Chemical composition of the essential oils and extracts of *Achillea* species and their biological activities: A review

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A B S T R A C T

Ethnopharmacological relevance: The Asteraceae (*alt.* Compositae) family incorporates a large number of flowering plants, which have been classified under ca. 1600 genera covering more than 23,000 species. The genus *Achillea* is one of the best-known genera of this family. The *Achillea* species are important for their uses in the chemical and pharmaceutical purposes, and traditional and folk medicines. From ethnobotanical point of view, they heve been recommended as effective tonic, sedative, diuretic and carminative remedies and extensively prescribed for the treatment of stomachache, inflammation, gastrointestinal, hemorrhoid, hay fever, and wound healing in indigenous medicines. They are also known as effective remedies that promote breast-feeding s and regulate women menstruation. This review presents an overview on the ethnopharmacological knowledge of the *Achillea* genus and provides a deeper insight into medicinal and pharmaceutical applications of different *Achillea* species.

Materials and methods: Relevant data were obtained through systematic electronic searches from various scientific databases including the Institute of scientific information (ISI)-Web of Science, Google Scholar, Scopus, Pubmed, other relevant texts and local books.

Results: A variety of ethnopharmacological properties of the *Achillea* have been documented, and a broad spectrum of medicinal applications, and phytochemicals of the essential oils and extracts of this genus have been identified.

Conclusions: General correlations between the ethnopharmacological uses and medicinal properties identified through systematic research have been observed. Some of the medicinal properties could also be linked to the phytochemicals present in this genus. The findings of the studied reports in this review article represent therapeutic characteristics of a *Achillea* species and account for their significant impact on the current and future modern medicine.

Keywords: Essential oils, Extracts, GC-MS, *Achillea*, Biological activity, Phytochemical activity

1. Introduction

The genus *Achillea* is one of the most important genera in the Asteraceae (*alt.* Compositae) family comprising more than 100 species growing wild in different parts of the world, and with enthnopharmacological significance. Among them about 19 species are found in Iran, e.g., *A. aucheri* Boiss., *A. callichora* Boiss., *A. eriphora* DC., *A. kellalensis* Boiss., *A. oxyodonta* Boiss., *A. pachycephala* Rech.f. and *A. talagonica* Boiss. (Mozaffarian, 1996; Zargari, 1996). The *Achillea* species are endemic to North America, different parts of Europe, Eastern and Western Asia, Australia, New Zealand and Middle East regions. The main habitats of this genus are concentrated in different parts of Iran, Turkey, Serbia and Eastern regions of Europe (Mozaffarian, 1996; Başer, 2016).

The essential oils and extracts of the *Achillea* species exhibit antioxidant, antibacterial, antifungal, antimicrobial, and herbicidal activities, which have been described in detail in the later parts of this review. Essential oils (EOs) as secondary metabolites involve complex mixtures of natural compounds with versatile organic structures representing useful medicinal properties (Mohammadhosseini and Nekoei, 2014). They can be extracted from different parts of the plant materials using classical and advanced techniques (Mohammadhosseini, 2017). Hydrodistillation (HD) and steam distillation (SD) are among the most important traditional approaches to extract the EOs (Mohammadhosseini et al., 2011; Mohammadhosseini et al., 2013; Mohammadhosseini, 2015a). However, these laborious and time-consuming procedures often need larger amounts of samples and are not cost-effective. Therefore, development of alternative extraction techniques for isolation of EOs has always been felt essential. Over recent decades, some effective techniques have been introduced for fast separation and subsequent analysis of the EOs. Many of these techniques are based on application of microwave under different conditions (Hashemi-Moghaddam et al., 2014; Mohammadhosseini et al., 2015; Mohammadhosseini et al., 2016a; Mohammadhosseini et al., 2016b). These advanced

techniques are secure, fast, environmentally friendly, efficient and also can be conveniently automated (Mohammadhosseini and Nekoei, 2014; Hashemi-Moghaddam et al., 2015). On the other hand, plant extracts are separated from raw and dried samples using aqueous and organic solvents. It has been shown that the extracts obtained from different parts of the plants possess various phytochemicals and show activities against harmful pathogens (Mohammadhosseini, 2016; Mohammadhosseini et al., 2016b). The compositions of the EOs are greatly influenced by diverse parameters involving time and season of harvesting of the plants, type of the plant organs and the corresponding family, geographical and climatic conditions, physiological age, developmental stage, nutritional status of the plants, post-harvest drying, plant storages, genetic diversity, extraction methods, elemental structure of the sampling area, physicochemical variables related to the respective soils and also stress during the growth or maturity (Tabanca et al., 2011; Raut and Karuppayil, 2014; Mohammadhosseini, 2015b, a; Nekoei and Mohammadhosseini, 2016). Some comprehensive reviews covering some important aspects, e.g., the status, preparation methods, biological activities, potential use and processing of the EOs (Radulovic et al., 2007; Bakkali et al., 2008; Nemeth and Bernath, 2008; Adorjan and Buchbauer, 2010; Rubiolo et al., 2010; Lang and Buchbauer, 2012; Shaaban et al., 2012; Tranchida et al., 2012; Oliveira et al., 2014; Raut and Karuppayil, 2014; Sivakumar and Bautista-Banos, 2014; Tongnuanchan and Benjakul, 2014; Xiao et al., 2014; Calo et al., 2015; Herman and Herman, 2015; Zeng et al., 2015; Sarmento-Neto et al., 2016) are available to date. Moreover, advanced sample preparation in different disciplines of analytical sciences is specified considering some effective parameters involving simplicity, size dimension, higher yields and concentration factors, lower amounts of the samples, time and solvent, among others.

Many *Achillea* species are rich sources of flavones (Falk et al., 1975; Aljančić et al., 1999; Moradkhani et al., 2014), other flavonoids (Bruno and Herz, 1988; Tzakou et al., 1995a;

Batanouny et al., 1999; Al-Gaby and Allam, 2000; Ahmed et al., 2003; Si et al., 2006; Boudjerda et al., 2008; Nemeth and Bernath, 2008; Abdel-Rahman et al., 2015), guaianolides (Todorova et al., 1998; Glasl et al., 2003; Li et al., 2012a), lignans (Trifunović et al., 2003), non-saturated carboxylic acids (Abdel-Rahman et al., 2015), phenolic glycosides (Yassa et al., 2007), phthalate derivatives (Manayi et al., 2014), piperidine amides (Bruno and Herz, 1988), polyacetylenes (Nemeth and Bernath, 2008), proazulenes (Glasl et al., 1999), sesquiterpene lactone-diol (Farooq et al., 2012), sesquiterpene lactones (Si et al., 2006; Nemeth and Bernath, 2008), sesquiterpenes (Yang et al., 2005; Werner et al., 2007), sesquiterpenoids (Glasl et al., 1997), spirodepressolide (Todorova et al., 2004), tannins (El-Ashmawy et al., 2016), and triterpene alkamides (Nemeth and Bernath, 2008). The names or groups of some of the identified and isolated compounds from different *Achillea* species have been summarized in Table 1.

This review aims to integrate the findings from more than 300 papers published since 1985, dealing with the chemical analysis and pharmacological activities of various species of the *Achillea* genus. In Fig. 1, the geographical distribution map of different species of this genus has been shown and compared. The most frequent published reports on this genus were observed in different regions of Iran, Turkey, Serbia, Italy, Egypt, Greece and Kazakhstan countries.

2. Methodology

This review has been prepared based on a comprehensive survey of major scientific databases relating to the EOs, extracts and their biological activities on native or endemic species of the *Achillea* genus involving the Google Scholar, Scopus, Pubmed, Institute for Scientific Information-Web of Science (ISI-WOS; accession date: 03.06.2016 and revisited 01-04.01.2017), published journals in Elsevier, Springer, John Wiley, Taylor and Francis, botanical and local books over the past few decades (1985 - present).

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3. Historical, traditional and ethnomedicinal uses of the *Achillea* species

The history of the herbal medicine in Iran goes back to the Aryan era about 7000 years B.C. and the first manuscripts accounting for the possible use of medicinal plants in great civilizations of the world involving the ancient Iran, Egypt, Middle East, Greece, India and China date back to around 3000 years B.C. (Omidbaigi, 2012). The diversity and widespread climatic situations in Iran, China and India have allowed the presence of more than 100 endemic and unique species of medicinal plants having impressive pharmaceutical and biological activities. Among these species, the black pepper, saffron, nutmeg and poppy have gained a growing interest in the marketing and medicinal disciplines.

Avicenna as one of the most famous Iranian scientists authored the famous book entitled "Canon of Medicine" which is a comprehensive encyclopedia in medicine with a main focus on herbal medicines. In this valuable reference book which is still a reliable reference in many medicinal universities worldwide, more than 811 herbal species have been discussed in detail (Ghasemi, 2009). In Iran, similar to many other countries, there is an increasing rate to the usage of medicinal plants regarding the unpleasant chemical side effects of the synthesized drugs and the consequent environmental pollutions. Iran is among the seven Asian countries with the highest rate of use of medicinal plants. According to reliable statistical reports, there are more than 130 herbal drugs with the plant origins in Iran (Mozaffarian, 2012).

The plants of the genus *Achillea* gained fame owing to their pharmaceutical and medicinal properties and even their pollens were found along the tombs of *Homo neanderthalensis* era. The ancient Chinese people widely used these medicinal plants and called them "predictive stems" (Ghasemi, 2009). The people of ancient Greece extensively utilized them during the sequential wars. According to some previous resources, *Achillea* is also called "Achill", since the great Greek hero namely Achilles used this plant for curing soldier wounds in the battlefield. Most of the therupatic properties of these plants were identified by Greek plant

protectors. The considerable healing power found for different *Achillea* species can be attributed to the high occurrence of proazulenes in their chemical profiles (Benedek et al., 2008; Nemeth and Bernath, 2008). Concerning the most important species of this genus, *A. millefolium* L., the name *millefolium* represents 1000 leaves showing its folious branches (Zargari, 1996). The other name attributed to this plant is nose bleeding accounting for their potential to stop the unwanted bleeding from the nose. Similar cases have been reported in tropical treating of the rural people in different parts of the world. American Indians realized remedial properties of the *Achillea* and some of their tribes used different parts of these plants to treat wounds, sores and some injuries. They also employed the concerned decoctions to treat some diseases involving bleeding, fever and also for food digestion as well as general strengthening of the body. In American traditional medicine, these plants were prescribed to reduce inflammation and cure rheumatism. In some cases, they were suggested along with elderberry and mint as effective drugs against influenza and colds with fever (Omidbaigi, 2012).

Different species of the *Achillea* are called "Bumadaran" in Persian language and many reports are found highlighting their ethnopharmacological usage. In the Iranian and Turkish folk medicines, diverse species of this genus are widely used for a variety of purposes. These plants have been known as carminative, tonic, diuretic, and diaphoretic remedies. Additionally, in the Persian traditional nomenclature, these herbal plants have been widely recommended to treat rheumatic and visceral pain, pneumonia, emphysema and hemorrhage (Zargari, 1996). Moreover, these species have been recognized as powerful analgesic (Garcia et al., 1997; Abdel-Rahman et al., 2015), antipyretic (Garcia et al., 1997), spasmolytic (Delapuerta and Herrera, 1995; Benedek et al., 2007), digestive (Nemeth and Bernath, 2008), cytoprotective (Giorgi et al., 2009), anti-inflammatory (Kupeli et al., 2007; Zaidi et al., 2012), anti-neuroinflammatory (Elmann et al., 2011), antinociceptive (Karabay-Yavasoglu et al., 2007),

anthelmintic (Tariq et al., 2008), antispasmodic (Karamenderes and Apaydin, 2003), anti-ulcer (Kundakovic et al., 2000), and antihypertensive and antihyperlipidemic (Asgary et al., 2000) agents. Furthermore, they have been pointed out as potent remedies to address some human disorders including haemorrhoid (Jaric et al., 2007) and gastrointestinal (Bibi et al., 2015; Martkoplishvili and Kvavadze, 2015) disturbances. They can also be utilized as effective factors in wound healing (Agar et al., 2015).

The other properties attributed to different species of the *Achillea* genus include their remedial impacts in humidifying the surface of the dry skins as well as stimulanting the hair growth and blood coagulation (Shams-Ardekani and Mohagheghzadeh, 2014). Additionally, different species relating to this genus have been used as local healers in some shampoo formulations. They are also known as effective anti-cough and anti-dandruff remedies (Zargari, 1996). It should be noted that chewing of the fresh leaves of different species of these plants has been advised to relieve severe tooth pains. Meanwhile, some species of this herbal plant can noticeably reduce the amounts of vaginal discharges in women (Micozzi and Dog, 2004; Omidbaigi, 2012).

Some of the common traditional and ethnomedicinal properties in different species of this genus have been summarized in Table 2.

In the Iranian folk medicine, *A. millefolium* L. is known as an emmenagogue, and its crude extract exhibits an esterogenic activity which is on the basis of recombinant MCF-7 cell. It has been well-documented that among different bioactive compounds present in the extracts of this plant, luteolin V and apigenin VI represent the highest esterogenic activity. Of these two natural compounds, apigenin could be considered as an effective stimulant in the biological pathways of ERs-dependent which is lower than that of the endogenous hormone (Schulz et al., 2001).

In Persian references, some extracts of the *Achillea* genus or the respective powder samples have been characterized as potent agents to treat soft tissue and skin infections (Shariat-Samsam, 1992; Zargari, 1996).

The water-ethanol extract (1:1) of *A. wilhelmsii* Koch. Has been shown to exhibit an inhibitory effect on rat's gastric motility under both basal and vagal stimulated conditions (Niazmand and Khoshnood, 2011).

Duo to the diuretic property *A. millefolium* L., helps removal of kidney stones. In the past, it was also used to stop hair loss and to improve hair growth. It can also highly address gallbladder disorders. In addition, the cataplasm of *A. millefolium* L. is a good remedy against breast pain and headaches. The common modes of uses of *A. millefolium* L. in Iranian folk medicine are as follows.

i) One to three cups of its fresh infusions prepared from 10-20 g of its aerial parts or leaves in 0.5 liter of water.

ii) Fresh sap over the dose 50-100 g to improve wounds and hemorrhoids, daily.

iii) Tincture: 30-50 droplets, daily.

iv) 30-60 parts per thousand (ppt) to prepare lotions and for treating anemia

v) 20 g of *A. millefolium* L. essential oil + 45 g camphorate ointment to be rubbed on the painful rheumatism position.

vi) Boiling of 50 g portions of the plant sample in a tin to overcome intense itching (Hosseini-Rad, 2008; Afsharipour et al., 2013; Shams-Ardekani and Mohagheghzadeh, 2014).

In the Indian traditional medicine, *A. millefolium* L. has some common medicinal properties with the Iranian folk medicine. Apart from some similarities between these, this species is widely utilized as a flavouring agent in the preparation of salads, soups and fish. The powder of *A. millefolium* L. added to food stuffs can remove their unpleasant smell. In fact, in India *A. millefolium* L. has been shown to increase mucus discharge. It is also noteworthy that the cotton

cloths soaked in the homogenized paste of this species have found remedial applications for toothache (Anonymous, 1985; Shawl et al., 2002; Rao et al., 2015) .

In some references, the potential use of some species of the *Achillea* has been implied to treat dysentery which was the main death-causing factor among the soldiers within the past centuries (Ross and Press, 2003).

In different geographical areas of Europe and American continent including some parts of Spain, Southern Colorado and New Mexico, the local name attributed to the most common species of this genus, namely *A. millefolium* L. is "plumajillo" representing "little feather", more specifically due to the particular shape of the concerned leaves. Notably, the native people of the the American continent and the early immigrants believed in its high astringent qualities and frequently employed *A. millefolium* L. as a proper abortifacient, emmenagogue, anti-bleeding and contraceptive herbal drug (Dodson and Dunmire, 2007). A literature survey shows that *A. millefolium* L., as the most famous species of the *Achillea* genus, has remarkable medicinal properties and for this reason it has been included in the national Pharmacopoeias of some European countries including France, Germany, England, Czech Republic and Switzerland (Saeidnia et al., 2011).

In the Anatolia region, the dominant plant coverage comprises different species of the *Achillea* genus, specifically *A. biebersteinii* Afan. And *A. millefolium* L. species. In fact, the flora of Turkey involves most of the *Achillea* species. *A. millefolium* L. growing wild in Turkey can improve colds, ulcer, and diarrhea. The other properties attributed to this species are diuretic, emmenagog, appetizer, carminative, and insecticidal features (Baytop, 1994; Honda et al., 1996; Tuzlacı and Erol, 1999; Sezik et al., 2001; Ezer and Arisan, 2006; Cakilcioglu et al., 2011). The traditional potential use of the herbal teas from these plant species have been mentioned in the treatment of flatulence and abdominal pain in Turkey (Saeidnia et al., 2011). In Northern Greece, *A. millefolium* L. is used for the preparation of herbal tea as well as the

production of lotions and ointments which are specifically prescribed for external uses (Chatzopoulou et al., 1992). Regarding the traditional Chinese medicine (TCM), the *Achillea* plants always possess three main medicinal characteristics involving diaphoretic, tonic and anti-hypertention behaviors (Ross and Press, 2003). In this direction, *A. wilsoniana* Heimerl ex Hand.-Mazz is highly used for the detoxification, hemostasia and is also known as an aphrodisiac drug (Xie and Yu, 1996; Yang et al., 2005).

The potential cytotoxic and antiulcer properties of these herbal drugs could be attributed to the presence of some secondary metabolites involving different classes of terpene compounds, phenolic, flavonoid, sterol and coumarins. More importantly, these medicinal behaviors are often related to those species having constituents with some immunomodulatory properties. It should be also noted that the anti-inflammatory activities of these plants could be justified considering diverse sesquiterpenes and alkamides in the corresponding chemical profiles (Mohammadhosseini, 2016).

In the Sicilian folk medicine, *A. ligustica* All. has been recommended to treat stomachache. Moreover, it's infusions can relief gastralgia and neuralgia. This valuable species is also known as a haemostatic plant, a cataplasm against rheumatism and for skin disorders in the Southern Italy (Table 2). In addition, sap of *A. ligustica* All. is traditionally prescribed as a proper anthelmintic agent in Sicily (Bruni et al., 1997; Viegi et al., 2003; Bader et al., 2007). Meanwhile, it can be mixed with some additives, e.g. garlic, beet, eggs, borage and cheese to prepare an energetic soup. This tonic soup is highly recommended for men and children during times of high activity (Cornara et al., 2014). According to Maffei (1989), *A. wilhelmsii* Koch. can be used for treating gastrointestinal disorders in different parts of Italy.

In Corsica (Table 2), *A. ligustica* All. is used in cataplasms to relief sprains and insect bites. It can also address haemorrhages (Muselli et al., 2009). In Arab countries located in the Middle East (Jordan, Egypt and Palestine), *A. fragrantissima* (Forssk.) Sch. Bip. is used as an

antiseptic, antipyretic and carminative herbal drug, and has a reputation for the preparation of antidiuretic drinks and for reducing fever, as well as improving nervous disorders (Boulos, 1983; Barel et al., 1991; El-Shazly et al., 2004; Abdel-Rahman et al., 2015), while *A. santolina* L. is a depurative herbal drug and frequently utilized for addressing intestinal colics, dysentery and for the repulsion of annoying insects (Alkofahi et al., 1996; Alkofahi et al., 1997; Al-douri, 2000). This species (*A. santolina* L.) has effective toothache properties in North Africa, as well (Boulos, 1983).

Moreover, in South-Western Morocco (Table 2), *A. ageratum* L. has been advised to treat stomach and gastrointestinal disorders and exhibits considerable cytostatic, anti-inflammatory, analgesic, and antipyretic effects (El Bouzidi et al., 2012).

In Pakistan (Said, 1982; Yaeesh et al., 2006), *A. millefolium* L. has been recognized as a diaphoretic and stimulant medicinal plant which can treat various liver diseases (see Table 2). It is also a good remedy for gynecological disorders, lung cancer, rheumatism, fever, cardiopathy, migraine, dizziness, menstrual regularity and headache (Ahmad et al., 2016).

In Kazakhstan, *A. filipendulina* Lam. has been presented as an abortifacient agent and its decoctions are used to improve gastrointestinal malfunctions (Sadyrbekov et al., 2006).

4. Results and discussion

4.1. Chemical composition of the EOs and extracts of the Achillea genus

Many reports could be found representing chemical compositions of the EOs and extracts from different members of the genus *Achillea* growing wild worldwide. One of the main goals of this review is to give an overview on the chemical and structural diversities of the compositions of the EOs and extracts from a large number of native or endemic plants species in the genus *Achillea*. For this reason, we have systematically reviewed the respective articles reported over the past three decades. In Table 3, the most abundant constituent components of the EOs and extracts relating to different species of this genus have been listed. Moreover, the percentage

yield of the EO, characterization methods, plant organs, dominant group of the natural compounds in each profile, sampling area, number and total percentage of the identified chemical profiles have been pointed out. This genus has broad habitats in the world and approximately the composition of the respective EOs or extracts isolated by different classical and advanced methods highly consists of oxygenated monoterpenes. The most encountered components of this genus are camphor, 1,8-cineole (eucalyptol), *cis* and *trans*-sabinene hydrate, borneol, α-thujone, β-thujone, linalool and α-terpineol (see Table 3). However, some of the other oxygenated monoterpenes like lavandulol (Kokkalou et al., 1992), *cis*-piperitol (Baser et al., 2000), *trans*-*p*-menth-2-en-1-ol (Baser et al., 2000; Simic et al., 2000), *cis*-*p*-menth-2-en-1-ol (Baser et al., 2000; Simic et al., 2000), and chrysanthenone (Chalchat et al., 2000; Benelli et al., 2015) have been characterized among the prevailing constituents of some reported profiles in the literature. The molecular structures of the most frequently occurring oxygenated monoterpenes in the chemical profiles of the EOs and extracts of *Achillea* species are shown in Fig. 2. On the other hand, regarding the reports highlighting the profiles of the EOs or extracts of this genus, monoterpene hydrocarbons, sesquiterpene hydrocarbons, oxygenated sesquiterpenes and non-terpene hydrocarbons are less common compared to the frequency of the oxygenated monoterpenes. Chemical structures of the most prevailing natural compounds (MH, SH, OS and NH groups) in the given categories of Table 3 have been demonstrated in Fig. 3, 4, 5 and 6.

