:79–97.

Moein M, Zomorodian K, Almasi M, Pakshir K, Zarsheian MM. 2017. Preparatory and analysis of Zataria multiflora essential oil composition and antioxidant activity assessment. Iran J Sci Technol Trans Sci. 41(1):87–94.

Moghadam M, Mehdizadeh L, Mirzaei Najafgholi H, Ghasemi Pirbalouti A. 2018. Chemical composition and antibacterial activity of Zataria multiflora Boiss. essential oil and hydroalcoholic extract of Rhus coriaria L. J Food Qual Hazards Control. 6(1):16–24.

Mortez-Semnani K, Ahadi H, Hashemi Z. 2016. The genus Hymenocrater: a comprehensive review. Pharm Biol. 54(12):3156–3163.

Mohammadi Gholami AN, Shiravand S, Ebrahimi K. 2018. Chemical composition and antimicrobial activity of essential oil of Hymenocrater calycinus (Boiss.) Benth. J Essent Oil-Bear Plants. 15(5):708–714.

Motaghipishesh I, Kiss T, Tóth B, Cuspor D. 2020. The Prangos genus: a comprehensive review on traditional use, phytochemistry, and pharma-

Mozafarian V. 1996. Dictionary of Iranian plant names. Tehran, Iran.

Muhajeri F. 2019. Chemical composition and antifungal activity of essential oils and extracts. Biocatal Agric Biotechnol. 22:101407–101430.

Nabihi F, Mosadegh M, Mohammedi Matmed M, Ghorbani A. 2005. Labiatae family in folk medicine in Iran: from ethnomedicine to pharma-

Nasab FK, Khosravi AR. 2014. Ethnobotanical study of medicinal plants of Sirjan in Kerman Province. J Ethnopharmacol. 154(1):190–197.

Nasser M, Gholamhoammadzadeh S, Arrouiee H, Jaafari MR, Neamatlali H. 2016. Antifungal activity of Zataria multiflora essential oil-loaded solid lipid nanoparticles in vitro condition. Iran J Basic Med Sci. 19:1231–1237.

Newman DJ, Cragg GM. 2012. Natural products as sources of new drugs over the 30 years from 1981 to 2010. J Nat Prod. 75(3):311–335.

Nickavar A, Adeli A, Nickavar A. 2014. Analyses of the essential oil from Bunium persicum fruit and its antioxidant constituents. J Oleo Sci. 63(7):741–746.

Nouedeh GD, Sharififar F, Noodeh AD, Moshaﬁ MH, Afzal MA, Behravan E, Aref M, Sakhtianchi R. 2010. Antitumor and antibacterial activity of four fractions from Heracleum persicum Desf. and Cinnamomum zeylan-

Omidpanah N, Valiﬁd M, Emaeili M, Yousseﬁ R, Moghadam A. 2015. Antioxidant and antibacterial properties of the essential oils of two Iranian medicinal plants: Zumeria majdai and Salvia mizaryanii. J Adv Med Sci Appl Technol. 1(1):51–60.

Oroojalian F, Kasra-Kermanshahi R, Azizi M, Bassami MR. 2010. Phytochemical composition of the essential oils from three Apiaceae species and their antibacterial effects on food-borne pathogens. Food Chem. 120(3):765–770.

Owﬁ R, Safaian N. 2017. Overview of important medicinal plants at Fars province. Iran J Med Aromat Plants. 6:4–12.

Pan SY, Litscher G, Gao SH, Zhou SF, Yu ZL, Chen HQ, Zhang SF, Tang MK, Sun JN, Ko KM. 2014. Historical perspective of traditional indigenous medical practices: the current renaissance and conservation of herbal resources. Evid Based Complement Alternat Med. 2014:525340–525361.

Pauli A, Kubeckza KH. 2010. Antimicrobial properties of volatile phenolpro-

Pharmacological properties of herbal oil extracts used in Iranian traditional medicine. Adv Environ Biol. 6:153–164.

Miller HE. 1971. A simplified method for the evaluation of antioxidants. J Am Oil Chem Soc. 48(2):91–92.

Mirdelilani SZ, Barani H, Mahboubi M, Heshmati GA. 2011. Phytochemical composition of the essential oils from three Apiaceae species and their antibacterial effects on food-borne pathogens. Food Chem. 120(3):765–770.

Mozaffarian V. 1996. Dictionary of Iranian plant names. Tehran, Iran.

Munkivand H, Aghemiri A, Aghemiri A, Morshedloo MR, Nikoumanesh K. 2019. Ferulago angulata and Tetrataenia lasiopetalum: essential oils composition and antibacterial activity of the oils and extracts. Biocatal Agric Biotechnol. 22:101407–101430.