4.2. Biological and immunological activities

In view of the ethnopharmacological significance of the *Achillea* species, numerous phytochemical and pharmacological investigations have been conducted to date. In this review, we aim to outline the biological and pharmacological activities of the different species of this genus. These mainly include potential antifungal, herbicidal, larvicidal and insecticidal, antibacterial and/or antimicrobial, antioxidant, immunological, anti-inflammatory and

antinociceptive, genotoxicity, antiproliferative, anxiolytic, anti-platelet, anti-ulcerogenic properties and activities (Fig. 7).

4.2.1. Antibacterial activities

The antibacterial activity of the EOs and extracts are considerably sensitive to the factors like concentration, the family, genus, species of the plant of interest, the climatic conditions of the sampling area, and the polarity of the extracting solvents as well as the bacterial strains being used (Khaled-Khodja et al., 2014; Mohammadhosseini et al., 2016a). The antibacterial activities of the EOs and extracts from different parts of the *Achillea* species are shown in Table 4 which are often evaluated using inhibition zone diameter (IZD) and minimum inhibitory concentration (MIC) approaches. In some cases, the minimum bactericidal concentration (MBC) or the bacteriostatic concentration is stated, both terms agreeing closely with the general meaning of the MIC term (Burt, 2004). To evaluate antibacterial activities basing on dilution in the agar medium, different solvents have been utilized to incorporate the EOs or extracts. In addition, different volumes of inoculum have been employed which either dotted or streaked onto the agar surface in such types of studies.

A detailed list of *in vitro* antibacterial activities involving IZDs (in mm), MICs and MBCs against a broad set of Gram-positive and Gram-negative bacterial strains for different EOs and extracts of the *Achillea* plants is presented in Table 4. According to this table, it rapidly becomes apparent that the majority of these plants exhibit moderate to strong antibacterial characteristics.

4.2.2. Antifungal activities

Fungi and bacteria can exert unpleasant impacts on the quality, safety and preservation of food samples and products resulting in their spoilage. According to the report of Kordali et al. (2009), the EOs and extracts of two species of *Achillea*, namely *A. gypsicola* Hub-Mor. and *A. biebersteinii* Afan. have shown moderate to strong antifungal activities against 12

phytopathogenic fungi. This study was conducted using a contact assay (*in vitro*), capable of hyphal growth inhibition production. In this report, potato dextrose agar (PDA) plates containing DMSO-water solution (1.0%, v/v), without the EO or the hexane extract solutions were used as negative control, while PDA plates treated with benomyl (20.0 mg/Petri dish or 1000 mg/l concentration) were utilized as a positive control. Compared to the extracts, the EOs of these two species were found to be more effective against the fungi with the exception of *F. graminearum* and *F. equiseti*. This study also revealed that of the two studied EOs, the oil of *A. gypsicola* Hub-Mor. was more effective than that of *A. biebersteinii* Afan. oil. However, unlike the EOs, the hexane extracts of the flowers of these species showed weak or no inhibitory effects on the growth of the tested fungi.

In another report, the antifungal activity of the EO of *A. atrata* and 1,8-cineole were evaluated against 18 micromycetes (Ristic et al., 2004). A concentration of 2.0 µl/ml of *A. atrata* oil inhibited the growth of *P. helianthi* and *T. mentagrophytes*, whilst a concentration of 3.0 µl/ml inhibited growth of *C. cladosporioides*, *T. rubrum* and *T. tonsurans*. Moreover, *A. alternata*, *A. ochraceus*, *A. niger* and *A. terreus* were inhibited by 4.0 µl/ml of this oil. The growth of *A. flavus* and *A. versicolor* was inhibited by 5.0 µl/ml of oil, whilst dermatomycetes *M. canis*, *M. gypseum* and *E. floccosum* were inhibited by 6 µl/ml of oil. In this attempt, the oils of *T. viride*, *P. ochrochloron* and *P. funiculosum* all having an MIC of 7 µl/ml were reported as the most resistant fungi. As discussed, higher antifungal activity of 1,8-cineole could be attributed to higher diffusion capacity of this compound through the agar medium. In a related study, five EOs separated from the aerial parts of *A. biebersteinii* Afan. were subsequently evaluated for their antifungal activity against the strawberry anthracnose-causing fungal plant pathogens, namely *C. acutatum*, *C. fragariae* and *C. gloeosporioides* using the direct overlay bioautography assay (Tabanca et al., 2011). The EOs showed no antifungal activity at 80.0 and 160.0 µg/spot. In a search for novel antifungals from natural sources, EOs and extracts of forty-

nine medicinal plants were studied against an aflatoxin (AF)-producing *A. parasiticus* NRRL 2999 a known producer of AFs of the B and G series using a microbioassay technique and the AF levels were subsequently measured in culture broth by using high performance liquid chromatography (Alinezhad et al., 2011). It was found that *A. millefolium* subsp., markedly inhibited *A. parasiticus* growth (IC_{50}=35.0 µg/ml) without affecting AF production by the fungus. This study offered a deeper insight into explaining the possible use of these plants as effective antimicrobial candidates to protect foods from toxigenic fungus growth and subsequent AF contamination.

Similar results were also reported in the literature representing high sensitivities of diverse species of *Achillea* against many of fungal strains, e.g., *A. alternate* (Ristic et al., 2004), *A. fumigatus* (Bezic et al., 2003; Bekhechi et al., 2011; Falconieri et al., 2011), *A. niger* (Bezic et al., 2003; Ristic et al., 2004; Stojanovic et al., 2005; Falconieri et al., 2011), *C. albicans* (Barel et al., 1991; Magiatis et al., 2002; Unlu et al., 2002; Bezic et al., 2003; Candan et al., 2003; Sokmen et al., 2003; El-Shazly et al., 2004; Sokmen et al., 2004; Stojanovic et al., 2005; Tuberoso et al., 2005; Iscan et al., 2006; Bader et al., 2007; Karamenderes et al., 2007; Maggi et al., 2009; Tzakou et al., 2009; Turkoglu et al., 2010; Falconieri et al., 2011; Kucukbay et al., 2011; Radulovic et al., 2012; Albayrak, 2013; Kazemi and Rostami, 2015; Turkmenoglu et al., 2015; Fahed et al., 2016), *C. glabrata* (Magiatis et al., 2002; Al-Snafi, 2013), *C. krusei* (Candan et al., 2003; Sokmen et al., 2003; Falconieri et al., 2011; Turkmenoglu et al., 2015), *C. herbarum* (Bekhechi et al., 2011), *C. kefyr* (Ghasemi et al., 2008), *C. krusei* (Candan et al., 2003; Sokmen et al., 2003; Falconieri et al., 2011; Turkmenoglu et al., 2015), *C. parapsilosis* (Falconieri et al., 2011; Turkmenoglu et al., 2015), *C. tropicalis* (Magiatis et al., 2002; Demirci et al., 2009; Falconieri et al., 2011; Kucukbay et al., 2011; Turkmenoglu et al., 2015), *F. oxysporum* (Tuberoso et al., 2005), *S. cerevisiae* (Albayrak, 2013), *T. mentagrophytes* (Ristic et al., 2004; Falconieri et al., 2011; Fahed et al., 2016), *T. rubrum* (Ristic et al., 2004; Falconieri

et al., 2011; Fahed et al., 2016), *T. soudanense* (Fahed et al., 2016), *T. tonsurans* (Ristic et al., 2004; Fahed et al., 2016) and *T. violaceum* (Fahed et al., 2016). The results of the antifungal activities of the EOs and extracts of some species of the *Achillea* are summarized in Table 5. Moreover, among the EOs from three species of *Achillea* (*A. biebersteinii* Afan., *A. teretifolia* Willd. and *A. vermicularis* Trin.), the highest fumigant toxicity was observed for *A. biebersteinii* Afan. collected from Mt. Ararat, Turkey (36.64 ± 0.12%). However, the tested EOs showed low insecticidal fumigant toxicity against *Lemna minor* and *S. granarius* (Polatoglu et al., 2013).

4.2.3. Herbicidal effects

In the recent report by Kordali et al. (2009) concerning the potential impact of the EOs and hexane extracts of *A. gypsicola* Hub-Mor. and *A. biebersteinii* Afan. from Turkey on seed germination and seedling growth of *A. retroflexus*, *C. album*, *C. arvense*, *L. serriola* and *R. crispus*, a broad range of inhibitory activities was observed compared to control groups (Table 6). Among these five important weeds, the seed germination and seedling growth of three ones (*A. retroflexus*, *C. arvense* and *L. serriola*) were greatly affected by the corresponding EOs. Furthermore, the EO of *A. gypsicola* Hub-Mor. increased the germination of *C. album*, whereas it was found to be ineffective on the germination of *R. crispus*. However, the oil of *A. biebersteinii* Afan. exhibited a suppressing influence on the germination of *C. album* and similarly to the EO of *A. gypsicola* Hub-Mor., no significant inhibitory effect was noted against the germination of *R. crispus*, while the germination of both weeds was rapidly suppressed in the presence of the EOs of *A. gypsicola* Hub-Mor.

On the other hand, compared to the herbicidal effects of the EOs, non-polar extracts of the two species of *Achillea* showed low herbicidal effect against the tested weeds. It should be noted that germination and seedling growth of *A. retroflexus*, *C. arvense* and *L. serriola* was inhibited by the extracts. In spite of considerable reduction in seedling growth of *C. album* and *R. crispus*,

the respective germination was not significantly impressed by the organic extracts. Regarding these results, it was concluded that the EOs were more effective herbicidal agents than the hexane extracts of *A. gypsicola* Hub-Mor. and *A. biebersteinii* Afan. A perusal of the chemical profiles of the EOs and extracts of these two species reveals that the great differences in the herbicidal activities of the oils and extracts could be attributed to their major natural compounds constituting groups. In this regard, the profile of the EOs was characterized by high frequency of oxygenated monoterpenes, while that of the extract was dominated by high amounts of non-terpene hydrocarbons. This observation is in agreement with previous investigations in the literature (Angelini et al., 2003; Zunino and Zygadlo, 2004; Kordali et al., 2008).

4.2.4. Larvicidal and insecticidal activity

The general toxicity effects of the EOs highly relate to the corresponding plant species. The performance of the plant extracts or volatile oils as larvicidal agents is of great interest, as well. In a report on the larvicidal activity of the major components (1,8-cineole, camphor and *p*-cymene) of the EOs of *A. biebersteinii* Afan., 1,8-cineole, camphor and *p*-cymene exerted mortalities 63.4% ± 0.58 and 40.0% ± 0.0 (at 500 and 250 ppm); 50.0% ± 0.71 and 20.0% ± 0.0 (at 250 and 125 ppm); 90.0% ± 0.71 ppm and 0% ±0 (at 125 and 62.5 ppm), respectively (Tabanca et al., 2011). Accordingly, these pure natural compounds independently had significantly weaker larvicidal activities than the unfractionated EO, implying that minor compounds are probably the active principles responsible for the observed *Ae. aegypti* larvicidal activity.

In another study, laboratory bioassays on insecticidal activity of the EOs separated from *A. millefolium* L. Mediterranean plant were carried out against the larvae of the Culicidae mosquito *Ae. albopictus* (Conti et al., 2010). The insecticidal activities of the tested oils showed differences in mortality rates as a function of both oil and dosage. At the concentration of 300

ppm as the highest dosage used, the EO of *A. millefolium* L. resulted in higher mortality than the other three oils having mortality rates of 98.3%. The insecticidal effects of the EOs from the aerial parts of *A. gypsicola* Hub-Mor. were assessed at 5.0, 10.0 and 20.0 µl/l air concentrations. In this study, all the samples were toxic against adults of *B. dentipes* and caused complete mortality after 30 h of exposure (Tozlu et al., 2011). It was also realized that the mortality increased with increasing doses and exposure times of the studied EOs. In fact, remarkable toxicities of the EOs of the *Achillea* species against a wide spectrum of insect species could be referred to the high prevalence of oxygenated monoterpenes involving camphor, 1,8-cineole, borneol, and bornyl acetate (Calmasur et al., 2006; Kordali et al., 2006). The toxicity and subsequent repellent activity of *A. millefolium* L. EOs have been examined against *S. zeamais* Motsch. (Coleoptera Dryophthoridae) using specific bioassays (Bertoli et al., 2012). Accordingly, the mortality rate was about 64.6% and the obtained results represent considerable repellent activity toward *S. zeamais* adults. In addition, the composition of the oil mainly consisted of 1,8-cineole (14.2%), β-pinene (12.0%) and camphor (6.1%). The significant insecticidal activity observed was most probably owing to the ingredient blend and also the presence of minor constituents. Khani and Asghari (2012) have tested volatile toxicity of the EOs from the aerial parts of *A. wilhelmsii* Koch. against two stored-product insects, the flour beetle, *T. castaneum* Herbst (Coleoptera: Tenebrionidae) and the cowpea weevil, *C. maculatus* F. (Coleoptera: Bruchidae). Taking into account the numerical values of 50% lethal doses (LC_{50}) and fumigant toxicities of this report, the oil showed a strong insecticidal activity against *C. maculatus* (LC_{50}= 2.65 µl/l air) and *T. castaneum (*LC_{50}=10.02 µl/l air). In addition, all of the EOs from three species of *Achillea* (*A. biebersteinii* Afan., *A. vermicularis* Trin. and *A. teretifolia* Willd.) in Turkey showed high insectidal contact toxicities against *S. granarius* (Polatoglu et al., 2013). Of these three oils, the highest contact toxicity was observed for *A. biebersteinii* Afan. collected from Mt. Ararat (100.00 ± 0.00%) at a concentration of 0.2 µl/ml

in comparison to the other oil samples. Moreover, the insecticidal and repellence activities of the oils of the *Achillea* genus have been well-documented in some other reports (Nenaah, 2014b; Kesdek et al., 2015; Song et al., 2016).

4.2.5. Antioxidant activity

Antioxidants can protect cells against oxidative stress mainly caused by the active free radicals in human beings, and they have been considered as powerful remedies to improve plant defense responses (Espinoza et al., 2013). The oxidative stress plays a key role in the etiology of a variety of diseases and metabolic disorders. The natural compounds extracted from different parts of plant materials are of vital importance to maintain health, reinforce the human immunity system and prevent diseases (Bessada et al., 2015; Chang et al., 2016). In Table 7, the results of the investigations concerning the assessment of the antioxidant activities of the EOs and extracts of some species of the genus *Achillea* are shown. For this purpose, well-known antioxidant assays including 1,1-diphenyl-1-picrylhydrazil or 2,2-diphenyl-1-picrylhydrazil (DPPH), Fe^{3+}-EDTA-H_2O_2 deoxyribose (hydroxyl radical scavenging activity: FEHD or HRSA), inhibition of lipid peroxidation assay (ILPA), inhibition of superoxide radicals assay (ISRA), inhibition of hydroxyl radicals (IHRA), phosphomolybdenum (PM), ferric thiocyanate (FTC), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS), β-carotene-linoleic acid bleaching assay (BCLBA), chemiluminescence assay (CLA) were utilized. In some of these studies, satisfactory IC_{50} values were reported which were even less than those of some synthetic or natural antioxidants (Candan et al., 2003; Sokmen et al., 2004; Jianu et al., 2015; Kazemi, 2015c, b; Milutinovic et al., 2015; Turkmenoglu et al., 2015; Venditti et al., 2015).

4.2.6. Immunological investigation

In the study conducted by Saeidnia et al. (2004), BALB/c albino female mice (17-22 g) were used as experimental animals, which were fed under a standard pellet diet and water, and

maintained in the conditioned rooms under the regular light and temperature. The mice were then classified into seven groups. The test groups received oils of *A. talagonica* Boiss. and *A. millefolium* L. intraperitoneally in safe doses of 0.05, 0.1, 0.2 and 0.4 g/kg body weight daily for six days, while the control group was treated with 0.5 ml of (2:8) DMSO in normal saline (NS), and the native group received nothing. In the different groups of mice, the potential impacts of the EOs on anti-SRBC (sheep red blood cells) haemagglutinating antibody titer (HA) were studied. According to the obtained results, the oil of *A. millefolium* L. markedly decreased the anti-SRBC antibody titer in a dose dependent manner. Moreover, by increasing the dosage, a significant decrease in the antibody titer was noted, whereas no decrease in the anti-SRBC titer of mice treated with the oil of *A. talagonica* Boiss. was observed. The considerable suppression of the primary humoral immune responses in mice with the volatile oil of *A. millefolium* L. may be attributed to the occurrence of proazulene or possibly other sesquiterpenes in the corresponding chemical profile which were not detected in *A. talagonica* Boiss oil.

4.2.7. Anti-inflammatory and anti-nociceptive activities

The EOs of *A. schischkinii* Sosn. and *A. aleppica* DC. subsp. *aleppica* were evaluated for their *in vivo* anti-inflammatory and anti-nociceptive activities (Iscan et al., 2006). For the determination of anti-nociceptive activity in mice, the inhibitory effects of the oils on *p*-benzoquinone-induced writhing was followed, while to assess the anti-inflammatory characteristics of the two EOs, carrageenan-induced hind paw edema model was utilized as a widely used screening protocol. As shown in this investigation, *A. schischkinii* Sosn. oil did not exhibit any noticeable anti-inflammatory activity. However, the oil of *A. aleppica* DC. subsp. *aleppica* exerted significant activity (in 200 mg/kg dose) over the inhibition range of 22.9%-23.8% within 270-360 min., without inducing any apparent acute toxicity or gastric damage as compared to indomethacine, the reference drug having an activity at the inhibition

range of 31.3-42.8% (90-360 min). The antinociceptive or analgesic activities of the EOs as well as aqueous and methanol extracts of some species from the *Achillea* genus have been discussed in the literature. In one study using PBQ-induced writhing model in mice, *A. aleppica* DC. subsp. *aleppica* oil inhibited the writhes but was not as potent as acetylsalicylic acid. The aqueous and methanol extracts of *A. ageratum* L. have been evaluated for analgesic and anti-inflammatory properties. The aqueous extract exhibited significant activity in the analgesic and anti-inflammatory assays (Garcia et al., 1997). Moreover, a tincture of *A. collina* showed anti-nociceptive activity in 250 mg/kg (Gherase et al., 2001). Sesquiterpene lactones isolated from *A. setacea* (Zitterleglseer et al., 1991) and a germacrane derivative isolated from *A. pannonica* Scheele (Sosa et al., 2001) showed good anti-inflammatory activity. In some of the other similar reports, the anti-nflammatory (Saratikov et al., 1986; Karabay-Yavasoglu et al., 2007; Kupeli et al., 2007) and anti-nociceptive (Karabay-Yavasoglu et al., 2007; Kupeli et al., 2007; Pires et al., 2009; Radulovic et al., 2012; Radulovic et al., 2015) properties have also been evaluated.

4.2.8. Genotoxicity

de Sant'Anna et al. (2009) reported the genotoxicity of the EO of *A. millefolium* L. at concentrations of 0.13, 0.19 and 0.25 µl/ml using a heterozygous diploid strain of *A. nidulans*, namely A757//UT448, with green conidia. In accordance with this study, a statistically significant increasing number of yellow and white mitotic recombinants, per colony, of the diploid strain were reported after the oil treatments at concentrations of 0.19 µl/ml and 0.25 µl/ml. The results of this attempt indicate that the genotoxicity of the oil is related to the induction of mitotic non-disjunction or crossing-over of the oil.

4.2.9. Antiproliferative activity

The anti-proliferative activities of EO of *A. ligustica* All. were tested by Maggi et al. (2009). This study was conducted on a selection of tumour cell lines by using the 3-(4,5-

dimethylthiozol-2-yl) 2-5-diphenyl-tetrazolium bromide (MTT) assay. In this report, three human cell lines e.g., glioblastoma multiforme cell line (T98G), a squamous carcinoma cell lines (A431) and a prostatic adenocarcinoma cell line (PC-3) along with a murine cell line (melanoma cell line (B16-F1)), were treated with different concentrations of the EOs from the flowers and vegetative parts (stems/leaves) of *A. ligustica* All. and the respective effects on cell proliferation were recorded after 24, 48, and 72 h. The results of this study revealed the activity of the aforementioned EOs against all of the tested four tumour cell lines. However, the determined anti-proliferative activity for the flower oils of *A. ligustica* All. was significantly higher than that of vegetative parts from statistical point of view. This finding is highly correlated with stronger antioxidant activity of the oils obtained from the flowers in comparison with the vegetative EO of *A. ligustica* All.

4.2.10. Anxiolytic properties

In the literature, only afew papers could be found dealing with the anxiolytic/genic behavior of the EOs and organic extracts of different *Achillea* species signifying acute intoxication (Shetty Akhila and Alwar, 2007). Practically speaking, antiaxiety or hypno-sedative agents are immensely employed to manage stress. Since the continuous use of these agents has some serious drawbacks, it seems logical to introduce safer natural products extracted from medicinal plants as proper alternative choices. The mean value of the LD_{50} term of this work was reported as 853 mg/kg confirming the toxicity of the EO.

4.2.11. Anti-platelet activity

Recently, the antiplatelet activity of the EO of *A. biebersteinii* Afan. has been pointed out in human whole blood, *in vitro*. After preliminary steps, blood was withdrawn using vacutainer containing 3.8% of sodium citrate (9:1 v/v) as the control group (Al-Jaber et al., 2014). After diluting the blood in normal saline and dissolving the EO with a final concentration of 2.0 µg/ml, distinct volumes of the oils (5-30 µl) were transferred to a standard cuvette having the

diluted whole blood. In the next step, the mixture was incubated at 37°C for 4 min. prior to the addition of adenosine diphosphate (ADP: 10 μM) or collagen (2.0 μg/ml). Finally, the platelet aggregation was determined by a whole blood Chrono-log 700 lumi-aggregometer using an electrical impedance method as a change in impedance over 6 min. after the addition of the inducers through comparison with that of a control group impedance. In this study and in the absence of the EO, ADP and collagen induced an entire platelet aggregation (100%), while in the presence of the EO of *A. biebersteinii* Afan., strong dose-dependent inhibition of platelet aggregation was noted using ADP (10 μM) and collagen (2.0 μg/ml).

4.2.12. Anti-ulcerogenic potential

The anti-ulcerogenic activity of the *A. fragrantissima* (Forssk.) Sch. Bip. extracts was tested using an acetic acid-induced colitis model (Abdel-Rahman et al., 2015). In this investiogation, non-polar and polar extracts of the plant were obtained by successive foliar extraction using $CHCl_2$:CH_3OH (1:1) and an aqueous solution of CH_3OH (70% v/v). The model was capable of integrating many histologic features of ulcerative colitis in humans including mucosal edema, leukocyte infiltration of the mucosa and submucosal ulceration (Benedek et al., 2007). The anti-ulcerogenic effect was further confirmed by histological preservation of the colon and gastric architecture. To test the anti-ulcerogenic potential, all rats were treated with different doses of the plant extracts (non-polar and polar) and were found alive during the 48 h of observation indicating an extract LD_{50} higher than 4000 mg/kg (Abdel-Rahman et al., 2015). Since substances possessing LD_{50} greater than 50 mg/kg are classified as non-toxic (Osweiler et al., 1985) materials, the tested plant extract can be categorized as a benign one.

5. Conclusion

The Asteraceae is one of the most important families in the flora of different countries, which contains a large number of genera and species. This broad family consists of a wide range of aromatic, annual or perennial herbs, sub-shrubs, or shrubs, which are of economical

importance. The genus *Achillea* has been well-known for its diversity, frequency and pharmaceutical uses in traditional and folk medicine since the ancient time. From ethnobotanical approach, the species belonging to this genus have been widely prescribed in different traditional and folk medicines from long times ago. The origin of this genus name historically dates back to the mythical Greek hero, Achilles when using these plants for healings of the wounded soldiers. Fortunately, most of these plants have rich literature data. However, new aspects of their diverse biological activities are still encountered in the recently published reports. In fact, the majority of the performed researches on characterization, biological activities and isolation of bioactive compounds are referred to the Middle East and some countries in Europe. A brief survey reveals that Iran, Turkey, Serbia, Italy, Egypt, Greece and Kazakhstan have the highest records in this area, respectively. As discussed earlier, promising remedial characteristics have been attributed to a wide variety of the *Achillea* species in different regions of the word. Regarding the vital functions of many *Achillea* species in the treatment of severe diseases involving rheumatism, skin disorder, neuralgia, abdominal pains, inflammation, cold, cough, ulcer, epilepsy, flatulence, colic, heartburn, hysteria, stomachache, etc., they have been included in most of Pharmacopoeias. In this relation, European and British Pharmacopoeia involves *Achillea* plants, specifically the most famous species of this genus, namely *A. millefolium* L. (Anonymous, 2001, 2008).

In the first phase of this pervasive review, chemical composition of the EOs and volatiles from different species of the genus *Achillea* were compared with each other over a 31-year period. With respect to the published papers within this timeframe, it can be concluded that most of the EOs or volatiles separated from different organs of a large number of *Achillea* plants are rich sources of oxygenated monoterpenes including camphor, 1,8-cineole (eucalyptol), *cis* and *trans*-sabinene hydrate, borneol, α-thujone, β-thujone, linalool and α-terpineol. On the other hand, oxygenated monoterpes involving lavandulol, *cis*-piperitol, *trans*-*p*-menth-2-en-1-ol,

cis-*p*-menth-2-en-1-ol, chrysanthenone, *trans*-pinocarveol, *trans*-carveol, piperitone, carvacrol, *cis*-ascaridole, carvenone oxide, artemisia ketone, artemisia alcohol, geranyl acetate, yomogi alcohol, fragranol, fragranyl acetate, pinocarvone, isopinocamphone, grandisol, isoborneol, *cis*-chrysanthenol, cuminaldehyde, (*Z*)-chrysanthenyl acetate, linalyl acetate, dihydrocarvone and *trans*-sabinol have been characterized among the most dominant compounds in some profiles of the concerned EOs and extracts. However, monoterpene hydrocarbons, sesquiterpene hydrocarbons, oxygenated sesquiterpenes are not so prevalent in the corresponding chemical profiles. Menwhile, in the chemical profiles dominated by high frequency of non-terpene hydrocarbons, chamazulene was found to be the most abundant constituent compound. More specifically, as discussed in detail in this paper, the EOs and organic extracts of the divese plants of the *Achillea* genus exhibit effective and powerful immunological, phytochemical and biological activities against a very broad set of pathogens. As a matter of fact, secondary metabolites and extracts of these plants are potent antioxidant, antibacterial and/or antimicrobial, insecticidal, herbicidal, antifungal, antiproliferative, anti-nociceptive and/or analgesic agents, anti-inflammatory, larvicidal, anti-ulcerogenic, anti-platelet, anxiolytic as well as genotoxic agents. All the findings of these reports over the past three decades confirm the potential use of these herbal plants to be considered as effective and proper alternatives versus the chemical drugs which are highly toxic towards human beings.

Many reports relating to the phytochemical evaluations of the *Achillea* species account for the presence of a broad spectrum of flavones, flavonoids, guaianolides, lignans, non-saturated carboxylic acids, phenolic glycosides, phthalate derivatives, piperidine amides, polyacetylenes, proazulenes, sesquiterpenes, spirodepressolide, tannins, and triterpene alkamides which are of vital importance in different pharmacological and medicinal disciplines.

A large number of the previously published papers on biological activities of *Achillea* plants have been conducted *in vitro*. Therefore, it seems logical to establish complimentary *in vivo*

investigations in animal models to realize side effects and potential use of these valuable medicinal plants for therapeutic proposes. Furthermore, exhaustive studies are essential under the optimized experimental conditions and double-blind clinical trials focusing on the efficacy and probable mechanisms of the main bioactive compounds occurring in the corresponding profiles. Accordingly, a rationale and close relationship will be maintained between pharmacological aspects and traditional ethnobotanical uses of different *Achillea* species.

Taking into account these points, the future of the investigations on *Achillea* plants is bright and will address more challenging problems in the human life. Among the *Achillea* species, the highest rate of scientific records is due to *A. millefolium* L. Nonetheless, the literature is poor for some other species, namely *A. alpine* L., *A. alexandri*-regis, *A. stricta* schleicher et Koch., *A. depressa* Janka, *A. crithmifolia* Waldst. & Kit., *A. sibirica* L., *A. biserrata* M.Bieb. *A. phrygia* Boiss. & Balansa, *A. ketenoglui* H. Duman, *A. fraasii* Sch.Bip., *A. asplenifolia* Vent., *A. albicaulis* C.A.Mey., *A. micrantha* Willd., *A. moschata* Wulfen, Among others. Therefore, to determine the efficacy of these rather rare plants, more studies are indispensable in future researches of biologists, chemists, pharmacists and phytochemists. Also, some reported properties of these species have not been well-documented in the literature, e.g. snake repellency of *A. biebersteinii* Afan (Polatoglu et al., 2013), and anti-diabetic properties of *A. santolina* L. (Ardestani and Yazdanparast, 2007). It is anticipated that some of the remarkable medicinal properties of these herbal plants have not been distinguished so far. Hence, complimentary investigations should be undertaken to develop the literature data concerning the rare plants species from the genus *Achillea*.

Microorganisms and insects abbreviations:

Aedes aegypti: *Ae. Aegypti*; *Achromobacter piechaudii*: *A. piechaudii*; *Acinetobacter baumanii*: *A. baumanii*; *Acinetobacter lwoffii*: *A. lwoffii*; *Aedes albopictus*: *Ae. Albopictus*; *Alternaria alternate*: *A. alternate*; *Alternaria alternate*: *A. alternate*; *Aspergillus flavus*: *A. flavus*; *Aspergillus nidulans*: *A. Nidulans*; *Aspergillus niger*: *A. niger*; *Aspergillus ochraceus*: *A. ochraceus*; *Aspergillus parasiticus*: *A. parasiticus*; *Aspergillus terreus*: *A. terreus*; *Aspergillus versicolor*: *A. versicolor*; *Bacillus brevis*: *B. brevis*; *Bacillus cereus*: *B. cereus*; *Bacillus megaterium*: *B. megaterium*; *Bacillus pumilus*: *B. pumilus*; *Callosobruchus maculatus*: *C. maculatus*; *Candida albicans*: *C. albicans*; *Candida glabrata*: *C. glabrata*; *Candida kefyr*: *C. kefyr*; *Citrobacter freundii*: *C. freundii*;

Cladosporium cladosporioides: *C. cladosporioides*; *Cladosporium herbarum*: *C. herbarum*; *Colletotrichum acutatum*: *C. acutatum*; *Colletotrichum fragariae*: *C. fragariae*; *Colletotrichum gloeosporioides*: *C. gloeosporioides*; *Corynebacterium diphtheria*: *C. diphtheria*; *Corynebacterium jeikeium*: *C. jeikeium*; *Debaryomyces hansenii*: *D. hansenii*; *Echinococcus intermedius*: *E. intermedius*; *Enterobacter aerogenes*: *E. aerogenes*; *Enterobacter cloacae*: *E. cloacae*; *Enterococcus avium*: *E. avium*; *Enterococcus faecalis*: *E. faecalis*; *Epidermophyton floccosum*: *E. floccosum*; *Erwinia carotovora*: *E. caratovora*; *Erwinia chrysanthemi*: *E. chrysanthemi*; *Erwinia rhapontici*: *E. rhapontici*; *Escherichia coli*: *E. coli*; *Flavobacter*: *Fb*; *Fusarium equiseti*: *F. equiseti*; *Fusarium oxysporum*: *F. oxysporum*; *Micrococcus luteus*: *M. luteus*; *Micropsorum canis*: *M. canis*; *Haemophilus influenza*: *H. influenza*; *Klebsiella pneumonia*: *K. pneumonia*; *Kluyveromyces fragilis*: *K. fragilis*; *Lactobacillus acidophilus*: *L. acidophilus*; *Lactobacillus casei*: *L. casei*; *Listeria monocytogenes*: *L. monocytogenes*; *Methicillin-resistant Staphylococcus aureus*: MRSA; *Methicillin-sensitive Staphylococcus aureus*: MSSA; *Micrococcus flavus*: *M. flavus*; *Micropsorum gypseum*: *M. gypseum*; *Moraxella catarrhalis*: *M. catarrhalis*; *Morganella morganii*: *M. morganii*; *Mycobacterium smegmatis*: *M. smegmatis*; *Nocardia asteroids*: *N. asteroids*; *Propionibacterium acnes*: *P. acnes*; *Pseudomonas aeruginosa*: *P. aeruginosa*; *Pantoea agglomerans*: *P. agglomerans*; *Pseudomonas cichorii*: *P. cichorii*; *Penicillium funiculosum*: *P. funiculosum*; *Phomopsis helianthi*: *P. helianthi*; *Proteus mirabilis*: *P. mirabilis*; *Penicillium ochrochloron*: *P. ochrochloron*; *Pseudomonas syringae*: *P. syringae*; *Proteus vulgaris*: *P. vulgaris*; *Rhodotorula rubra*: *R. rubra*; *Streptococcus viridans*: *S .viridans*; *Streptococcus agalactiae*: *S. agalactiae*; *Streptomyces albus*: *S. albus*; *Staphylococcus aureus*: *S. aureus*; *Streptomyces avidinii*: *S. avidinii* ; *Saccharomyces cerevisiae*: *S. cerevisiae*; *Streptomyces coelicolor*: *S. coelicolor*; *Shigella dysenteriae*: *S. dysenteriae*; *Streptococcus dysgalactiae*: *S. dysgalactiae*; *Salmonella enterica*: *S. enterica*; *Salmonella enteritidis*: *S. enteritidis*; *Staphylococcus epidermidis*: *S. epidermidis*; *Shigella flexneri*: *S. flexneri*; *Sitophilus granaries*: *S. granaries*; *Staphylococcus haemolyticus*: *S. haemolyticus*; *Staphylococcus hominis*: *S. hominis*; *Streptococcus mitis*: *S. mitis*; *Streptococcus pneumonia*: *S. pneumonia*; *Streptococcus pyogenes*: *S. pyogenes*; *Streptococcus salivarius*: *S. salivarius*; *Streptococcus sanguinis*: *S. sanguinis*; *Streptococcus sobrinus*: *S. sobrinus*; *Shigella sonnei*: *S. sonnei*; *Salmonella typhi*: *S. typhi*; *Salmonella typhimurium*: *S. typhimurium*; *Salmonella typhosu*: *S. typhosu*; *Staphylococcus warneri*: *S. warneri*; *Sitophilus zeamais*: *S. zeamais*; *Streptococcus mutans*: *S.mutans*; *Tribolium castaneum*: *T. castaneum*; *Trichophyton interdigitale*: *T. interdigitale*; *Trichophyton mentagrophyte*: *T. mentagrophytes*; *Trichophyton mentagrophytes*: *T. mentagrophytes*; *Trichophyton rubrum*: *T. rubrum*; *Trichophyton soudanense*: *T. soudanense*; *Trichophyton tonsurans*: *T. tonsurans*; *Trichophyton violaceum*: *T. violaceum*; *Trichoderma viride*: *T. Viride*; *Xanthomonas axonopodis*: *X. axonopodis*; *Xanthomonas campestris*: *X. campestris*; *Yersinia enterocolitica*: *Y. enterocolitica*.

Acknowledgments

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Table 1

Names and groups of the organic compounds isolated from different *Achillea* species.

Achillea species	Name(s) or group(s) of compound(s)	Reference
A. atrata L.	**Two flavonoid aglycones**: **1)** 5,7,3′-Trihydroxy-6,8,4′-trimethoxy flavone (acerosin), or 5,7,8-trihydroxy-6,3′,4′-trimethoxy flavone, and **2)** 5,8-dihydroxy-6,7,4′-trimethoxy flavone (pedunculin)	(Ristic et al., 2004)
A. atrata subsp. *multifida*	Flavones and sesquiterpene lactones	(Aljančić et al., 1999)
A. biebersteinii Afan.	2-Tricosanone, patulitrin, quercetagitrin, jaceidin, quercimeritrin, 1-hexacosanol, *n*-pentacosane, 6-epiroseoside, ascaridole, strictic acid, centipedic acid, an ionone glucoside, and biebersteiniside	(Oskay and Yesilada, 1984; Mahmoud and Al-Shihry, 2006)
A. ceretanica Sennen	**Proazulenes**: 2α,8α-Dihydroxy-1α,5α,6β,7α,11βH-guaia-3,10(14)-dien-12,6-olide and its 8α-acetate	(Glasl et al., 1999)
A. ceretanica Sennen (tetraploid)	**Sesquiterpenoids**: 8α-Tigloxy-artabsin, 8α-angeloxy-artabsin, achillicin (= 8α-acetoxy-artabsin), 8α-tigloxy-3-oxa-artabsin, 8α-angeloxy-3-oxa-artabsin, 3-oxa-achillicin, 8-deacetyl-matricarin, and matricarin	(Glasl et al., 1997)
A. clypeolata Sm.	**A sesquiterpene alcohol**: Eudesm-4(15)-em-3α,7α, 11-triol + **two sesquiterpene lactones**: Guaianolides 3α,4α-epoxyrupicolin-A and 3α,4α- epoxyrupicolin-B	(Todorova et al., 1998)
A. clypeolata Sm.	**Sesquiterpenes**: **one guaiane**: 4,10,11-Trihydroxy-guaiane; **four eudesmanes**: 4(15)-Eudesmene-1β, 11-diol, clypeotriol, 3-*epi*-clypeotriol, and cryptomeridiol; **one diterpene**: Sugeroside, and **two phenolic compounds**: Centaureidin, and scopoletin	(Werner et al., 2007)
A. depressa Janka	**Spirodepressolide**: Bis-norsesquiterpene lactone	(Todorova et al., 2004)
A. fragrantissima (Forssk.) Sch. Bip.	Flavonoids and tannins	(El-Ashmawy et al., 2016)
A. fragrantissima (Forssk.) Sch. Bip.	Flavonoids afroside, cirsimaritin, chrysoplenol, cirsiliol, common fatty acids like lauric acid, myristic acid, palmitic acid, stearic acid, linoleic acid, linolenic acid, oleic acid, sesquiterpene lactones: 13-O-desacetyl-1-β-hydroxyafraglouclide, achilloide A, a bitter substance named keissoside, taraxasterol, and pseudotaraxasterol	(Batanouny et al., 1999; Al-Gaby and Allam, 2000; Abdel-Rahman et al., 2015)
A. fragrantissima (Forssk.) Sch. Bip.	A **flavonoid**: 3,5,4′-Trihydroxy-6,7,3′-trimethoxyflavone (TTF)	(Elmann et al., 2014)
A. ligustica All.	An epimeric sesquiterpene lactone + matricarin + 5-hydroxy-5,6-secocaryophyllen-6-one (3)	(Mahmoud et al., 2012)
A. ligustica All.	Piperidine amides, sesquiterpene lactones with rare 5/6/5 skeletons, guaianolides, and flavonoids	(Bruno and Herz, 1988; Tzakou et al., 1995a; Ahmed et al., 2003; Boudjerda et al., 2008)
A. lingulata Waldst. & Kit.	Lignans	(Trifunović et al., 2003)
A. millefolium L.	**Three flavones**: 5-Hydroxy-3,6,7,4′-tetramethoxyflavone, artemetin, and casticin	(Falk et al., 1975)
A. millefolium L.	Two sesquiterpene lactone-esters, and one sesquiterpene lactone-diol	(Farooq et al., 2012)
A. millefolium L.	**Guaianolides**: Leucodin, 8α-angeloxy-leucodin, achillin, 8α-angeloxy-achillin, and desacetylmatricarin	(Glasl et al., 2003)

A. millefolium L.	**Three phenolic glycosides**: Luteolin 7-O-glucoside, apigenin 7-O-glucoside, and caffeic acid glucoside	(Yassa et al., 2007)
A. millefolium L.	Achillinin A, a cytotoxic guaianolide	(Li et al., 2011)
A. millefolium L.	Millifolides A-C: 1,10-seco-guaianolides	(Li et al., 2012a)
A. millefolium L.	**Sesquiterpene dimers**: Achillinin B and C	(Li et al., 2012b)
A. pratensis Saukel & R. Langer	**Eudesmanolides**: Tauremisin, arglanin, 4-*epi*-arglanin, 4α-hydroperoxy-4α-dehydroxy-arglanin, and santamarin	(Glasl et al., 1995)
A. santolina L.	A guaianolide and a germacranolide	(Balboul et al., 1997)
A. santolinoides subsp. *wilhelmsii* (K. Koch) Greuter	Santolinoidol, a bisabolene sesquiterpene	(Fahed et al., 2016)
A. setacea Waldst. & Kit.	α-Methylene-γ-lactones	(Eglseer et al., 1990)
A. sintenisii Hub. Mor.	A sesquiterpene lactone, sintenin	(Gören et al., 1988)
A. tenuifolia Lam.	Phthalate derivatives	(Manayi et al., 2014)
A. tenuifolia Lam.	**Two flavones**: 3', 5-Dihydroxy-4', 6, 7-trimethoxy flavone (eupatorine), 5-hydroxy-3',4', 6, 7-tetramethoxyflavone, along with stearic acid, lupeol, daucosterol (β-sitosterol 3-O-β-D-glucopyranoside), and 2, 4-dihydroxy methyl benzoate	(Moradkhani et al., 2014)
A. wilsoniana Heimerl ex Hand.-Mazz.	**Sesquiterpenes and other constituents**: 4E, 10E-9β-Hydroxy-3-(2-methylbutyroyloxy)-germacra-4,10(1)-diene-12,6α-olide, 4E,10E-3-(2-methylbutyroyloxy)-germacra-4,10(1)-diene-12,6α-olide, 1β,6α -dihydroxy-10βmethyl-5αH,7αH-eudesm-4-one,1β,6α-dihydroxyeudesm-4(15)-ene, 1β-hydroxyα-xyperone, 2E,4E-N-isobutyl-2,4-decadienamide, 2E,4E-undeca-2,4-diene-8,10-diynoic acid isobutyamide, 2E,4E,8Z-N-isobutyl-2,4,8-decatrienamide, 2E,4E-undeca-2,4-diene-8,10-diynoic acid piperidide, 2E,4E-1-piperidin-1-yl-deca-2,4-dien-1-one, 4-(1-hydroxy-1-methyl-ethyl)-cyclohex-1-enecarbaldehyde, β-sitosterol, stigmast-5-ene-3β,7a-diol, 7β-methoxy-stigmast-5-ene-3β-ol, saringosterol, stigmast-4-en-6βol-3-one, 3β,5α,8α-trihydroxycampest-6,22-diene, daucosterol, sitoindoside I, cycloart-5-ene-3β,25-diol, sesamin, 6-acetyl-3,60-diferuloylsucrose, and 1,2-dilinolenyl-3-O-β-D-galactopyranosyl-sn-glycerol	(Yang et al., 2005)
Different species	Sesquiterpene lactones, flavonoids, alkaloids, lignans, triterpenes, alkamides, and polyacetylenes	(Si et al., 2006; Nemeth and Bernath, 2008)

Table 2
Some of the most important traditional and ethnomedicinal properties of some *Achillea* species *.