Norghad M, Mosadegh M, Mohammedi Matmed M, Ghorbani A. 2005. Labiatae family in folk medicine in Iran: from ethnomedicine to pharmacol-

Otrooji M, Ghasemi-Moghadam A. 2014. Antioxidant and antibacterial activities of the essential oils of two Iranian medicinal plants: Zumeria majdai and Salvia mizaryanii. J Adv Med Sci Appl Technol. 1(1):51–60.

Oroojalian F, Kasra-Kermanshahi R, Azizi M, Bassami MR. 2010. Phytochemical composition of the essential oils from three Apiaceae species and their antibacterial effects on food-borne pathogens. Food Chem. 120(3):765–770.

Owﬁ R, Safaian N. 2017. Overview of important medicinal plants at Fars province. Iran J Med Aromat Plants. 6:4–12.

Pan SY, Litscher G, Gao SH, Zhou SF, Yu ZL, Chen HQ, Zhang SF, Tang MK, Sun JN, Ko KM. 2014. Historical perspective of traditional indigenous medical practices: the current renaissance and conservation of herbal resources. Evid Based Complement Alternat Med. 2014:525340–525361.

Pauli A, Kubeckza KH. 2010. Antimicrobial properties of volatile phenolpro-

Pharmacological properties of herbal oil extracts used in Iranian traditional medicine. Adv Environ Biol. 6:153–164.
used to treat the most frequent diseases encountered in Ambalabe rural community, Eastern Madagascar. J Ethnobiol Ethnomed. 11:68–84.

Rao J, Chen B, McClements DJ. 2019. Improving the efficacy of essential oils as antimicrobials in foods: Mechanisms of action. Annu Rev Food Sci Technol. 10:365–387.

Rashidipour M, Ezatpour B, Talei GR, Pournia Y. 2016. Antifungal plants of Iran: an insight into ecology. Chemistry and molecular biology. Heidelberg, Berlin: Springer Publisher.

Rechia M, Farajpour M, Boroomand N, Solaimani-Sardou F. 2017. Ethnopharmacological studies of indigenous medicinal plants in the south of Kerman, Iran. J Ethnopharmacol. 199:194–204.

Rechinger K. 1982. Flora Iranica, Labiatae. Akad Druke-u Verlag. 150:

Rashedizadeh M, Shams-Ghahfarokhi M, Ramezani M. 2016. Synergistic properties of two Peruvian medicinal plants. J Ethnopharmacol. 145(3):686–698.

Rashedizadeh M, Shams-Ghahfarokhi M, Ramezani M. 2016. Synergistic properties of two Peruvian medicinal plants. J Ethnopharmacol. 145(3):686–698.

Razzaghi-Abyaneh M, Shams-Ghahfarokhi M, Rai M. 2013. Antifungal plants of Iran: an insight into ecology. Chemistry and molecular biology. Heidelberg, Berlin: Springer Publisher.

Rechia M, Farajpour M, Boroomand N, Solaimani-Sardou F. 2017. Ethnopharmacological studies of indigenous medicinal plants in the south of Kerman, Iran. J Ethnopharmacol. 199:194–204.

Rashedizadeh M, Shams-Ghahfarokhi M, Ramezani M. 2016. Synergistic properties of two Peruvian medicinal plants. J Ethnopharmacol. 145(3):686–698.

Razzaghi-Abyaneh M, Shams-Ghahfarokhi M, Rai M. 2013. Antifungal plants of Iran: an insight into ecology. Chemistry and molecular biology. Heidelberg, Berlin: Springer Publisher.

Rashedizadeh M, Shams-Ghahfarokhi M, Ramezani M. 2016. Synergistic properties of two Peruvian medicinal plants. J Ethnopharmacol. 145(3):686–698.

Razzaghi-Abyaneh M, Shams-Ghahfarokhi M, Rai M. 2013. Antifungal plants of Iran: an insight into ecology. Chemistry and molecular biology. Heidelberg, Berlin: Springer Publisher.
Zolfaghari MR, Jalali Yazdi A, Fatemi F. 2015. Effect of γ-irradiation on the antibacterial activities of Cuminum cyminum L. essential oils in vitro and in vivo systems. J Essent Oil-Bear Plants. 18:582–591.
Zomorodian K, Ghadiri P, Saharkhiz MJ, Moein MR, Mehriar P, Bahrani F, Golzar T, Pakshir K, Fani MM. 2015. Antimicrobial activity of seven essential oils from Iranian aromatic plants against common causes of oral infections. Jundishapur J Microbiol. 8(2):e17766.
Zomorodian K, Moein M, Pakshir K, Karami F, Sabahi Z. 2017. Chemical composition and antimicrobial activities of the essential oil from Salvia mirzayani leaves. Evid Based Complement Alternat Med. 22(4):770–776.