Achillea species	Traditional, etnomedicinal properties, prescriptions, and uses	Country/region	Reference
A. ageratum L.	To treat stomach and gastrointestinal disorders [a] representing cytostatic, anti-inflammatory, analgesic, and antipyretic activities	South-western Morocco	(El Bouzidi et al., 2012)
A. aleppica DC. subsp. *aleppica*	Diuretic, for the treatment of hemorrhoid, and as a medicinal plant with antimicrobial, anti-inflammatory (for urinary inflammations), and antinociceptive properties	Turkey	(Başer et al., 1986; Turkoglu et al., 2010; Cakilcioglu et al., 2011)
A. alpine L.	To treat acute inflammation with considerable anti-inflammatory, antipyretic, and sedative properties	China	(Zhang et al., 2014)
A. atrata L.	As a tonic remedy for bronchial and laryngeal troubles, and to cure pulmonary ailments	Serbia	(Ristic et al., 2004)
A. biebersteinii Afan.	A snake repellent; for wound healing and the treatment of abdominal pains, and stomachache	Turkey	(Baytop, 1994; Sezik et al., 2001; Polatoglu et al., 2013)
A. biebersteinii Afan.	As a carminative treatment	Jordan	(Alkofahi et al., 1996)
A. biebersteinii Afan.	An antihelmintic agent; to cure fever, digestive disorders, deep wound and burns, as well as cardiac disorders [b]	Iran	(Ghorbani, 2005)
A. clypeolata Sm.	To address kidney problems, increasing appetite, and soothing coughs (tea)	Serbia	(Jarić et al., 2015)
A. collina (Wirtg.) Heimerl	Digestive as an infusion form	Italy	(Cornara et al., 2014)
A. collina Becker	Effective antispasmodic, and bitter tonic having antihemorrhagic actions	Romania	(Jianu et al., 2015)
A. erba rotta All.	**Inflorescences**: As a compress on eyes towards conjunctivitis and styes	Italy	(Cornara et al., 2014)
A. filipendulina Lam.	An abortifacient agent and for gastrointestinal illnesses (as a decoction)	Kazakhstan	(Sadyrbekov et al., 2006)
A. fragrantissima (Forssk.) Sch. Bip	A hypoglycaemic drug, to prepare antidiuretic drinks and for treating stomach ailments	Palestine	(Barel et al., 1991; El-Shazly et al., 2004)
A. fragrantissima (Forssk.) Sch. Bip.	As a powerful anti-helminthic, emmenagogue, antiseptic, antipyretic, antispasmodic plant; to reduce fever, headache and weakness (extract), having medicinal value for anaemia, various central nervous system (CNS) disorders, both psychic and motor, such as hysteria, mild convulsion, epilepsy, for the therapy of eyes diseases (external use) and other CNS problems	Egypt and North Africa	(Boulos, 1983; Eissa, T.A.F. et al., 2014; Abdel-Rahman et al., 2015)
A. ligustica All.	As an antimicrobial and haemostatic, to treat stomachache [c], **Inf** [d]: To relief gastralgia and neuralgia as well as a cataplasm against rheumatism and skin disorders; **Sap**: An anthelmintic agent	Italy	(Bruni et al., 1997; Viegi et al., 2003; Bader et al., 2007)

A. ligustica All.	In cataplasms to relieve sprains and insect bites, to stop haemorrhages, and as an additive to the fritters of the Holy Friday	Corsica	(Muselli et al., 2009)
A. millefolium Agg.	In medicinal, veterinary, and cosmetic uses	India	(Agnihotri et al., 2005)
A. millefolium L.	To prepare herbal filter tea; an antiviral, gastroprotective, antiphlogistic, diuretic, and analgesic herbal medicine; to treat bruises, pulmonary disorders, inflammation, respiratory ailments, urinary and hepato-biliary disorders, overactive cardiovascular, spasmodic gastrointestinal complaints; as an appetite enhancing drug with remarkable wound healing impacts, and gastric anti-secretory characteristics	Europe [e]	(Lin et al., 2002; Cavalcanti et al., 2006; Benedek et al., 2008; Chou et al., 2013; Vladic et al., 2016)
A. millefolium L.	As a diuretic, emmenagog, appetizer, carminative, antispasmodic, and insecticidal agent; to cure abdominal pain and stomachache; showing symptomatic relief against colds, ulcer, and diarrhea	Turkey	(Baytop, 1994; Honda et al., 1996; Tuzlacı and Erol, 1999; Sezik et al., 2001; Ezer and Arisan, 2006; Cakilcioglu et al., 2011)
A. millefolium L.	**Inflorescences**: for the preparation of a relaxing tea (*camomillùn*)	Italy	(Cornara et al., 2014)
A. millefolium L.	As a flavoring agent in the preparation of salads, soups and fish, and a substitute for hops in production of beer; known as a astringent, stimulant, tonic, diaphoretic, antispasmodic, vulnerary remedy; to cure rheumatism, epilepsy, flatulence, colds, colic, heartburn, hysteria; to suppress haemorrhage; in treating skin diseases, toothache, and to profuse mucous discharge	India	(Anonymous, 1985; Shawl et al., 2002; Rao et al., 2015)
A. millefolium L.	Herbal tea; in the lotions and ointments for external uses in pharmaceutical formulations	Northern Greece	(Chatzopoulou et al., 1992)
A. millefolium L.	An an expectorant, anti-infection, anti-convulsion, astringent, anti-diabetic, anti-allergy, antispasmodic, anti-dandruff, antipyretic, anti-inflammatory and a tonic remedy; a carminative and effective wound healing agent; treating the digestion issues, hay fever, hypertension, eczema, and hemorrhoid; compression of the blood vessels and anorexia; tonic of stomach; disinfectants of the urinary tract; lowering hypertension and asthma; Possessing antibacterial and antimicrobial, antiviral, anti-worm, insecticidal, febrifuge, sedative features; in promotion of breast-feeding of the infants, regulation of the women menstruation, and in the prevention of epilepsy	Iran	(Shariat-Samsam, 1992; Mozaffarian, 1996; Zargari, 1996; Ardestani and Yazdanparast, 2007; Omidbaigi, 2012)

A. millefolium L.	A diaphoretic, stimulant, antipyretic, analgesic, anti-inflammatory, antispasmodic, carminative, antihelmentic, hepatoprotective, antispasmodic remedy; in the treatment of various liver diseases	Pakistan	(Said, 1982; Yaeesh et al., 2006)
A. millefolium L.	Effective anti-inflammatory, analgesic, antispasmodic, and antiseptic properties	Brazil	(Cavalcanti et al., 2006)
A. millefolium L.	For women's illnesses (menopause-related problems), colds, respiratory problems, and nausea (tea)	Serbia	(Jarić et al., 2015)
A. millefolium L.	An antistyptic; for the treatment of gastrointestinal diseases along with anaemia	Georgia	(Martkoplishvili and Kvavadze, 2015)
A. moschata Wulfen	A proper healing, analgesic, digestive, and hemostatic remedy	Italy	(Dei Cas et al., 2015)
A. nigrescens (E. Mey.)Rydb	Diuretic and hemorrhoids [f]	Turkey	(Polat et al., 2015)
A. nobilis (A. Kern.) Formanek	As an animal parasite, dermal wound, and anti-infection herbal drug	Iran	(Ghorbani, 2005)
A. santolina L.	Depurative, anti-helminthic, with promising carminative properties for intestinal colics, insect-repellent as well as to cure stomachache, dysentery and inflammation	Jordan and Iraq	(Alkofahi et al., 1996; Alkofahi et al., 1997; Al-douri, 2000; Al-Qura'n, 2009; Eissa, T.A.F. et al., 2014)
A. santolina L.	To treat toothache	North Africa	(Boulos, 1983)
A. santolina L.	For the treatment of chest disorders; also as a tonic, and carminative drug	Iran	(Afsharypuor et al., 1996)
A. santolinoi des subsp. *wilhelmsii*(K.Koch)Greuter.	For stomach disorder, diabetes, obesity, and diarrhea [g]	Pakistan	(Ahmad et al., 2016)
A. schischkinii Sosn.	Antimicrobial, anti-inflammatory, and antinociceptive characteristics	Turkey	(Turkoglu et al., 2010)
A. talagonica Boiss.	Immunosuppressive, anti-inflammatory, and analgesic activities	Iran	(Rezaeipoor et al., 1999; Javidnia et al., 2004)
A. tomentosa L.	In stomachache	Jordan	(Al-Qura'n, 2009)
A. vermicularis Trin.	To cure cold, flu, and stomachache	Turkey	(Mükemre et al., 2015)
A. wilhelmsii Koch.	*In vivo* antihypertensive and antihyperlipidemic impacts	Iran	(Asgary, S et al., 2000)
A. wilhelmsii Koch.	To treat gastrointestinal disorders	Italy	(Maffei et al., 1989)
A. wilhelmsii Koch.	For the treatment of hemorrhoids	Turkey	(Cakilcioglu et al., 2011)
A. wilhelmsii Koch.	Theraputic effects towards stomachache, diabetes, gastric, and obesity (both decoction and infusion)	Pakistan	(Bibi et al., 2014)
A. wilsoniana Heimerl ex Hand.-Mazz	In TCM [h]: For detoxifcation, hemostasia and acesodyne	China	(Xie and Yu, 1996; Yang et al., 2005)

*Different species of the genus *Achillea* have been sorted alphabetically; [a] As a powder mixed with honey; [b] Either decoction or infusion; [c] Sicilian folk medicine, Italy; [d] Inf.: Infusion; [e] In traditional European medicine as aqueous and alcoholic extracts and industrial scales; [f] Synonym with *Achillea millefolium* L.) with promising antianemic, antiemetic, antispasmodic, hemorrhoids, menstruation disorders and wound healing properties; The whole plant sample is boiled in milk and under severe constipation.; [h] TCM: traditional Chinese medicine.

Table 3

Main components of essential oils, volatile constituents and extracts from different species of *Achillea* genus worldwide (1992-2016).

Plant name (s)	Main components (%)	EOY [a]	Dominant group	Extraction method (s)	Characterization or analysis methods (s)	Part(s)		Area/Country	Identified		Ref.
									Num.	%	
A. millefolium L.	1,8-Cineole (29.0%), sabinene (15.0%), and *trans*-sabinene hydrate (3.1%)	0.2	OM [b]	HD [c]	GC and GC-MS	Flowers		Botanical Garden of Lisbon, Portugal	34	85	(Cristina Figueiredo et al., 1992)
	LF: 1,8-Cineole (25.0%), *trans*-sabinene hydrate (10.0%), and sabinene (5.4%)					Leaves	LF [d]		LF: 28	86	
	LV: Germacrene D (65.0%), α-farnesene (12.0%), and δ-elemene (4.6%)						LV [e]		LV:22	95.5	
A. sibirica L.	Camphor (25.1%), terpinen-4-ol (10.7%), and ascaridole (7.3%) α-terpinene (6.7%), and camphene (5.3%)	NR [f]	OM	HD	GC and GC-MS	NR		North Asia and Japan	22	78.6	(Maffei et al., 1994)
A. clypeolata Sm.	β-Pinene (23.7%), 1,8-cineole (10.1%), sabinene (9.2%), germacrene-D (9.2%), and camphor (2.2%)		MH [g]					Balkan peninsula, extending to southeast Romania	29	80.4	
A. crithmifolia Waldst. & Kit.	β-Pinene (18.7%),1,8-cineole (12.3%), α-pinene (6.7%), and germacrene-D (5.2%)		MH					Balkan peninsula, extending northwards to southeast Czechoslovakia	33	73.6	
A. filipendulina Lam.	Artemisia acetate (28.2%), 1,8-cineole (7.7%), and borneol (5.8%)		OM					Asia Minor	36	64.2	
A. macrophylla L.	Germacrene-D (17.5%), borneol (8.2%), camphor (7.7%), and 1,8-cineole (6.2%)		OM					North Italian Appennini	38	74.7	
A. pannonica Scheele	Germacrene-D (20.5%), 1,8-cineole (11.6%), α-pinene (7.6%), and carvacrol (6.5%)		OM					Central and Southeast Europe	38	75.2	
A. biserrata M.Bieb.	1,8-Cineole (26.3%), camphor (10.5%), borneol (5.7%), and sabinene (5.6%)		OM					Asia Minor	35	64.6	
A. pyrenaica Sibth. ex Godr.	Germacrene-D (13.9%), 1,8-cineole (11.3%), and β-sesquiphellandrene (7.5%)		OM					Pyrenees and mountains of south central France	29	90.5	
A. taygetea Boiss. & Heldr.	Camphor (15.8%), α-pinene (13.6%), and β-pinene (7.6%)		MH					Greece	29	78.4	
A. tenuifolia Lam.	Bisabolene oxide (15.1%), β-pinene (14.7%), borneol (10.6%) 1,8-cineole (6.7%), β-caryophyllene (5.3%), germacrene-D (5.1%), and camphor (1.0%)		OM					Balkan peninsula	21	77.7	
A. grandifolia Friv.	Camphor (25.6%), 1,8-cineole (12.8%), α-thujone (11.9%), β-thujone (9.2%), and *p*-cymene (6.7%)	0.57	OM	HD	GC and GC-EIMS	Aerial parts		Deciduous Carpinus forest, Vikos Gorge, NW Greece	60	94	(Hanlidou et al., 1992)
A. collina (Becker ex Wirtg.) Heimerl	Chamazulene (153.8 mg/g), β-caryophyllene (141.9 mg/g), sabinene (96.8 mg/g), and germacrene D (71.3 mg/g)	0.11-0.27	SH	SD	GC and GC-MS	NR		D-Halle, Proa	54	98.6	(Hofmann et al., 1992)

A. pannonica Scheele	Linalool (215 mg/g), borneo1+ α-terpineol (154.4 mg/g), and 1,8-cineole (116.9 mg/g)		OM				Krlmer, Bulgaria	83	98.1	
A. millefolium L.	Sabinene (52.1 mg/g), β-pinene (48.4 mg/g), α-terpineol (34.2 mg/g), and β-caryophyllene (31.3 mg/g)		MH				Bot. Garden, E-Madrid	89	97.1	
A. millefolium L.	Camphor (22.2%), 1,8-cineole (11.9%), borneol (8.5%), and lavandulol (7.3%)	0.3	OM	HD	GC and GC-MSIE	Aerial parts	Village of Vrisochori, N.W. Greece	69	92.0	(Kokkalou et al., 1992)
A. fragrantissima (Forssk.) Sch. Bip.	α-Thujone (25.5-36.5%), artemisia ketone (13.2-23.8%), and santolina alcohol (12.5-21.2%)	NR	OM	HD	GC-FID	Whole samples	Three locations of the Negev desert (Dimona, Mizpe Ramon, and Central Wady Faran) and one in the vicinity of Mt. Sinai	34-40	90.7-95.9	(Fleisher and Fleisher, 1993)
A.lingulata Waldst. & Kit.	Linalool (28.15%) and 1,8-cineole (4.6%)	NR	OM	HD	GC-FID and GC-MS	Leaves	Parnis mountain, Greece	40	50.26	(Tzakou et al., 1995b)
	Linalool (70.8%) and 1,8-cineole (7.0%)					Flowers		45	93.4	
A. millefolium L.	*epi*-Cubenol (18.0%), δ-elemene (6.9%), germacrene-D-4-ol (4.5%), and β-pinene (4.4%)	0.1	OS	HD	GC and GC-MS	Aerial parts	Botanical Garden of Lisbon (BGL), Portugal	36	59.3	(Lourenco et al., 1999)
	epi-Cubenol (26.1%), β-pinene (6.5%), T-cadinol (3.9%), and δ-elemene (3.6%)	0.05					Canecaao Garden of Almada (CGA), Portugal	42	62.7	
A. wilhelmsii Koch.	Caryophyllene oxide (12.5%), *cis*-nerolidol (10.8%), camphor (9.0%), oleic aldehyde (6.7%), borneol (6.1%), linalool (5.5%), 1,8-cineole (3.6%), chrysanthenol acetate (2.8%), and carvacrol (2.0%)	0.4	OM	HD	TLC [h], GC and CC-MS	Aerial parts	Kerman-Iran	19	70.1	(Afsharypuor et al., 1996)
A. tenuifolia Lam.	Camphor (18.0%), 1,8 cineole + limonene (9.0%), and spathulenol (7.0%)	0.23	OM	HD	GC and GC-MS	Aerial parts	Iran	48	88.0	(Rustaiyan et al., 1999)
A. tenuifolia Lam.	Camphor (36.9%), α-pinene (7.7%), and *p*-cymene (5.4%)	0.76	OM	HD	GC and GC-MS	Flower	Iran	24	76.2	(Aghjani et al., 2000)
A. phrygia Boiss. & Balansa	*cis*-Piperitol (11.2%, 31.2%), *trans*-*p*-menth-2-en-1-ol (11.0%, 14.7%),1,8-cineole (9.1%, 9.9%), and *cis*-*p*-menth-2-en-1-ol (7.2%, 9.9%)	0.7	OM	HD	GC and GC-MS	Air-dried herbal parts	Eskisehir, Turkey	A: 92	99.2	(Baser et al., 2000)
								B: 87	93.5	
A. clavenae L.	Camphor (29.6%), bornyl acetate (10.8%), and α-thujone (5.8%)	0.21	OM	HD	GC and GC-MS	Aerial parts	Mount Durmitor, Montenegro	41	78.6	(Chalchat et al., 2000)
A. collina (Becker ex Wirtg.) Heimerl	1,8-Cineole (27.6%), camphor (9.0%), and chrysanthenone (8.5%)	0.17					Mount Rtanj, Serbia	36	84.2	
A. lingulata Waldst. & Kit.	Borneol (20.3%), α-pinene (6.8%), and *trans*-pinocarveol (4.2%)	0.10					Mount Veliki Streselj, Southern Serbia	36	72.8	

A. crithmifolia Waldst. & Kit.	Camphor (5.4-77.4%), 1,8-cineole (0.0-46.0%), and borneol (1.5-24.2%)	NR	OM	HD	GC- FID	Flowers	Different parts of Hungary	12	NR	(Nemeth et al., 2000)
A. chrysocoma Friv.	Borneol (10.1%), terpinen-4-ol (9.2%), *cis*-*p*-menth-2-en-1-ol (8.2%), and *trans*-*p*-menth-2-en-1-ol (7.9%)	0.03	OM	HD	GC and GC-MS	Aerial parts	Besna Kolbila, Furious Mare Mountain, Serbia	28	91.5	(Simic et al., 2000)
A. lycaonica Boiss. & Heldr.	*trans*-Sabinene hydrate (9.3%), terpinen-4-ol (9.0%), and caryophyllene oxide (7.2%)	NR	OM	HD	GC-MS	Aerial parts	Turkey	92	91.5	(Baser et al., 2001a)
A. ketenoglui H. Duman	Borneol (14.1%), 1,8-cineole (13.8%) and camphor (13.4%) [i]; Terpinen-4-ol (14.5%), *trans*-sabinene hydrate (10.9%), and *cis*-sabinene hydrate (5.9%) [j]	NR					Ankara, Eskisehir, Turkey	96 [i], 104 [j]	91.3 [i]; 91.8 [j]	
A. goniocephala Boiss. & Balansa	Camphor (32.6%), and 1,8-cineole (23.2%)	0.40	OM	HD	GC-MS	Flowering herbal parts	Kahraman Maras, Goksun-Yesilkent, Binboga dagi, Dogankonak koyii, Turkey	73	98.1	(Baser et al., 2001b)
A. tenuifolia Lam.	γ-Muurolene (13.3%), α-pinene (10.0%), camphor (9.4%), *p*-cymene (8.5%), and *trans*-carveol (8.4%)	0.20	OM	HD	GC and GC-MS	Flowers	National Botanical Garden of Iran, Tehran, Iran	31	87.1	(Jaimand and Rezaee, 2001)
A. biebersteinii Afan.	Piperitone (45.9%), 1,8-cineole (17.6%), limonene (5.6%), and *p*-cymene (5.2%)		OM				Tabriz, Herby village toward Sahand Mountain, Iran	32	88.5	
A. filipendulina Lam.	Limonene (26.7%), carvacrol (9.3%), 1,8-cineole (8.7%), borneol (7.8%), and α-humulene (5.6%)		MH				National Botanical Garden of Iran, Tehran, Iran	36	82.3	
A. millefolium L.	β-Pinene (14.9-29.2%), sabinene (2.9-17.6%), 1,8-cineole (6.9-18.3%), β-caryophyllene (3.3-6.2%), (*E*)-nerolidol (0.5-6.4%), guaiol (0.3-11.8%), and chamazulene (0.1-13.3%)	2-3.9	MH	SSDE [k]	GC-FID and GC-MS	Aerial parts	Near Tallinn, Estonia	66	92.8-94.0	(Orav et al., 2001)
A.lingulata Waldst. & Kit.	Borneol (29.6%), α-thujone (6.3%), (*E*)-nerolidol (5.8%), terpinen-4-ol (4.8%), *trans*-pinocarveol (4.4%), spathulenol (4.0%), and β-caryophyllene (3.9%)	0.06	OM	HD	GC-FID and GC-MS	Aerial parts	Vranje: Location Mount Besna Kobila, Serbia	39	84.1	(Stojanovic et al., 2001)
A. millefolium L.	Camphor (16.0%), 1,8-cineole (8.7%), borneol (6.2%), β-eudesmol (6.1%), α-terpineol (5.9%), and α-bisabolol (5.5%)	0.33	OM	HD	GC-MS	Aerial parts	Karaganda region, near Spassk Place, Kazakhstan	23	93.1	(Suleimenov et al., 2001)
A. nobilis L.	Camphor (17.0%), 1,8-cineole (15.6%), terpinen-4-ol (10.0%), borneol (7.2%), and β-eudesmol (7.1%)	0.21					Karaganda region, Karkaraly village, Kazakhstan	87	90.2	

A. grandiflora M.Bieb.	β-Pinene (8.9%), selin-11-en-4α-ol (8.5%), and γ-eudesmol (6.3%)	0.18					Karaganda Botanic garden, Kazakhstan	114	86.7	
A. multifida (DC.) Griseb.	α-Thujone (60.9%), β-thujone (9.1%), sabinene (4.1%), and camphor (3.7%)	0.99	OM	HD	GC-FID and GC-MS	Aerial parts	Bursa: Uludug, Turkey	58	93.9	(Baser et al., 2002)
A holosericea Sm.	Camphor (20.3%), borneol (16.3%), and *cis*, *trans*-farnesyl acetate (9.6%)	0.11	OM	SD	GC-MS	Aerial parts	Taygetos Mountain, Greece	14	69.6	(Magiatis et al., 2002)
A. taygetea var. taygetea	1,8-Cineole (26.6%), camphor (25.7%), and borneol (6.7%)	0.4					Taygetos Mountain, Greece	13	75.0	
A. fraasii Sch.Bip.	Camphor (16.3%), 1,8-cineole (11.9%), and borneol (8.6%)	0.12					Tymfi Mountain, Greece	14	58.6	
A. millefolium L.	Camphor (28.0%), 1,8-cineole (12.0%), germacrene-D (12.0%), and *cis*-chrysanthenyl acetate (8.0%)	0.014	OM	HD	GC and GC-MS	Aerial parts	CIMAP Field Station, Pulwama, Jammu and Kashmir	86	97.2	(Shawl et al., 2002)
A. asplenifolia Vent.	β-Caryophyllene (17.6%), germacrene D (15.6%), and chamazulene (13.3%)	0.10	SH	HD	GC-MS	Aerial parts	Selevenyi near Horgos, Yugoslavia	49	79	(Simic et al., 2002)
A. setacea Waldst. & Kit.	Eucalyptol (1,8-cineole): (18.5%), sabinene (10.8%), and camphor (5.3%)	0.25	OM	SD	GC-MS	Aerial parts	Kizildag Pass, East of Sivas, Turkey	51	79.8	(Unlu et al., 2002)
A. teretifolia Willd.	Eucalyptol (1,8-cineole): (19.9%), borneol (11.9%), and camphor (11.1%)	0.43						42	87.1	
A. santolina L.	1,8-Cineole (17.6%), camphor (17.5%), 4-terpineol (7.0%), and *trans*-carveol (4.8%)	0.18	OM	HD	GC and GC-EI-MS	Flowering aerial parts	Naur, Jordan	45	85.1	(Bader et al., 2003)
A. biebersteinii Afan.	*cis*-Ascaridole (36.2%), *p*-cymene (31.6%), carvenone oxide (6.4%), and camphor (4.7%)	0.20	OM					33	95.4	
A. sintenisi Hub. Mor.	Crude EO: Camphor (14.8%), eucalyptol (12.9%), β-pinene (12.8%), borneol (10.8%), and piperitone (10.2%)	0.6	OM	HD	GC-MS	Aerial parts	Hafik District, Sivas, Turkey	32	90.2	(Sokmen et al., 2003)
	Fractionated EO: Eucalyptol (0-71.4%), camphor (0-63.3%), piperitone (0-57.8%), β-pinene (0-34. 8%), and borneol (0-27.8%)									
A. clavennae L.	Camphor (29.5%), myrcene (5.5%), 1,8-cineole (5.3%), β-caryophyllene (5.1%), and linalool (4.9%)	0.7	OM	HD	GC-MS	Leaves	Velebit Mountains	25	81.6	(Bezic et al., 2003)

							Dalmatia-Croatia,			
A. millefolium L.	Eucalyptol (24.6%), camphor (16.7%), α-terpineol (10.2%), β-pinene (4.2%), and borneol (4.0%)	0.6	OM	HD	GC-MS	Aerial parts	Kizildag Pass, Sivas, Turkey	36	90.8	(Candan et al., 2003)
A. albicaulis C.A.Mey.	1,8-Cineole (10.1%), camphor (9.2%), germacrene D (7.8%), piperitone (6.2%), α-pinene (5.9%), and artemisia ketone (5.7%)	0.5	OM	HD	GC-FID and GC-MS	Aerial parts	Tehran Province (between Karaj and Taleghan), Iran	31	85	(Feizbakhsh et al., 2003)
A. falcate L. [l]	(a) Camphor (24.0%), artemisia alcohol (20.1%), 1,8-cineole (14.4%), and α-pinene (1.5%)	0.8	OM	HD	GC-MS and MD-GC-MS [m]	Aerial parts	Antalya: Elmali, Tekke village to Ciglikara, Turkey	52	95	(Kurkcuoglu et al., 2003)
	(b) 1,8-Cineole (23.8%), α-pinene (12.3%), piperitone (10.3%), terpinen-4-ol (5.3%), and camphor (4.2%)	0.3					Antalya: Anamur, Abanoz yaylasi, Turkey	60	90	
A. millefolium L.	**I: Four samples:** Borneol (11.5-13.2%)+camphor (7.2-13.1%); **II: Four samples:** Chamazulene (9.8-23.2%)+β-pinene (9.7-26.5%); **III: Seven samples:** *trans*-Nerolidol (5.5-13.5%)+β-pinene (5.5-12.0%); **IV: 25 samples:** β-Pinene (7.3-31.1%)+1,8-cineole (3.1-17.0%).	0.7-1.2	OM	HD	GC and GC-MS	Inflorescences	21 Localities of Lithuania	42	74.1–98.7	(Mockute and Judzentiene, 2003)
		0.1-0.4				Leaves				
A. pseudoaleppica Hub.-Mor.	Camphor (29.1%), 1,8-cineole (17.7%), and artemisia ketone (10.3%)	1.2	OM	HD	GC and GC-MS	Aerial parts	Near Diyarbakir, Turkey	70	92.4	(Ozen et al., 2003)
A. crithmifolia Waldst. & Kit.	Camphor (27.6%), 1,8-cineole (26.5%), and *trans*-chrysanthenyl acetate (18.8%)	0.28	OM	HD	GC and GC-MS	Aerial parts	Selicevica, near Nis, Serbia	36	96.2	(Palic et al., 2003)
A. nobilis L.	α-Thujone (25.7%), artemisia ketone (14.8%), borneol (9.9%), and camphor (8.2%)	0.56					Kovanlucka Cuka, near Nis, Serbia	25	84.8	
A. coarctata Poir.	1,8-Cineole (20.1%), camphor (15.6%), and viridiflorol (11.8%)	0.9	OM	HD	GC and GC-MS	Aerial parts	Southeastern Anatolia, Turkey	47	85.5	(Toker et al., 2003)
A. oligocephala DC.	1,8-Cineole (18.6%), α-terpineol (6.8%), and linalool (6.0%)	1.0						52	84.8	
A. clavennae L.	Camphor (29.5%), myrcene (5.5%), 1,8-cineole (5.3%), β-caryophyllene (5.1%), linalool (4.9%), and geranyl acetate (4.2%)	0.7	OM	HD	GC-MS	Leaves and flowers	Velebit Mountains, Dalmatia, Croatia	25	81.6	(Skocibusic et al., 2004)
A. wilhelmsii C. Koch	Carvacrol (25.1%), linalool (11.0%), 1,8-cineol (10.3%), *E*-nerolidol (9.0%), and borneol (6.4%)	0.15	OM	HD	GLC and GC-MS	Aerial parts	Kazeroon, Fars Province, Iran	57	98.5	(Javidnia et al., 2004)
A. atrata L.	1,8-Cineole (22.6%), sabinene (12.0%), camphor (8.8%), and α-thujone (8.6%)	NR	OM	HD	GC and GC-MS	Aerial parts	Vicinity of Jazinacko Lake	83	94.6	(Ristic et al., 2004)

A. fragrantissima (Forssk.) Sch. Bip.	*cis*-Thujone (29.5%), santolina alcohol (18.3%), artemisia ketone (15.2%), *trans*-thujone (10.8%), *trans*-pinocarveol (6.8%) and yomogi alcohol (4.3%)	1.0	OM	SD	GLC and GLC-MS	Flowering aerial parts	Sinai desert, vicinity of Sader Hetan, Egypt	49	98.7	(El-Shazly et al., 2004)
A. santolina L.	Flower: Fragranyl acetate (51.7%), fragranol (11.8%), terpinen-4-ol (6.6%), borneol (4.5%) camphor (3.8%), and 1,8-cineole (3.0%)	0.1	OM			Flower	Vicinity of Alexandria Province, Egypt	54	97.6	
	Leaf: Fragranyl acetate (47.1%), fragranol (13.2%), terpinen-4-ol (6.5%), borneol (4.8%), camphor (3.0%), and 1,8-cineole (1.9%)	0.12				Leaf		43	95.6	
	Stem: Fragranyl acetate (45.1%), fragranol (18.7%), terpinen-4-ol (5.9%), borneol (3.6%), camphor (3.4%), and 1,8-cineole (0.7%)	0.04				Stem		37	96.1	
A. talagonica Boiss.	Camphor (21.9%), 1,8-cineole (9.7%), and borneol (6.2%)	0.4	OM	HD	GC and GC-MS	Aerial parts	Talegan, North of Iran	47	90.0	(Saeidnia et al., 2004)
A. millefolium L.	α-Copaene (11.1%) (*E*)-nerolidol (8.8%), 1,8-cineole (6.1%), camphor (5.9%), and linalool (4.1%)	0.2					KordKooy, near Dakal-e-Derazno, Golestan, Iran	64	88.2	
A. biebersteinii Afan.	Eucalyptol (0-71.4%), camphor (0-63.3%), piperitone (0-57.8%), and borneol (0.0-30.0%)	0.6	OM	HD	CC [a] and GC-MS	Aerial parts	Hafik District, Sivas, Turkey	32	90.2	(Sokmen et al., 2004)
A. sieheana Stapf.	Enantiomerically pure (1S)-(-)-Camphor (39.9%), 1,8-cineole (15.5%), and camphene (8.3%)	0.25	OM	HD	GC-MS	Aerial parts	Kayseri: Develi, Sindelhoyuk to Karacaoren in Turkey	108	95.3	(Tabanca et al., 2004)
A. millefolium L.	α-Pinene (10.6 -17.7%), β-caryophyllene (8.5-16.2%), 1,8-cineole (3.0-15.1%), and borneol (0.2-12.1%)	NR	OM	HD	GLC and GC-MS	Aerial parts	Srinagar, Kashmir, India	70	91.0	(Agnihotri et al., 2005)
								62	93.8	
							Sisso, Lahaul-Spiti, Himachal Pradesh, India	68	93.3	
								66	97.3	
A. holosericea Sm.	1,8-Cineole (47.4%), camphor (23.5%), and borneol (17.1%)	0.09	OM	HD	GC-MS	Aerial parts	Galicica mountain, Ohrid, Macedonia	16	99.6	(Boskovic et al., 2005)
A. clavennae L.	Camphor (46.9%), 1,8-cineole (43.9%), and camphene (3.1%)	0.17	OM				Galicica mountain, Ohrid, Macedonia	12	99.2	
A. millefolium L.	β-Pinene (32.6%), β-caryophyllene (16.5%), sabinene (11.5%), and chamazulene (5.9%)	0.08	MH				Banks of the river Nisava, urban surroundings, Eastern Serbia	21	92.6	
A.lingulata Waldst. & Kit.	Ţ-Cadinol (22.5%), caryophyllene oxide (16.6%), α-bisabolene oxide (12.8%), and borneol (8.0%)	0.07	OS				Mountain Stara Planina, Eastern Serbia	24	90.6	
A. abrotanoides (Vis.) vis.	β-Thujone (16.8%), pinocarvone (15.6%), and 1,8-cineole (11.3%)	0.4	OM	HD	GC and GC-MS	Aerial parts	Durmitor Mountain, Montenegro	36	90.6	(Chalchat et al., 2005)
A. clypeolata Sm.	1,8-Cineole (38.6%), and camphor (19.9%)	0.1	OM				Rtanj Mountain, Eastern Serbia	30	93.3	

A. depressa Janka	Camphor (38.7%), and 1,8-cineole (24.1%)	0.6	OM				Vicinity of Prokuplje , Southern Serbia	43	97.0	
A. stricta schleicher et Koch.	Camphor (23.7%), borneol (17.3%), and 1,8-cineole (14.1%)	0.2	OM				Kopaonik Mountain, Serbia	39	82.3	
A. schischkinii Sosn.	1,8-Cineole (31.0%), and camphor (20.0%)	0.29	OM	HD	GC and GC-MS	Aerial parts	Kizildag Pass, Imranlı-Sivas, Turkey	31	91.5	(Donmez et al., 2005)
A. millefolium L.	Inflorescence: β-Pinene (13.1-19.3%), (*E*)-nerolidol (7.0-16.1%), piperitone (10.8%, deep pink inflorescences), β-eudesmol (8.4%, white) , and β-caryophyllene (6.7%, pink)	0.8-1.0	OS, MH	HD	GC and GC-MS	Aerial parts	Vilnius, Eastern Lithuania	27-31	93.0-96.6	(Judzentiene and Mockute, 2005)
	Leaf: β-Eudesmol (12.8%, white flowering plant), borneol (10.7%, pink), piperitone (10.0%, deep pink), caryophyllene oxide (6.4-10.4%), selin-11-en-4α-ol (6.5-7.5%), and spathulenol (6.1%, pink)	0.2-0.4	OS					31-39	69.2-74.1	
A. alexandri-regis	α-Pinene (14.4-15.7%)[O], isopinocamphone (5.4-23.5%), α-phellandrene epoxide (5.0-19.0%), borneol (3.6-7.7%), and spathulenol (1.4-9.7%)	0.25	OM	HD	GC-FID and GC-MS	Full-blooming herb	Mountain Os ljak, Serbia	23-24	60.8-83.0	(Kovacevic et al., 2005)
A. holosericea Sm.	Borneol (17.3-18.1%), camphor (9.7-15.1%), terpinen-4-ol (6.3-11.1%), and camphene (5.7-7.2%)	0.1	OM				Mountain Ostrovica, locality of Rusenica River, Serbia	24-25	73.9-78.0	
A.lingulata Waldst. & Kit.	Borneol (23.0-40.7%), β-thujone (5.5-7.6%), bornyl acetate (3.5-7.8%), and sabinene (1.7-6.7%)	0.05	OM				Kopaonik Mountian, Serbia	25-32	70.3-78.4	
A. falcate L.	Isomers of the cyclobutane ethanol, 1-methyl-2-(1-methylethenyl): Grandisol (21.4%) and fragranol (16.8%), artemisia ketone (5.2%), terpinen-4-ol (4.5%), and 1,8-cineole (4.0%)	0.62	OM	HD	GC and GC-MS	Aerial parts	Jab. Kneissé, Lebanon	58	94.4	(Senatore et al., 2005)
A. clypeolata Sm.	(*E*)-γ-Bisabolene (17.9%), 1,8-cineole (16.0%), borneol (11.9%), and caryophyllene-oxide (11.5%)	0.05	OM	HD	GC-FID and GC-MS	Aerial parts	Rudina Mountain, near Bosilegrad, Eastern Serbia	18	89.8	(Simic et al., 2005)
A. clavennae L.	Camphor (41.9%), and 1,8-cineole (22.5%)	0.12	OM	HD	GC-FID and GC-MS	Aerial parts	Mount Galicica, Ohrid, Macedonia	9	93.2	(Stojanovic et al., 2005)
A. holosericea Sm.	Borneol (30.2%), and camphor (14.8%)	0.07						12	75.7	
A. ligustica All.	Santolina alcohol (6.7-21.8%), borneol (3.4-20.8%), sabinol (2.1-15.5%), *trans*-sabinyl acetate (0.9-17.6%), α-thujone (0.4-25.8%), and viridiflorol (0.7-3.6%)	0.88	OM	HD	GC-FID and GC-MS	Flowering tops	Eight localities of Sardinia, Italy	85	100	(Tuberoso et al., 2005)
		0.43		SDE [gg]						
A. pachycephala Rech.f.	1,8-Cineole (27.7%), and camphor (27.4%)	0.15	OM	HD	GC and GC-MS	Aerial parts	North of Gorgan Province, Iran	32	96.0	(Esmaeili et al., 2006)
A. oxyodonta Boiss.	1,8-Cineole (38.5%), and artemisia ketone (23.0%)	0.17					East of Tehran, Latian area, Iran	28	96.4	
A. biebersteinii Afan.	Flower: Camphor (36.3%), and 1,8-cineole (22.3%)	0.18				Flower		26	92.0	

	Leaf: Camphor (33.7%), and borneol (20.8%)	0.22				Leaf	Makuo, Province, West Azerbaijan, Iran	26	90.3	
	Stem: Camphor (38.1%), borneol (22.6%), and 1,8-cineole (13.5%)	0.20				Stem		14	87.6	
A. ligustica All.	Camphane derivatives: > 30% (camphor: 21.3%; borneol: 6.2%; bornyl acetate: 3.5%), artemisia ketone (5.9%), and santolina alcohol (19.3%)	0.4	OM	HD	Enantioselective GC and GC-MS	Aerial parts	U Rugnicone, near Ajaccio, Corsica	82	94.0	(Filippi et al., 2006)
A. monocephala Bioss.	Leaf: Camphor (28.7-30.5%), borneol (9.9-15.6%), and α-terpineol (5.5-5.9%)	2.90	OM	Superheated water [vv]	Comprehensive GC-TOF-MS [p]	Leaf	Cukurova University, Adana, Mid-Southern Turkey	53	94.6-97.9	(Gogus et al., 2006)
	Flower: Camphor (33.4%-35.2%), borneol (13.9%-23.6%), 1,8-cineole (7.9%-12.4%), and α-campholenal (13.9%-15.2%)	1.58				Flower		46	96.7-97.2	
A. schischkinii Sosn.	1,8-Cineole (32.5%)	0.3	OM	HD	GC and GC-MS	Aerial parts	Spikor Mountain, Erzincan, Turkey	44	87.3	(Iscan et al., 2006)
A. aleppica DC. subsp. *aleppica*	1,8-Cineole (26.1%,), bisabolol, and its derivatives (6.6%)	0.1					Sof Mountain, Isüıklar Village, Gaziantep, Turkey	83	91.8	
A. millefolium L.	Flower: HD: Chamazulene (54%), camphor (8.0%), and isoborneol (7.6%)	0.5	NH	HD	GC and GC-MS	Flower	Elburse Mountains, Dizin, North of Tehran, Iran	26	99.1	(Jaimand et al., 2006)
	Flower: SD: Chamazulene (78.4%), and longifolene (7.6%)	0.2	NH					13	99.8	
	Leaf: HD: Chamazulene (35.0%), isoborneol (18.2%), and *p*-cymene (14.8%)	0.09	NH	SD		Leaf		20	99.7	
	Leaf: SD: Chamazulene (82.5%), and germacrene B (3.6%)	0.07	NH					15	98.9	
A. millefolium L.	α-Thujone (0-26.6%), camphor (0.1-24.5%), β-bisabolol (0-21.6%), 1,8-cineole (0.8-20.3%), β-pinene (0-20.3%), artemisia ketone (0-12.6%), (*E*)-caryophyllene (0-12.5%), sabinene (tr.-11.7%), β-thujone (0-11.0%), fenchyl acetate (0-9.8%), linalool (tr.-9.5), borneol (0-9.2%), δ-cadinol (0-6.4%), germacrene D (0-6.0%), caryophyllene oxide (0.2-5.2%), and chamazulene (0-42.0%)	0.9-9.5	OM	DM [q]	GC and GC-MS	NR	Estonia and different European countries	102	>85	(Orav et al., 2006)
A. filipendulina Lam.	Santolina alcohol (29.1%), borneol (27.9%), 1,8-cineole (19.1%), and bornyl acetate (8.1%)	0.76	OM	HD	GC-MS	NR	Botanical Garden of the Institute of Phytochemistry, Karaganda, Kazakhstan	19	99.5	(Sadyrbekov et al., 2006)
A. sudetica Opiz.	Linalool (11.8%), caryophyllene (8.9%), borneol (5.9%), and 1,8-cineole (5.9%)	0.4					Botanical Garden of the Institute of Phytochemistry, Karaganda, Kazakhstan	65	81.3	
A. ledebourii Heimerl.	Germacrene D (20.6%), spatulenol (10.9%), caryophyllene oxide (6.2%), and bicyclogermacrene (4.5%)	0.23	SH				Eastern Kazakhstan district, Kazakhstan	19	76.2	
A. cartilaginea Ledeb. ex Rchb.	α-Thujone (26.2%), and β-thujone (11.8%)	0.18	OM				Near Balkhash, Kazakhstan	50	97.0	

A. ligustica All.	Leaves: 4-Terpineol (19.3%), 4-terpineol (12.0%), carvone (10.0%), carvone (8.9%), γ-terpinene (7.2%), β-phellandrene (6.8%), and β-phellandrene (5.4%)	0.38	OM	HD	GC and GC-EIMS	Leaves	Fantina, Messina, Sicily, Italy	31	88.9	(Bader et al., 2007)
	Flower: Linalool (20.4%), and cedrol (4.3%)	0.48				Flowers		27	88.1	
A. millefolium L.	EO: Camphor (38.4%), 1,8-cineole (16.2%), γ-terpinene (9.4%), bornyl acetate (4.3%), and terpinolene (3.9%)	Ground: 0.65	OM	HD	GC-FID	Flowers	Near Skopje, Macedonia	16	100	(Bocevska and Sovova, 2007)
		Intact: 0.7								
	Ex [nm]: Camphor (26.4%), bornyl acetate (16.7%), 1,8-cineole (9.6%), γ-terpinene (9.0%), and terpinolene (7.6%)	NR		Supercritical CO_2 [r]				27	100	
	Ex [m]: Camphor (31.6%), bornyl acetate (15.6%), 1,8-cineole (12.5%), γ-terpinene (6.2%), and terpinolene (4.8%)							26	100	
A.lingulata Waldst. & Kit.	Borneol (30.7%), bornyl acetate (8.5%), decanoic acid (4.2%), vulgarone B (3.9%), γ-palmitolactone (3.5%), and camphor (2.5%)	0.22	OM	HD	GC and GC-MS	Flower heads	Stara Planina Mountains, Eastern Serbia	42	86.4	(Kundakovic et al., 2007)
A. umbellate Sm.	Camphor (18.4%),1,8-cineole (12.4%), α-thujone (12.2%), β-thujone (10.4%) artemisia alcohol (4.0%), sabinene (4.0%), and borneol (2.3%)	0.45					Mount Killini, Peloponnesus, Southern Greece	40	90.0	
A. ageratum L.	1,8-Cineole (41.0%), yomogi alcohol (22.3%), santolina alcohol (10.0%), and artemisyl acetate (7.6%)	0.8	OM	HD	GC and GC-MS	Aerial parts	Near Corti, Corsica, France	39	96.5	(Muselli et al., 2007)
A. millefolium L.	1,8-Cineole (9.7%-14.8%), *cis*-chrysanthenyl acetate (4.5%-12.4%), *epi*-α-cadinol (3.7%-9.8%), *cis*-chrysanthenol (3.4%-8.2%), germacrene D (2.6%-5.2%), (*E*)-caryophyllene (1.9%-5.2%), α-eudesmol (0%-15.4%)v *neo*-intermedeol (0%-13.0%) sabinene (1.03%-6.5%), and cuminaldehyde (0.0%-6.5%)	0.7- 1.3	OM	SD	GC and GC-MS	NR	Cultivated plants Herboratum, Faculty of Pharmacy, Tehran university of medical sciences Tehran, Iran	May: 33	90.7	(Amin et al., 2008)
								June: 41	91.0	
								September: 26	88.2	
A. wilhelmsii Koch.	Camphor (39.6%), artemisia alcohol (17.9%), and 2,5,5-trimethyl-3,6-heptadien-2-ol (16.1%)	0.3	OM	HD	GC and GC-MS	NR	NR	16	100	(Azaz et al., 2008)
A. lycaonica Boiss. & Heldr.	L-Camphor (43.2%), artemisia alcohol (21.2%), and camphor (16.5%)	0.9						13	99.1	
A. collina (Becker ex Wirtg.) Heimerl	β-Pinene (22.5%), (*E*)-caryophyllene (14.9%), 1,8-cineole (11.4%), and germacrene D (11.1%)	0.73	SH	HD	GC-MS	NR	Local market in Novi Sad, Serbia	17	98.1	(Bozin et al., 2008)
A. pannonica Scheele	1,8-Cineole (40.4%), camphor (11.1%), germacrene D (11.1%), (*E*)-chrysanthenyl acetate (6.0%), and terpinen-4-ol (4.4%)	0.98	OM					18	99.9	
A. eriophora DC.	Camphor (30.4%), 1,8-cineole (25.2%), and camphene (6.2%)	2.0	OM	HD	GC and GC-MS	Aerial parts	Golmakan, Khorasan	30	99.0	(Ghani et al., 2008)
A. nobilis L.	α-Thujone (34.1%), 1,8-cineole (14.1%), and β-cedren epoxide (9.6%)	0.8						21	92.6	

A. biebersteinii Afan.	1,8-Cineole (32.8%), carvacrol (10.8%), and piperitone (7.3%)	0.8					Razavi Province, Iran	29	98.5	
A. wilhelmsii Koch.	Camphor (19.7%), α-pinene (10.0%), and1,8-cineole (9.1%)	0.65						29	88.4	
A. biserrata M. Bieb.	Camphor (36.8%), 1,8-cineole (19.4%), camphene (16.4%), and artemisia alcohol (14.3%)	0.07	OM	HD	GC and GC-MS	Aerial parts	Gumushane between Trabzon, Turkey	10	100	(Azaz et al., 2009)
A. salicifolia Besser subsp salicifolia	Camphor (55.3%), 1,8-cineole (22.8%), artemisia alcohol (3.2-14.3%), and camphene (3.2%)	0.08	OM				Ardahan between Gole, Turkey	16	100	
A. millefolium L.	1,8-Cineole (15.2%), and germacrene D (14.1%)	0.21	OM	HD	GC-FID and GC-MS	NR	Research Station of Alborz in Karaj, North of Tehran, Iran	50	98.1	(Barghamadi et al., 2009)
	1,8-Cineole (13.2-17.6%), germacrene D (33.1-43.2%), β-cubebene (3.1-4.9%), camphor (3.7-4.7%), and humulene epoxide (2.0-4.7%) [ss]	0.25-3.6	SH	SFE				38-42	97.0-100	
A. millefolium L.	**Four samples**: germacrene-D (-%), bicyclogermacrene, camphor, borneol, 1,8-cineole, spathulenol, and bornyl acetate	0.15-0.63	SH, OM	HD	GC-MS	leaves	Ten provinces in north, northwest, west, south and center of Iran,	6-20	56.6-85.4	(Rahimmalek et al., 2009)
A. filipendulina Lam.	**Two samples**: germacrene-D, bicyclogermacrene, camphor, borneol, 1,8-cineole, spathulenol, and bornyl acetate	0.55 – 0.72	OM, SH					17	62.4-77.0	
A. tenuifolia Lam.	**Five samples**: germacrene-D, bicyclogermacrene, camphor, borneol, 1,8-cineole, spathulenol, and bornyl acetate	0.15 – 0.83	SH, OS					12-23	53.4-90.0	
A. santolina L.	**Four samples**: germacrene-D, bicyclogermacrene, camphor, borneol, 1,8-cineole, spathulenol, and bornyl acetate	0.1 – 0.6	SH, OM					7-22	32.1-71.8	
A. biebersteinii Afan.	**Three samples**: germacrene-D, bicyclogermacrene, camphor, borneol, 1,8-cineole, spathulenol, and bornyl acetate	0.41 – 2.7	OM, OS					12-17	26.5-91.5	
A. eriophora DC.	**One sample**: germacrene-D, bicyclogermacrene, camphor, borneol, 1,8-cineole, spathulenol, and bornyl acetate	0.2	SH					19	51.2	
A. millefolium L.	Leaves: 1,8-Cineole (27.7-41.5%)	NR	OM	MD [s]	GC-MS	Leaves and inflorescences	Karaj, Iran	25-26	81.5-90.8	(Azizi et al., 2010)
	Inflorescences: 1,8-Cineole (34.2-36.8%)							26-35	88.4-90.5	
A. nobilis L.	Leaves: α-Thujone (40.4-64.1%)						Golmakan, Khorasan Razavi, Iran	35-36	96.2-98.9	
	Inflorescences: α-Thujone (24.7-58.7%)							29-34	94.5-99.2	
A. eriophora DC.	Leaves: 1,8-Cineole (24.8-29.8%)						Jahrom, Fars Province, Iran	34	96.5-98.3	
A. biebersteinii Afan.	Leaves: 1,8-Cineole (46.1-59.6%)						Golmakan, Khorasan Razavi, Iran	31-34	97.8-98.7	
	Inflorescences: 1,8-Cineole (26.4-49.7%)							29-36	97.7-97.9	
A. millefolium L.	Chamazulene (42.2%), sabinene (19.7%), terpinen-4-ol (5.2%), β-caryophyllene (4.4%), and eucalyptol (3.1%)	0.7	NH	HD	GC-MS	NR	Curitiba PR, Brazil	23	88.6	(de Sant'Anna et al., 2009)
A. teretifolia Willd.	1,8-Cineole (34.0%), camphor (11.0%), terpinen-4-ol (8.0%), and α-thujone (5.0%)	0.48	OM	HD	GC and GC-MS	Aerial parts	Roadside, Beyşehir-Şarkikaraağac Road, Turkey	68	96.4	(Demirci et al., 2009)
A. nobilis L.	Fragranyl acetate (32.0%), fragranol (24.0%), and β-eudesmol (8.0%)	0.28	OM				Roadside,	43	85.0	

							Beyşehir-Yeşildağ road, Turkey			
A. gypsicola Hub-Mor.	EO [t]: Camphor (40.2%), 1,8-cineole (22.0%), piperitone (11.3%), borneol (9.5%), and α-terpineol (1.6%)	0.65	OM	HD	GC and GC-MS	Aerial parts	Erzurum region, Turkey	28	97.1	(Kordali et al., 2009)
	EX [u]: Camphor (25.8%), piperitone (17.7%), 1,8-cineole (15.8%), linoleic acid (6.2%), borneol (5.7%), *n*-tricosane (3.5%), *n*-eicosane (2.8%), and *n*-heneicosane (2.0%)	1.91		*n*-Hexane extracts		Flowers		28	97.9	
A. biebersteinii Afan.	EO: 1,8-Cineole (38.1%), camphor (23.6%), borneol (5.9%), α-terpineol (5.2%), and piperitone (0.4%)	0.63		HD		Aerial parts	Corum region, Turkey	32	99.3	
	EX: Camphor (18.0%), linoleic acid (16.4%), 1,8-cineole (15.1%), *n*-tricosane (9.8%), *n*-heneicosane (7.2%), borneol (5.2%), *n*-eicosane (2.7%), and piperitone (1.0%)	2.05		*n*-Hexane extracts		Flowers		20	94.6	
A. ligustica All.	Linalool (24.8%), viridiflorol (9.6%), β-pinene (6.4%), 1,8-cineole (5.8%), and terpinen-4-ol (5.3%)	0.91	OM	HD	GC-FID and GC-MS	Flowers	Cultivated at the Botanical Garden, Camerino, Central Italy	71	92.8	(Maggi et al., 2009)
	Virdiflorol (14.5%), terpinen-4-ol (13.0%), β-pinene (9.6%), and 1,8-cineole (3.4%)	0.18				Stems/leaves [v]		67	87.6	
A. ligustica All.	Aerial Parts: Camphor (22.8%), artemisia ketone (20.4%), camphene (4.8%), santolina alcohol (3.8%), *trans*-sabinyl acetate (3.0%), and viridiflorol (2.7%)	-	OM	HS-SPME	GC-FID and GC-MS	Aerial parts, flowers and leafy stems	Corsican, France	49	95.9	(Muselli et al., 2009)
	Flowers: Camphor (29.8%), camphene (9.0%), *trans*-sabinyl acetate (5.5%), and viridiflorol (3.0%)							48	90.3	
	Leafy stems: Artemisia ketone (26.7%), camphor (14.2%), santolina alcohol (9.4%), camphene (3.0%), viridiflorol (2.3%), and *trans*-sabinyl acetate (1.6%)							44	94.5	
	Aerial Parts: Camphor (17.4%), santolina alcohol (9.1%), artemisia ketone (7.5%), viridiflorol (7.2%), *trans*-sabinyl acetate (6.2%), and camphene (3.1%)	0.58		HD			Sardinian, Italy	58	98.6	
	Flowers: Camphor (17.2%), *trans*-sabinyl acetate (10.2%), viridiflorol (8.2%), artemisia ketone (5.9%), santolina alcohol (3.8%), and camphene (1.4%)	0.81						50	97.6	
	Leafy stems: Camphor (17.0%), santolina alcohol (10.1%), viridiflorol (9.5%), *trans*-sabinyl acetate (7.6%), camphene (3.3%), and artemisia ketone (3.2%)	0.21						52	95.8	
A. millefolium L.	1,8-Cineole (17.2%), sabinene (14.6%), γ-eudesmol (8.7%), terpinen-4-ol (5.7%), α-terpineol (5.2%), and 6S,7R-bisabolone (4.4%)	0.46	OM	HD	GC-FID and GC-MS	Aerial parts	Villamassargia, Cagliari, Italy	54	96.1	(Tuberoso and Kowalczyk, 2009)
	γ-Eudesmol (13.9-17.9%), 1,8-cineole (11.9-12.6%), 6S,7R-bisabolone (11.8-14.9%), sabinene (11.6-11.8%), α-terpineol (4.8%), and terpinen-4-ol (3.7-5.5%)	-	OS	SMDE [w]				41-42	94.7-94.8	
	Sabinene (13.1%), γ-eudesmol (12.9%), 1,8-cineole (10.4%), 6S,7R-bisabolone (6.8%), α-terpineol (4.4%), and terpinen-4-ol (2.4%)	0.48	OS	MAHD				49	96.5	
A. coarctata Poir.	Inflorescences: 1,8-Cineole (26.9%), camphor (22.1%), and borneol (5.0%)	0.26	OM	HD	GC-FID and GC-MS	Inflorescences	Grevena, Greece	16	86.1	(Tzakou et al., 2009)
	Leaves: 1,8-Cineole (29.1%), camphor (9.2%), and borneol (6.8%)	0.58				Leaves		13	83.6	

A. umbellate Sm.	β-Thujone (62.8%), and camphor (8.7%)	1.07	OM	HD	GC and GC-MS	Aerial flowering parts	Styx on Chelmos Mountain, Greece	66	93.5	(Tzakou and Loukis, 2009)
A.lingulata Waldst. & Kit.	Neryl tiglate (16.2%), *tau*-cadinol (12.2%), neryl isovalerate (9.7%), and cubenol (8.9%)	0.112	OS	HD	GC and GC-MS	Aerial parts	Mountain top Cemernik, vicinity of Lake Vlasina, Southeastern Serbia	120	94.1	(Jovanovic et al., 2010)
A. biebersteinii Afan.	HD: 1,8-Cineole (38.1%), camphor (23.6%), borneol (5.9%), and α-terpineol (5.2%)	NR	OM	HD	GC and GC-MS	Aerial parts	Anatolia Region of Turkey	33	99.3	(Kotan et al., 2010)
	Extract: Camphor (18.0%), linoleic acid (16.4%), 1,8-cineole (15.1%), methyl linoleate (10.2%), *n*-tricosane (9.8%), *n*-heneicosane (7.2%), and borneol (5.2%)		OM	Extract [x]				20	94.6	
A. millefolium L.	HD: 1,8-Cineole (6.6%), δ-cadinol (6.2%) viridiflorol (5.6%), and α-terpineol (3.5%)		OM	HD				71	73.5	
	Extract: *n*-Hexacosane (23.2%), *n*-tricosane (10.3%), *n*-heneicosane (9.0%), and *n*-eicosane (5.8%)		NH	Extract [x]				21	83.9	
A. distans Willd. subsp. distans	Ţ-Cadinol (17.6%), alismol (14.1%), α-cadinol (9.1%), and caryophyllene oxide (5.0%)	0.11	OS	HD	GC and GC-MS	Pulverised underground parts (roots)	Natural populations from pastures, Mt Stara planina Babin Zub, Serbia	185	93.6	(Lazarevic et al., 2010)
A. millefolium L.	1,8-Cineole (28.8%), camphor (11.0%), and borneol (5.9%)	0.16	OM	HD	GC; GC-MS; ^{13}C NMR; high resolution LC-MS	Aerial parts	Gorge Sicevacka klisura, nearby Nis, Serbia	20	73.2	(Smelcerovic et al., 2010)
A. crithmifolia Waldst. & Kit.	Borneol (21.1%), 1,8-cineole (15.2%), and camphor (5.9%)	0.58					Mountain Vidojevica, near Prokuplje, Southern Serbia	22	77.0	
A. mollifolifium L.	Geraniol (33.4%), neryl acetate (17.5%), faranesol (7.6%), benzyl benzoate (6.1%), linalool (3.2%), and α-pinene (2.5%)	1.23	OM	HD	GC-MS	Aerial parts	Lorestan, Iran	36	97.2	(Srabi and Meshkatalsadat, 2010)
A. clusiana Tausch	β-Thujone (17.2%), 1,8-cineole (11.2%), camphor (11.1%), α-thujone (7.8%), farnesol (3.1%), nerolidol (2.7%) and oxygenated nerolidol derivatives (cabreuva oxides A-D, isohumbertiols A-D, bejarol, and 7-hydroxy-6,7-dihydro-5,6*E*-dehydronerolidol)	0.57	OM	MDE [y]	GC and GC-MS	Flower heads	Bulgaria	44	92.5	(Trendafilova et al., 2010)
A. odorata L.	Full flowering period: Camphor (22.9-26.3%), 1,8-cineole (15.7-17.8%), and α-pinene (11.3-12.5%)	015-1.29	OM	HD	GC (RIs); ^{13}C-NMR	Aerial parts	Northwestern Algeria	26-28	85.6-92.9	(Bekhechi et al., 2011)
	End of flowering: Thymol (2.7-4.5%), and *iso*-thymol (1.3-2.7%)									
A. millefolium L.	Italian SFE extract: β-Bisabolene (27.3%), α-asarone (25.6%), and α-pinene (10.0%)	0.7	SH	HD	GC-FID and GC-MS	Aerial parts	Sardinia Island, Italy	19	97.8	(Falconieri et al., 2011)

	Italian EO: α-Asarone (33.3%), α-pinene (17.2%), β-bisabolene (16.6%), and (*E*)-methyl isoeugenol (8.8%)	0.9	SH					25	96.8	
	Portuguese SFE extract: *trans*-Thujone (31.4%), *trans*-crhysanthenyl acetate (19.8%), camphor (3.3%), and β-pinene (1.2%)	0.7	OM				Atlantic coast (Portugal- Serra de Montemuro)	21	100	
	Portuguese EO: *trans*-Thujone (29.0%), *trans*-crhysanthenyl acetate (15.8%) β-pinene (11.1%), and camphor (9.7%)	0.7	OM					27	99.4	
A. eriophora DC.	Growing wild: Camphor (30.4%), 1,8-cineole (25.2%,), and camphene (6.2%)	2.0	OM	HD	GC and GC-MS	Flowering parts	Jahrom, Fars Province, Iran	30	99.0	(Ghani et al., 2011)
	Cultivated: Camphor (30.0%), 1,8-cineole (27.0%), and camphene (6.0%)	2.25						36	99.4	
A. wilhelmsii Koch.	Growing wild: Camphor (19.7%), α-pinene (10.0%), and 1,8-cineole (9.1%)	0.65					Golmakan, Khorasan Razavi Province, Iran	29	88.4	
	Cultivated: Camphor (25.3%), α-pinene (7.9%), and 1,8-cineole (5.8%)	0.5						58	96.0	
A. distans W. et K.	1,8-Cineole (16.8%), *trans*-thujone (9.8%), sabinene (8.2%), borneol (7.5%), β-pinene (6.5%), and camphor (5.8%)	0.18	OM	HD	GC and GC-MS	Flower heads	Troyan Pass, Stara Planina Mountain, Bulgaria	43	93.5	(Konakchiev et al., 2011)
A. nobilis L.	Artemisia ketone (46.7%)	0.2	OM	HD	GC and GC-MS	Aerial parts	Sanandaj, Kordestan Province, Iran	30	95.4	(Rustaiyan et al., 2011)
A. santolina L.	Piperitone (49.1%), and camphor (34.5%)	NR	OM	HD	GC-MS	Various parts	Alexandria state and the Sinai Peninsula, Egypt	4	89.2	(Sallam et al., 2011)
A. biebersteinii Afan.	1,8-Cineole (9.0-37%), camphor (16.0-30.0%), and *p*-cymene (1.0-27.0%)	0.3-0.6	OM	HD	GC-FID; GC-MS	Aerial parts	Different localities in central Turkey	37-60	87.0-99.0	(Tabanca et al., 2011)
A. millefolium L.	Chamazulene (48.9%), isoborneol (10.2%), and camphor (9.5%)	NR	NH	HD	GC and GC-MS	Flowers	NR	23	94.6	(Alinezhad et al., 2011)
A. gypsicola Hub-Mor.	Camphor (40.2%), 1,8-cineole (22.0%), piperitone (11.3%), borneol (9.5%), and α-terpineol (1.6%)	0.65	OM	HD	GC, MS, RI	Aerial parts	Samsun, Turkey	28	97.1	(Tozlu et al., 2011)
A. ageratum L.[kk]	Artemisyl acetate (62.3-78.8%), yomogi alcohol (4.9-12.4%), santolina alcohol (4.9-11.8%), and artemisia alcohol (3.4-7.0%)	3.0	OM	HD	GC-MS	Flowers	Morocco	10	95.8-98.6	(El Bouzidi et al., 2012)
		2.0-2.5				Leaves				
A. ligustica All.	AP: β-Pinene (11.7%), viridiflorol (9.8%), terpinen-4-ol (8.0%), linalool (7.7%), germacrene D (7.0%), and 1,8-cineole (5.4%)	AP: 0.6	OM	HD	GC/FID and GC-MS	Flowering aerial parts (AP)	Botanical Garden , Camerino, Central Italy	101	91.0	(Cecchini et al., 2012)
	FL: Linalool (25.9%), viridiflorol (8.6%), terpinen-4-ol (7.6%), β-pinene (7.0%), and 1,8-cineole (6.8%)	FL: 3.0				Inflorescences (FL)		111	92.5	
	LV: β-Pinene (16.5%), terpinen-4-ol (13.8%), viridiflorol (8.7%), 1,8-cineole (7.0%), germacrene D (6.0%), and γ-terpinene (4.6%)	LV: 1.5				Leaves (LV)		117	96.6	

A. wilhelmsii Koch.	1,8-Cineole (13.0%), caranol (8.3%), α-pinene (6.0%), farnesyl acetate (6.0%), and *p*-cymene (6.0%)	NR	OM	HD	GC-MS	Flowers	Sade, Ghaenat, South Khorasan Province, Iran	>20	>88	(Khani and Asghari, 2012)
A. cretica L.	Caryophylladienol-II (13.4%), β-maaliene (6.1%), *neo*-intermedeol (6.0%), carvone (4.9%), spathulenol (4.5%), palmitic acid (3.3%), and selina-3,11-dien-6-α-ol (3.2%)	0.05	OS	HD	GC and GC-MS	Aerial parts	Datca-Knidos, Mugla Province of Turkey	76	86.4	(Kucukbay et al., 2012)
A. sieheana Stapf.	Camphor (43.4%), artemisia ketone (26.0%), 1,8-cineole (6.3%), and camphene (4.8%)	1.2	OM	HD	GC-MS	Aerial parts	Develi, Sindelhoyuk, Kayseri, Inner Anatolia, Turkey	22	96.2	(Albayrak, 2013)
A. biebersteinii Afan.	1,8-Cineole (30.6%), piperitone (28.9%), and camphor (11.7%)	0.6	OM	HD	GC-MS	Aerial parts	Mt. Ararat-Agrı, Turkey	70	91.9	(Polatoglu et al., 2013)
	1,8-Cineole (31.1%), camphor (14.4%), α-thujone (12.9%), *p*-cymene (4.6%), β-thujone (3.4%), and borneol (3.4%)	1.2					Mt. Dumluca-Sivas, Turkey	60	90.1	
A. vermicularis Trin.	1,8-Cineole (29.2%), camphor (25.8%), borneol (5.2%), piperitone (4.5%), and camphene (3.8%)	0.3					Van–Muradiye, Turkey	61	92.2	
A. teretifolia Willd.	1,8-Cineole (15.9%), borneol (8.1%), camphor (7.0%), T-cadinol (5.9%), *trans*-nerolidol (5.1%), and caryophyllene oxide (3.9%)	0.6					Mt. Dumluca-Sivas, Turkey	57	76.6	
A. ligustica All.	(Z)-Chrysanthenyl acetate (29.6%), viridiflorol (16.8%), bornyl acetate (8.7%), and 1,8-cineole (7.4%)	Leaves: 0.05	OM	HD	GC and GC-MS	Aerial parts	Lipari, Aeolian Islands, Italy	27	93.5	(Ben Jemia et al., 2013)
		Stems: 0.20								
	(Z)-Chrysanthenyl acetate (27.8%), viridiflorol (21.6%), bornyl acetate (11.6%), and 1,8-cineole (9.3%)	0.31				Flowers		30	97.4	
A. millefolium L.	Artemisia ketone (14.9%), camphor (11.6%), linalyl acetate (11.5%), and 1,8-cineole (10.2%)	NR	OM	SD	GC-MS	[z]	[z]	19	100	(Chou et al., 2013)
A. santolina L.	Fragranyl acetate (28.4%), fragranol (8.1%), terpinen-4-ol (6.4%), 1,8-cineole (5.0%), camphor (4.2%), (Z)-sabinene hydrate (3.5%), caryophyllene oxide (1.2%), and α-muurolol (1.1%)	0.7		SD	GC and GC-MS	Flowers	Jannatabad, Torbat Jam, Khorasan-Razavi Province, Iran	53	96.1	(Motavalizadehkakhky et al., 2013a)
	Fragranyl acetate (34.0%), fragranol (9.1%), terpinen-4-ol (7.1%), 1,8-cineole (4.5%), camphor (4.1%), α-muurolol (1.9%), (Z)-sabinene hydrate (1.8%), and caryophyllene oxide (1.2%)	0.25				Leaves		48	98.0	
	Fragranyl acetate (37.0%), fragranol (7.8%), terpinen-4-ol (6.1%), α-terpinyl acetate (5.1%),, camphor (3.8%), 1,8-cineole (3.0%), (Z)-sabinene hydrate (2.1%), caryophyllene oxide (1.4%), and α-muurolol (1.2%)	0.15				Stems		50	96.3	

	Fragranyl acetate (20.0%), fragranol (7.1%), hexadecanoic acid (5.2%), camphor (5.1%), eicosane (4.2%), terpinen-4-ol (4.0%), α-muurolol (3.6%), caryophyllene oxide (3.2%), methyl linoleate (3.1%), 1,8-cineole (3.0%), (*Z*)-sabinene hydrate (2.1%), and α-terpinyl acetate (1.1%)	1.2		Extract [aa]		Aerial parts		59	97.2	
A. pachycephala Rech.f.	1,8-Cineole (16.4%), camphor (11.2%), camphene (7.2%), borneol (5.2%), terpinen-4-ol (4.3%), and β-caryophyllene (4.1%)	0.8	OM	HD	GC and GC-MS	Flowers	Sakhdar, Neyshabur, Iran	53	98.2	(Motavalizadehkakhky et al., 2013b)
	1,8-Cineole (19.0%), camphor (12.0%), camphene (8.0%), β-caryophyllene (4.4%), terpinen-4-ol (3.9%), and borneol (3.7%)	0.2				Leaves		47	98.8	
	1,8-Cineole (18.2%), camphor (15.0%), camphene (5.3%), sabinene (5.1%), borneol (4.3%), β-caryophyllene (4.2%), and terpinen-4-ol (3.5%)	0.1				Stems		46	97.2	
	Hexane-ether: 1,8-Cineole (10.0%), camphor (10.0%), terpinen-4-ol (5.1%), β-caryophyllene (5.1%), methyl linoleate (4.2%), *n*-eicosane (4.0%), and borneol (2.7%)	0.9		Extract		Aerial parts		60	97.9	
	Methanolic: Camphor (7.5%), terpinen-4-ol (7.1%), 1,8-cineole (6.9%), thymol (5.1%), borneol (4.5%), fragranyl acetate (4.2%), and eugenol (4.2%)	1.7						48	95.4	
A. santolina L.	Fragranyl acetate (28.4%), fragranol (8.1%), terpinen-4-ol (6.4%), 1,8-cineole (5.0%), and camphor (4.2%)	0.7		HD		Flowers	Khorasan-Razavi Province, Iran	53	96.1	
	Fragranyl acetate (34.0%), fragranol (9.1%), terpinen-4-ol (7.1%), 1,8-Cineole (4.5%), camphor (4.1%), and borneol (3.5%)	0.25				Leaves		48	98.0	
	Fragranyl acetate (37.0%), fragranol (7.8%), terpinen-4-ol (6.1%), borneol (4.5%), camphor (3.8%), and 1,8-cineole (3.0%)	0.15				Stems		50	96.3	
	Hexane-ether: Fragranyl acetate (20.0%), fragranol (7.1%), camphor (5.1%), terpinen-4-ol (4.0%), and 1,8-cineole (3.0%)	1.2		Extract		Aerial parts		59	97.2	
	Methanolic: Fragranyl acetate (10.9%), 1,8-cineole (6.2%), fragranol (6.1%), camphor (6.1%), and terpinen-4-ol (5.0%)	1.8						49	95.9	
A. phrygia Boiss. & Balansa	Camphor (35.6%), 2-furaldehyde (16.6%), and 1,8-cineole (eucalyptol) (10.1%)	NR	OM	HD	GC-MS	Flowering aerial parts	Nevsehir, Avanos on limestone, Turkey [KPL]	31	87.1	(Akcin et al., 2014)
A. wilhelmsii Koch.	Borneol (21.2%), *cis*-chrysanthenyl acetate (20.9%), camphor (9.2%), *trans*-chrysanthenyl acetate (8.6%), and 1,8-cineole (7.2%)	1.02	OM	VAE-DLLME [bb]	GC-MS	Flowers	Zardkooh	50	95.4	(Sereshti et al., 2014)

							Mountain, Chaharmahal and Bakhtiari Province, Iran			
A. tenorii (Grande)	α-Thujone (29.7%), *trans*-sabinol (18.6%), and *trans*-sabinyl acetate (15.7%)	0.18	OM	HD	GC-FID; GC-MS	Aerial parts	Majella National Park, Italy	69	93.6	(Venditti et al., 2014)
A. biebersteinii Afan.	*cis*-Ascaridol (33.8%), *p*-cymene (22.4%), santolina alcohol (6.3%), and camphor (5.6%)	0.76	OM	HD	GC and GC-MS	Aerial parts	Sinai Peninsula, Egypt	26	96.7	(Nenaah, 2014a)
A. fragrantissima (Forssk.) Sch. Bip.	*cis*-Thujone (24.8%), *cis*-β-ocimene (16.1%), artmisia ketone (14.8%), and *trans*-thujone (12.5%)	0.93	OM					19	95.6	
A. millefolium L.	Chrysanthenone (24.1%), borneol (14.2%),2,6-dimethylphenol (9.2%), 4-terpineol (8.2%), and *p*-cymene (4.3%)	0.25	OM	HD	GC-EIMS[ll]	Aerial parts	Jijel, Italy	35	96.1	(Benelli et al., 2015)
A. fragrantissima (Forssk.) Sch. Bip.	*cis*-Thujone (28.4%), 2,5-dimethyl-3-vinyl-4-hexen-2-ol (santolina alcohol) (16.1%), 3,3,6-trimethyl-1,5-heptadien-4-one (artemisia ketone)(14.8%), and *trans*-thujone (12.5%)	0.93	OM	HD	GC and GC-MS	Aerial parts	Sinai Peninsula, Egypt	19	95.6	(Nenaah et al., 2015)
A. tenuifolia Lam.	Carvacrol (20.4%), Thymol (15.0%), α-pinene (10.1%), linalool (10.0%), camphene (9.4%), β-pinene (7.5%), α-terpinene (7.2%), and γ-terpinene (7.0%)	NR	MH	HD	GC-MS	Aerial parts	Ilam, Iran	22	98.6	
A. wilhelmsii Koch.	Carvacrol (20.1%), thymol (19.0%), linalool (10.0%), camphor (8.4%), *p*-cymene (7.0%), α-thujene (6.1%),1,8-cineole (6.0%), sabinene (5.2%), and α-pinene (5.1%)	0.82	OM	HD	GC-MS	Aerial parts	Central Regions, Iran	30	94.5	(Kazemi and Rostami, 2015)
A. tenuifolia Lam.	Limonene (27.5%), α-cadinol (16.4%), borneol (8.0%), and bornyl acetate (5.2%)	0.32	OM	HD	GC-MS	Aerial parts	Tabriz-Ahar Road, Iran	45	91.1	(Piryaei et al., 2015)
	Limonene (28.6%), α-cadinol (12.7%), borneol (6.8%), bornyl acetate (6.3%), bornyl acetate (4.3%), caryophyllene oxide (3.2%), camphene (3.2%), and *p*-cymene (2.3%)	-	MH	MA-HS-SPME [cc]				40	81.8	
A. eriophora DC.	Camphor (21.6%), artemesia ketone (13.8%), α-thujone (11.8%), and yomogi alcohol (7.7%)	0.2	OM	HD	GC-MS	Aerial parts	Sistan and Baluchestan, Iran	33	99.9	(Mottaghipisheh et al., 2015)
A. wilhelmsii Koch.	Carvacrol (22.5%), dihydrocarvone (13.2%), linalool (12.0%), 1,8-cineole (11.4%), camphene (8.3%), thymol (5.3%), camphor (3.7%), pulegone (2.8%), α-terpineol (2.1%), bornyl acetate (1.1%), and farganol (1.0%)	NR	OM	HD	GC-MS	Aerial parts	Golmakan, Khorasan Razavi, Iran	52	97.3	(Alfatemi et al., 2015)
A. biebersteinii Afan.	*cis*-Ascaridol (33.8%), *p*-cymene (22.4%), camphor (8.6%), 1,8-cineole (6.3%), and piperitone (5.4%)	0.76	OM	HD	GC and GC-MS; CC and TLC	Aerial parts	Allamain desert and Sinai Peninsula, Egypt	31	97.5	(Almadiy et al., 2016)
A. santolina L.	Fragranyl acetate (27.3%), 1,6-dimethyl-1,5-cyclooctadiene (14.6%), *cis*-thujone (8.4%), and 1,8-cineole (7.1%)	0.49	OM					38	94.7	
A. millefolium L.	Chamazulene (26.2%), β-pinene (16.6%), sabinene (9.2%), and germacrene D (6.7%)	0.21	MH					35	98.3	
A. fragrantissima (Forssk.) Sch. Bip.	*cis*-Thujone (28.4%), artemisia ketone (16.8%), santolina alcohol (13.1%), and *trans*-thujone (12.5%)	0.88	OM					19	95.1	
A. santolinoides subsp *wilhelmsii* (K. Koch) Greuter	Eucalyptol (8.0%), terpinen-4-ol (6.9%), α-pinene (6.0%), and *trans*-pinocarveol (3.5%)	0.58	OM	HD	GC-MS HPLC	Aerial parts	Lebanon	35	84.3	(Fahed et al., 2016)

A. tenuifolia Lam.	Germacrene-D (55.8%), camphor (13.2%), and spathulenol (8.7%)	NR	SH	HD	GC-MS	Leaves	Karaj, Alborz, Iran	17	100	(Gharibi et al., 2015)
A. biebersteinii Afan.	Camphor (26.3%), germacrene-D (15.8%), spathulenol (12.5%), 1,8-cineole (12.4%), α-terpineol (7.6%), and bicyclogermacrene (6.6%)	1.5	OM				Siah bishe, Mazandaran, Iran	11	90.1	
A. filipendulina Lam.	2,7-Dimethyl-4(*E*), 6-octadiene-2-ol (27.1%), germacrene-D (19.8%), bornyl acetate (15.9%), and borneol (7.8%)	NR	OM				Salafchegan, Markazi, Iran	15	79.4	
A.millefolium L.	Borneol (35.9%), camphor (18.8%), and spathulenol (5.7%)	NR	OM				Kandovan, Alborz, Iran	18	92.3	
A.nobilis L.	α-Thujone (25.2%), α-cubebene (16.4%), germacrene-D (8.7%), β-selinene (6.8%), and artemisia ketone (6.7%)	NR	OM				Shandiz, Khorasan, Iran	15	86.9	
A. vermicularis Trin.	Camphor (21.8%), 1,8-cineole (15.9%), and germacrene-D (12.4%)	NR	OM				Poloor, Tehran, Iran	17	77.0	
A. wilhelmsii Koch.	Germacrene-D (20.0%), camphor (17.3%), and borneol (11.8%)	0.35	OM				Shahrekord, Chahar Mahalo Bakhtiari, Iran	23	74.2	
A. eriophora DC.	Germacrene-D (21.8%), camphor (12.7%), and spathulenol (4.2%)	NR	SH				Mashhad, Khorasan, Iran	17	55.8	
A. filipendulina Lam.	1,8-Cineole (23.0%), *trans*-2,7-dimethyl-4,6-octadien-2-ol (21.9%), borneol (8.1%), *cis-p*-menth-2,8-dienol (7.9%), *iso*-terpinolene (6.1%), and bornyl acetate (5.0%)	NR	OM	HD	GC-MS	Aerial parts	Agricultural Faculty, Dicle University, Diyarbakir, Turkey	36	97.7	(Hasimi et al., 2015)
A. millefolium L.	EO: NR	NR	NR	HD	UV-Vis and C-MS	Inflorescences	Leordeni area, Pitesti hills, Romania	41	NR	(Fierascu et al., 2015)
	Extract: NR							82	NR	
A. collina (Becker ex Wirtg.) Heimerl	Chamazulene (38.9%), germacrene D (12.9%), β-caryophyllene (11.5%), and β-pinene (10.7%).	NR	NH	SD	GC-MS	Inflorescences	Hunedoara county, the Orăştioara de Sus commune, village of Ludeştii de Jos	30	99.9	(Jianu et al., 2015)
A. wilhelmsii Koch.	HS-SPME: Sabinol (47.3%), bornyl acetate (17.6%), and 1,8-cineole (9.7%)	-	OM	HD and HS-SPME	GC-MS	Aerial parts	Shiraz, Fars Province, Iran	35	100	(Karami-Osboo et al., 2015)
	HD: *trans*-Sabinyl acetate (41.2%), sabinol (32.0%), caryophyllene oxide (9.8%), and 1,8-cineole (2.5%)	0.33						44	99.0	
A. vermicularis Trin.	HS-SPME: Camphor (35.0%), and 1,8-cineole (22.0%)	-					Kandovan Mountain, North of Karaj, Alborz Province, Iran	29	96.4	
	HD: Camphor (35.0%), 1,8-cineole (15.8%), piperitone (6.3%), and camphene (6.1%)	0.85						42	100	
A. eriophora DC.	HS-SPME: Camphor (36.5%), 1,8-cineole (25.8%), germacrene D (22.2%), and camphene (9.3%)	-					Shiraz, Fars Province, Iran	31	100	
	HD: Camphor (38.6%), 1,8-cineole (28.3%), germacrene D (14.4%), and camphene (9.9%)	2.14						32	99.0	

A. ageratum L.	Artemisyl acetate (70.1%), yomogi alcohol (12.4%), and artemesia alcohol (7.1%)	2.04	OM	HD	GC and GC-MS	Aerial parts	Terrahla, Demnate, Morocco	8	96.9	(Kasrati et al., 2015)
A. millefolium L.	Thymol (26.5%), borneol (16.4%), limonene (14.5%), and carvacrol (10.1%)	0.96	OM	HD	GC and GC-MS	Aerial parts	NR	25	98.7	(Kazemi, 2015a)
A. millefolium L.	P1 [dd]: Chamazulene (15.8%), *trans*-caryophyllene (9.0%), β-pinene (8.9%), 1,8-cineole (5.3%), *trans*-chrysanthenyl acetate (5.8%), and germacrene D (5.0%)	1.01	OM	HD	GC-FID and GC-MS	Aerial parts	Vojvodina Province, Northern part, Serbia	33	99.6	(Stevanovic et al., 2015)
	P2 [ee]: lavandulyl acetate (14.9%), chamazulene (13.9%), *trans*-caryophyllene (7.6%), germacrene D (6.8%), *trans*-chrysanthenyl acetate (6.8%), and borneol (5.3%)	0.69						29	99.5	
	P3 [ff]: *trans*-Chrysanthenyl acetate (21.3%), *trans*-caryophyllene (9.5%) and germacrene D (7.1%)	0.32						33	99.1	
A. tenuifolia Lam.	Carvacrol (20.4%), thymol (15.0%), α-pinene (10.1%), linalool (10.0%), camphene (9.4%), β-pinene (7.5%), α-terpinene (7.2%), γ-terpinene (7.0%), *p*-cymene (4.0%), and 1,8-cineole (2.3%)	NR	OM	HD	GC-MS	Aerial parts	Mountains of Ilam, Iran	22	98.6	(Kazemi, 2015b)
A. millefolium L.	β-Thujone (96.2%), and α-thujone (1.2%)	0.03	OM	HD	GC-MS	Flowers and leaves	Purchased from Campestre Company, Temuco, Chile	10	99.4	(Tampe et al., 2015)
A. biebersteinii Afan.	*p*-Cymene (18.6%), 1,8-cineole (16.5%), camphor (11.7%), hexadecanoic acid (11.2%), and β-eudesmol (10.1%)	NR	MH	HD	GC and GC-MS	Aerial parts	Ankara: Beytepe Campus, the road into the forest, Turkey	55	95.7	(Turkmenoglu et al., 2015)
A. coarctata Poir.	Viridiflorol (25.9%), camphor (9.8%), caryophyllene oxide (9.6%), 15-hexadecanolide (9.4%), hexadecanoic acid (8.2%), and β-eudesmol (7.4%)	NR	OS				Nevşehir: Nevşehir to Aksaray, 2 km to Camiören village, Turkey	28	97.3	
A. hamzaoglui Arabaci & Budak.	1,8-Cineole (24.1%), linalool (12.2%) camphor (6.7%), and germacrene D (6.2%)	0.07	MH				Kırşehir: Kırşehir to Mucur, Kervansaray Mountain, junction of Bahçecik, Mehtap Hil, Turkey	45	93.0	
A. kotschyi Boiss.	1,8-Cineole (22.5%), caryophyllene oxide (10.1%), *p*-cymene (8.4%), and hexadecanoic acid (7.7%)	NR	MH				Yozgat: Akdağmadeni, above Kızılcaova village, Nalbant hill, Turkey	41	93.3	
A. lycaonica Boiss. & Heldr.	Nonacosane (10.6%), heptacosane (9.2%), and pentacosane (6.1%)	NR	NH				Sivas: Ulaş, Ziyarettepe, Turkey	48	76.1	
A. millefolium L.	α-Bisabolol (11.7%), caryophyllene oxide (7.7%), and muurola-4,10(14)-dien-1-ol (6.8%)	NR	OS				Yozgat: Akdağmadeni, Karababa Mountain, South of Çerçialan	57	84.8	

							village, Turkey			
A. schischkinii Sosn.	Caryophyllene oxide (17.5%), spathulenol (9.1%), *p*-cymene (8.5%), and (*E*)-nerolidol (6.2%)	NR	OS				Sivas: Şerefiye, Karabayır Passage, Turkey	82	89.9	
A. setacea Waldst. & Kit.	α-Bisabolene oxide A (27.0%), and hexadecanoic acid (16.4%)	NR	OS				Sivas: Zara, Avşar village, near Arapça, Turkey	31	86.6	
A. sintenisii Hub. Mor.	β-Eudesmol (26.4%), hexadecanoic acid (22.7%), and caryophyllene oxide (7.5%)	NR	OS				Sivas: Ulaş, Ziyarettepe, Turkey	30	95.8	
A. vermicularis Trin.	15-Hexadecanolide (19.6%), camphor (6.7%), heptacosane (6.3%), and bornyl acetate (5.1%)	NR	NH				Van: Van-Bahçesaray yolu, Sisar deresi mevkii, Turkey	46	90.3	
A. wilhelmsii Koch.	Camphor (41.3%), caryophylladienol II (6.4%), borneol (6.2%), and camphene (6.1%)	NR	OM				Niğde: Ovacık village, Ovacık-Çamardı road, Turkey	46	97.8	
A. falcate L.	AF1: *trans*-Sabinol (19.1%), and *trans*-sabinyl acetate (11.4%)	0.05	OM	HD	GC-FID and GC-MS	Above Parts (Aerial parts)	Vicinity of the town of Maloula, Syria	91	98.4	(Radulovic et al., 2015)
	AF2: γ-Costol (8.9%), *trans*-sabinol (6.5%), spathulenol (6.4%), eugenol (5.9%), (*E*)-nerolidol (4.5%), and *trans*-sabinyl acetate (4.2%)	0.004	OS			Underground parts (Roots)		56	97.2	
A. tenuifolia Lam.	Limonene (25.6%), α-cadinol (16.4%), borneol (8.0%), and α-humulene (4.8%)	NR	MH	HD	GC-MS	Aerial parts	Tabriz-Ahar Road, Iran	45	89.0	(Piryaei and Nazemiyeh, 2016)
	Limonene (28.4%), α-cadinol (17.2%), borneol (6.8%), and α-humulene (4.5%)			HD-HS-SDME				45	85.0	
	Limonene (26.5%), α-cadinol (15.3%), borneol (5.9%), and α-humulene (5.1%)			MA-SDME				45	83.4	
A. kellalensis Boiss.	α-Thujone (70.8%), 1,8-cineole (10.9%), and camphor (6.7%)	0.7	OM	HD	GC-FID and GC-MS	Aerial parts	Kallar Mountain in Charmahal Bakhtiari Province, Iran	26	70.8	(Saeidi et al., 2016)
A. millefolium L.	1,8-Cineole (22.8%), α-pinene (7.4%), β-pinene (5.7%), and terpinen-4-ol (4.5%)	0.18	OM	HD	GC-MS	Aerial parts	Gole province entrance zone on the Ardahan, Oltu road, Turkey	17	65.9	(Sevindik et al., 2016)
A. millefolium L.	Chamazulene (17.9- 23.2%), caryophyllene oxide (7.0-8.3%), and β-eudesmol (4.1-5.2%)	0.231-0.239	NR	SD	GC-MS	NR	Local herbal tea factory Fructus, Backa Palanka, Serbia	NR	NR	(Vladic et al., 2016)

A. kellalensis Boiss	α-Thujone (70.8%), 1,8-cineole (10.9%), and camphor (6.7%)	0.7	OM	HD	GC-MS	Aerial parts	Kallar Mountain in Charmahal Bakhtiari Province, Iran	26	98.2	(Saeidi et al., 2016)
A. millefolium L.	Camphor (19.2%), borneol (15.1%), 1,8-cineole (12.3%), and α-terpineol (5.1%)	0.02	OM	HD	GC-MS	Aerial parts	A local herbal store, Bosnia	49	96.4	(Vidic et al., 2016)
A. ligustica All.	Nonacosane (15%), heptacosane (8.1%), and pentacosane (5.1%)	NR	NH	HD	GC-FID and GC-MS	Aerial parts	Lipari (Aeolian Island, Sicily), Italy	34	90.9	(Venditti et al., 2016)
	Nonacosane (21.6%), heptacosane (11.6%), and pentacosane (6.2%)					Flowers		48	90.2	
A. moschata Wulfen	Camphor (27.2%), 1,8-cineole (10.7%), and bornyl acetate (6.2%)	0.81	OM	HD	GC-FID and GC-MS	Aerial parts	Valle dei Forni (Sondrio Province, Italy)	40	94.4	(Vitalini et al., 2016)
A. vermiculata Trin.	(*E*)-β-Damascenone (27.4%), (*E*)-2-hexenal (8.0%), eugenol (6.0%) and geranyl acetone (6.0%)	0.35	OM	HD	GC-MS	Flowers	Armand district, Chaharmahal and Bakhtiari Province, South-west of Iran	40	99.6	(Pirmohammadi et al., 2016)
A. micrantha Willd.	1,8-Cineole (26.9) and camphor (17.7 %)	0.2	OM	SD	GC-MS	Leaves	Zhezkazgan (Karaganda region), Kazakhstan	38	91.3	(Sampietro et al., 2016)
A. coarctata Poir.	EO: 1,8-Cineole (18.4%), *cis*-cadin-4-en-7-ol (8.8%), and α-terpineol (7.7%)	0.04	OM	HD	GC-FID and GC-MS	Inflorescence	Trgovište, Valley of Pčinja river, Serbia	89	95.7	(Kostevski et al., 2016)
	EO: Germacrene D (25.0%), *cis*-cadin-4-en-7-ol (11.1%), and ledol (7.0%)	0.007	SH			Stem and leaf		66	92.7	
	EO: Germacrene D (12.3%), α-terpineol (8.5%), and 1,8-cineole (7.4%)	0.013	OM			Aerial Parts		81	93.6	
	Volatiles: 1,8-Cineole (53.3%), β-pinene (28.2%), and α-pinene (4.5%)	-	OM	Headspace analysis		Inflorescence		28	98.8	
	Volatiles: 1,8-Cineole (51.2%), β-pinene (14.1%), and α-pinene (6.8%)		OM			Stem and leaf		33	97.9	
	Volatiles: 1,8-Cineole (51.8%), β-pinene (18.0%), and α-pinene (5.6%)		OM			Aerial Parts		36	98.1	
A. wilhelmsii Koch.	EO: 1,8-Cineole (26.9%), nerolidol (12.9%), α-pinene (10.9%), camphor (10.0%), caryophyllene oxide (6.4%), and α-terpineol (4.5%)	Ave [xy]: 0.345	OM	HD	GC and GC-MS	Aerial Parts	Ramian Mountains, Gorgan Province, Iran	22	93.6	(Nekoei and Mohammadhosseini, 2016)
	EO: Camphor (41.4%), α-pinene (9.0%), camphene (8.9%), linalool (7.7%), and 1,8-cineole (5.1%)	Ave [xy]: 0.26		SFME				22	92.4	
	EO: Camphor (44.7%), α-pinene (10.5%), camphene (10.1%), linalool (7.6%), and 1,8-cineole (4.0%)	Ave [xy]: 0.19		MAHD				22	94.9	
	Volatiles: Camphor (32.8%),α-pinene (13.8%), *p*-cymene (10.9%), camphene (9.6%), linalool (8.1%), and limonene (3.9%)	-		HS-SPME				18	93.0	

[a] Essential oil yield (in terms of w/w%, v/w%, v/v%, ml/kg and mg/g); [b] OM: Oxygenated monoterpenes; [c] Hydrodistillation; [d] LF: Leaves flowering period; [e] LV: Leaves vegetative phase; [f] NR: Not reported; [b] MH: Monoterpene hydrocarbons; [h] TLC: Thin layer chromatography; [i] From Ankara; [j] From Eskisehir; [k] SSDE: Simultaneous steam distillation and extraction; [l] (a) Antalya: Elmali, Tekke village to Ciglikara; (b) Antalya: Anamur, Abanoz yaylasi; [m] MD-GC-MS: Multidimensional gas chromatography-mass spectrometry; [n] Column chromatography on silica gel; [o] Full flowering and post flowering; [p] GC-TOF-MS: Gas chromatography-time of flight mass spectrometry; [q] DM: Distillation method: The volume ratio water: ethylene glycol was 1:9; [r] Pressure of 10 MPa and temperatures of 40-60 °C; [s] Microdistillation (using the automatic microdistillation unit MicroDistiller from Eppendorf); [t] EO: Essential oil; [u] Ex: Extract; [v] As vegetative parts (VP); [w] SMDE: Simultaneous micro-distillation-extraction with hexane lighter than water (L-SMDE) and simultaneous micro-distillation-extraction with dichloromethane heavier than water (H-SMDE); [x] Using *n*-hexane solvent; [y] MDE: Microdistillation-extraction in a Likens-Nickerson apparatus; [z] Purchased from Australian Botanical Products,

Pty Ltd. (Hallam, Victoria, Australia); [aa] Using hexane-ether mixture (1:1); [bb] VAE-DLLME:Vortex-assisted extraction-dispersive liquid-liquid microextraction; [cc] MA-HS-SPME: Microwave-assisted distillation headspace solid phase microextraction; [dd] P1: Locality: Slano Kopovo; [ee] P2: Locality: Aradac; [ff] P3: Locality: Seèanj; [kk] From wild and cultivated plant samples; [KPL] Slopes about 930 m above the sea level; [ll] GC-EIMS: Gas chromatography-electron impact mass spectroscopy; [VV] 150 °C, 2 ml/min and 60 bar for 30 min.; [gg] SDE:Simultaneous distillation-extraction; [ss] Over nine runs; [mm] At *T*=40 °C; [nn] *T*=60 °C; [xy] Ave: Avergae

Table 4
Antibacterial activities of the extracts and essential oils of some species of *Achillea* genus worldwide.

Sample	*Achillea* species	Extracting solvent(s)	IZD (mm)[a]	MIC value	MBC value	Bacterial strain	Ref.
EO*	*A. fragrantissima* (Forssk.) Sch. Bip.	-	22	1.80 mg/ml	-	*E. coli*	(Barel et al., 1991)
			30	1.00 mg/ml		*S. typhosu*	
			15	1.80 mg/ml		*S. sonnei*	
			17	1.80 mg/ml		*P. arruginosu*	
			12	1.90 mg/ml		*K. pneumoniae*	
			20	1.50 mg/ml		*S. feacalis*	
			32	1.10 mg/ml		*S. hemolyticus*	
			35	1.20 mg/ml		*S. aureus*	
EO	*Achillea multifida* (DC.) Griseb.	-	-	250 µg/ml	-	*B. cereus*	(Baser et al., 2002)
				62.5 µg/ml		*E. aerogenes*	
				125 µg/ml		*E. coli*	
				125 µg/ml		*P. vulgaris*	
				125 µg/ml		*P. aeruginosa*	
				62.5 µg/ml		*S. typhimurium*	
				125 µg/ml		*S. aureus*	
EO	*A. taygetea* Boiss. & Heldr.	-	-	4.86 mg/ml	-	*S. aureus*	(Magiatis et al., 2002)
				4.25 mg/ml		*S. epidermidis*	
				3.67 mg/ml		*P. aeruginosa*	
				2.90 mg/ml		*E. cloacae*	
				3.23 mg/ml		*K. pneumoniae*	
				2.87 mg/ml		*E. coli*	
	A. frasii subsp.*trojana*	-	-	6.35 mg/ml	-	*S. aureus*	
				6.87 mg/ml		*S. epidermidis*	
				3.21 mg/ml		*P. aeruginosa*	
				3.87 mg/ml		*E. cloacae*	
				4.23 mg/ml		*K. pneumoniae*	
				4.96 mg/ml		*E. coli*	
EO	*A. setacea* Waldst. & Kit.	-	10.0	4.50 mg/ml	-	*S. aureus*	(Unlu et al., 2002)
			18.0	18.0 mg/ml		*S. pneumoniae*	
			8.0	>72.0 mg/ml		*M. catarrhalis*	
			11	4.50 mg/ml		*B. cereus*	
			25	2.25 mg/ml		*A. lwoffii*	
			7.0	>72.0 mg/ml		*E. aerogenes*	
			7.0	>72.0 mg/ml		*E. coli*	
			-	>72.0 mg/ml		*K. pneumoniae*	
			-	>72.0 mg/ml		*P. mirabilis*	
			-	>72.0 mg/ml		*P. aeruginosa*	
			30	0.56 mg/ml		*C. perfringens*	
			18.0	18.0 mg/ml		*M. smegmatis*	
	A. teretifolia Willd.		11	36.0 mg/ml	-	*S. aureus*	
			24	2.25 mg/ml		*S. pneumoniae*	
			9.0	>72.0 mg/ml		*M. catarrhalis*	
			13	18.0 mg/ml		*B. cereus*	
			31	1.12 mg/ml		*A. lwoffii*	
			9	72.0 mg/ml		*E. aerogenes*	
			10	36.0 mg/ml		*E. coli*	
			9.0	72.0 mg/ml		*K. pneumoniae*	
			8.0	72.0 mg/ml		*P. mirabilis*	
			-	>72.0 mg/ml		*P. aeruginosa*	
			34	0.28 mg/ml		*C. perfringens*	

			35	2.25 mg/ml		*M. smegmatis*	
EO	*A. clavennae* L.	-	15.2	-	-	*E. coli*	(Stojanovic et al., 2005)
			9.2			*S. aureus*	
			8.7			*K. pneumonia*	
			9.7			*P. aeruginosa*	
	A. holosericea Sm.		10.3			*E. coli*	
			11.2			*S. aureus*	
			12.0			*K. pneumonia*	
			10.7			*P. aeruginosa*	
EO	*A. chrysocoma* Friv.	-	15.8	-	-	*E. coli*	(Simic et al., 2000)
			17.0			*S. aureus*	
			30.0			*P. aeruginosa*	
			30.0			*K. pnezimoniue*	
EO	*A. asplenifolia* Vent.	-	19.0	-	-	*E. coli*	(Simic et al., 2002)
			18.0			*S. aureus*	
			24.0			*P. aeruginosa*	
			24.0			*K. pnezimoniue*	
EO	*A. clavennae* L.	-	6.5	-	-	*B. subtilis*	(Bezic et al., 2003)
			4.0			*B. cereus*	
			12.5			*S. aureus*	
			6.0			*S. faecalis*	
			15.0			*E. coli*	
			26.4			*K. pneumoniae*	
			18.0			*P. aeruginosa*	
			12.6			*P. mirabilis*	
EO	*A. millefolium* L. [b]	-	8.0	72.0 mg/ml	-	*S. aureus*	(Candan et al., 2003)
			14.0	4.50 mg/ml		*S. pneumoniae*	
			NA	NA**		*M. catarrhalis*	
			10.0	72.0 mg/ml		*B. cereus*	
			15.0	18.0 mg/ml		*A. lwoffii*	
			7.0	72.0 mg/ml		*E. aerogenes*	
			NA	NA		*E. coli*	
			9.0	72.0 mg/ml		*K. pneumoniae*	
			NA	NA		*P. mirabilis*	
			NA	NA		*P. aeruginosa*	
			12.0	4.50 mg/ml		*C. perfringens*	
			12.0	9.0 mg/ml		*M. smegmatis*	
EO	*A. sintenisii* Hub. Mor. [c]	-	10.0	18.0 mg/ml	-	*S. aureus*	(Sokmen et al., 2003)
			11.0	18.0 mg/ml		*S. pneumoniae*	
			9.0	36.0 mg/ml		*B. cereus*	
			26.0	1.12 mg/ml		*A. lwoffii*	
			7.0	72.0 mg/ml		*E. aerogenes*	
			8.0	4.50 mg/ml		*K. pneumoniae*	
			15.0	0.56 mg/ml		*C. perfringen*	
			14.0	0.56 mg/ml		*M. smegmatis*	
Extract		Methanol	10.0	-		*S. aureus*	
			13.0	-		*A. lwoffii*	
			11.0	-		*E. coli*	
			11.0	-		*K. pneumoniae*	
EO	*A. fragrantissima* (Forssk.) Sch. Bip.	-	10.0	-	-	*E. coli*	(El-Shazly et al., 2004)
			15.0			*P. aeruginosa*	
			15.0			*S. aureus*	

			30.0			*B. subtilis*	
Extract		*n*-hexane-ether (1 : 1, v/v)	17.0	-	-	*E. coli*	
			19.0			*P. aeruginosa*	
			NA			*S. aureus*	
			19.0			*B. subtilis*	
EO	*A. santolina* L.	-	8.0	-	-	*E. coli*	
			30.0			*P. aeruginosa*	
			13.0			*S. aureus*	
			21.0			*B. subtilis*	
Extract		*n*-hexane-ether (1 : 1, v/v)	18.0	-	-	*E. coli*	
			17.0			*P. aeruginosa*	
			NA			*S. aureus*	
			17.0			*B. subtilis*	
EO	*A. crithmifolia* Waldst. & Kit.	-	23.0	-	-	*E. coli*	(Palic et al., 2003)
			22.0			*S. aureus*	
			22.0			*K. pneumoniae*	
			20.0			*P. aeruginosa*	
	A. nobilis L.		25.0			*E. coli*	
			24.6			*S. aureus*	
			25.0			*K. pneumoniae*	
			24.2			*P. aeruginosa*	
EO	*A. clavennae* L.	-	12.5	-	-	*S. aureus*	(Skocibusic et al., 2004)
			8.0			*S. pyogenes*	
			22.0			*H. influenzae*	
			26.4			*K. pneumoniae*	
			18.0			*P. aeruginosa*	
EO	*A. biebersteini* Afan. [d]	-	12.0	36.0 mg/ml	-	*S. aureus*	(Sokmen et al., 2004)
			24.0	2.25 mg/ml		*S. pneumoniae*	
			14.0	9.0 mg/ml		*B. cereus*	
			14.0	18.0 mg/ml		*E. coli*	
			NA	>72.0 mg/ml		*P. aeruginosa*	
			30.0	0.3 mg/ml		*C. perfringens*	
			14.0	18.0 mg/ml		*M. smegmatis*	
EO	*A. falcate* L.	-	-	12.5 µg/ml	25.0 µg/ml	*B. cereus*	(Sokmen et al., 2004)
				12.5 µg/ml	25.0 µg/ml	*B. subtilis*	
				25.0 µg/ml	25.0 µg/ml	*S. aureus*	
				6.25 µg/ml	12.5 µg/ml	*S. faecalis*	
				25.0 µg/ml	25.0 µg/ml	*E. coli*	
				50.0 µg/ml	50.0 µg/ml	*P. mirabilis*	
				50.0 µg/ml	100.0 µg/ml	*P. aeruginosa*	
				25.0 µg/ml	50.0 µg/ml	*S. typhi*	
EO	*A. ligustica* All.	-	10.0	>900µg/ml	-	*S. aureus*	(Tuberoso et al., 2005)
			12.0	>900µg/ml		*E. coli*	
			0	>900µg/ml		*P. aeruginosa*	
EO	*A. clypeolata* Sm.	-	2.3	-	-	*Escherichia coli*	(Simic et al., 2005)
			7.5			*Staphylococcus aureus*	
			12.3			*Pseudomonas aeruginosa*	
			12.5			*Klebskllu pnezimoniue*	
EO	*A. aleppica* DC. subsp. *aleppica*	-	-	62.5 µg/ml	-	*E. coli*	(Iscan et al., 2006)
				250.0 µg/ml		MRSA	

					500.0 µg/ml		*E. aerogenes*	
					250.0 µg/ml		*S. typhimurium*	
					62.5 µg/ml		*B. cereus*	
					125 µg/ml		*S. epidermidis*	
					62.5 µg/ml		*S. aureus*	
	A. schischkinii Sosn.				250.0 µg/ml		*E. coli*	
					250.0 µg/ml		MRSA	
					250.0 µg/ml		*E. aerogenes*	
					125.0 µg/ml		*S. typhimurium*	
					125.0 µg/ml		*B. cereus*	
					62.5.0 µg/ml		*S. epidermidis*	
					125.0 µg/ml		*S. aureus*	
EO	*A. ligustica* All.	LV [e]	-	10.3	-	-	*S. aureus*	(Bader et al., 2007)
				11.3				
				13.0			*P. aeruginosa*	
				12.0				
				11.2			*E. coli*	
				24.3				
		FL [f]		10.7			*H. alvei*	
				11.3				
				13.3			*L. monocytogenes*	
				11.7				
				12.7			*B. cereus*	
				23.7				
EO	*A. nobilis* L.		-	14.0	-	-	*E. coli*	(Karamenderes et al., 2007)
				NA			*P. aeruginosa*	
				10.0			*S. epidermidis*	
				14.0			*S. aureus*	
				12.0			*S. typhimurium*	
				9.0			*E. cloacae*	
				10.0			*E. faecalis*	
				14.0			*P. vulgaris*	
EO	*A.ligustica* All.		-	0-8 [g]	-	-	*E. coli*	(Filippi et al., 2006)
				0-17			*C. jeikeium*	
				0-11.5			*N. asteroids*	
				0-18			*S. coelicolor*	
				0-17			*S. avidinii*	
				9-20			*S. albus*	
				0-9			*P. aeruginosa*	
				0-8			*E. faecalis*	
				6.5-9			*S. aureus*	
EO	*A. collina* (Becker ex Wirtg.) Heimerl	Pure	-	14.0	-	-	*E. coli*	(Bozin et al., 2008)
				34.0			*S. aureus*	
				16.7			*S. pneumonia*	
				61.8			*S .viridans*	
				21.8			*S. pyogenes*	
				24.0			*S. agalactiae*	
		50%		12.0			*E. coli*	
				26.0			*S. aureus*	
				16.0			*S. pneumonia*	
				60.0			*S .viridans*	
				20.0			*S. pyogenes*	
				18.2			*S. agalactiae*	
	A. pannonica Scheele	Pure	-	18.6	-	-	*E. coli*	
				66.6			*S. aureus*	
				65.6			*S. pneumonia*	
				32.8			*S .viridans*	
				63.6			*S. pyogenes*	
				25.6			*S. agalactiae*	
		50%		16.0			*E. coli*	
				66.4			*S. aureus*	
				67.0			*S. pneumonia*	
				60.6			*S .viridans*	
				63.8			*S. pyogenes*	
				20.0			*S. agalactiae*	

EO	*A. teretifolia* Willd.		-	-	>2.0 mg/ml	-	*E. coli*	(Demirci et al., 2009)
					>2.0 mg/ml		*S. aureus*	
					>2.0 mg/ml		*P. aeruginosa*	
					>2.0 mg/ml		*E. aerogenes*	
					0.5 mg/ml		*P. vulgaris*	
					1.0 mg/ml		*S. typhimurium*	
					>2.0 mg/ml		*B. cereus*	
	A. nobilis L.				>2.0 mg/ml		*E. coli*	
					>2.0 mg/ml		*S. aureus*	
					>2.0 mg/ml		*P. aeruginosa*	
					>2.0 mg/ml		*E. aerogenes*	
					>2.0 mg/ml		*P. vulgaris*	
					>2.0 mg/ml		*S. typhimurium*	
					0.5 mg/ml		*B. cereus*	
EO	*A. ligustica* All.	FL	-	-	1250 µg/ml	2500 µg/ml [h]	*S. aureus*	(Maggi et al., 2009)
					155 µg/ml	310 µg/ml	*S. mutans*	
					78 µg/ml	78 µg/ml	*B. subtilis*	
					2500 µg/ml	5000 µg/ml	*E. faecalis*	
					310 µg/ml	625 µg/ml	*E. coli*	
		VP [i]			1250 µg/ml	2500 µg/ml	*S. aureus*	
					39 µg/ml	39 µg/ml	*S. mutans*	
					39 µg/ml	39 µg/ml	*B. subtilis*	
					1250 µg/ml	5000 µg/ml	*E. faecalis*	
					625 µg/ml	2500 µg/ml	*E. coli*	
EO	*A. coarctata* Poir.	INF [j]	-	-	100 µg/ml	200 µg/ml	*S. aureus*	(Tzakou et al., 2009)
					25 µg/ml	50 µg/ml	*S. epidermidis*	
					3.25 µg/ml	6.5 µg/ml	*M. flavus*	
					3.25 µg/ml	6.5 µg/ml	*E. faecalis*	
					25 µg/ml	50 µg/ml	*E. coli*	
					25 µg/ml	50 µg/ml	*K. pneumoniae*	
					100 µg/ml	400 µg/ml	*P. aeruginosa*	
		LV			100 µg/ml	200 µg/ml	*S. aureus*	
					50 µg/ml	100 µg/ml	*S. epidermidis*	
					3.25 µg/ml	6.5 µg/ml	*M. flavus*	
					6.5 µg/ml	13.0 µg/ml	*E. faecalis*	
					25 µg/ml	50 µg/ml	*E. coli*	
					25 µg/ml	50 µg/ml	*K. pneumoniae*	
					100 µg/ml	200 µg/ml	*P. aeruginosa*	
Extract	*A. teretifolia* Willd.		Chloroform	12	-	-	*E. coli*	(Turkoglu et al., 2010)
				13			*S. aureus*	
				15			*B. cereus*	
				16			*P. aeruginosa*	
				13			*K. pneumonia*	
				11			*E. aerogenes*	

EO	*A. biebersteinii* Afan.	-	9.0×	250.0µlml^{-1}	-	*A. piechaudii* RK-155	(Kotan et al., 2010)
			8.0×	500.0 µlml^{-1}		*B. pumilus* RK-106	
			10.0×	250.0 µlml^{-1}		*E. intermedius* RK-90	
			10.0×	250.0 µlml^{-1}		*E. caratovora* subsp. *atroceptica* RK-462	
			9.0×	250.0 µlml^{-1}		*E. chrysanthemi* RK-421	
			13.0×	250.0 µlml^{-1}		*E. rhapontici* RK-208	
			11.0×	125.0 µlml^{-1}		*Flavobacter sp.* RK-299	
			9.0×	125.0 µlml^{-1}		*P. agglomerans* RK-84	
			11.0×	250.0 µlml^{-1}		*P. aeruginosa* RK-168	
			11.0×	250.0 µlml^{-1}		*P. cichorii* RK-166	
			16.0×	250.0 µlml^{-1}		*P. syringae* pv. *syringae* RK-204	
			9.0×	250.0 µlml^{-1}		*P. syringae* pv. *tomato* RK-Ps-tom	
			13.0	125.0 µlml^{-1}		*X. axonopodis* pv. *malvacearum* RK-Xa-mal	
			9.0×	250.0 µlml^{-1}		*X. axonopodis* pv. *vesicatoria* Xcv110c	
			12.0×	250.0 µlml^{-1}		*X. axonopodis* pv. *campestris* RK-Xa-cam	
			12.0×	250.0 µlml^{-1}		*X. campestris* pv. *raphani* RK-Xc-rap	
			16.0	125.0 µlml^{-1}		*X. axonopodis* pv. *vesicatoria* RK-Xcv761	
			11.0×	125.0 µlml^{-1}		*X. axonopodis* pv. *vitians* Xa-vit	
			8.0×	250.0 µlml^{-1}		*X. campestris* pv. *zinniae* Xc-zin	
			16.0	125.0 µlml^{-1}		*X. axonopodis* pv. *pelargonii* RK-Xa-pel	
EO	*A. odorata* L.	-	6.0	-	-	*Pseudomonas aeruginosa*	(Bekhechi et al., 2011)
			17.0			*E. coli*	
			9.0			*S. aureus*	
			7.0			*E. faecalis*	
Extract	*A. aleppica* D.C. subsp. *aleppica*	Ethanol	10	-	-	*K. pneumoniae*	(Baris et al., 2011)
			10			*E. cloacae*	
			10			*S. typhimurium*	
			30			*S. epidermis*	
			8			*E. coli*	
			8			*E. aerogenes*	
			10			*S. aureus*	
			8			*K. oxytoca*	
			10			*S. pyogenes*	

				10			*P. aeruginosa*	
	A. aleppica D.C. subsp. *zederbaueri* (Hayek) Hub.-Mor			10	-	-	*K. pneumoniae*	
				10			*E. cloacae*	
				10			*S. typhimurium*	
				28			*S. epidermis*	
				10			*E. coli*	
				10			*E. aerogenes*	
				10			*S. aureus*	
				10			*K. oxytoca*	
				10			*S. pyogenes*	
				12			*P. aeruginosa*	
	A.biebersteinii Afan.			10	-	-	*K. pneumoniae*	
				10			*E. cloacae*	
				10			*S. typhimurium*	
				24			*S. epidermis*	
				10			*E. coli*	
				10			*E. aerogenes*	
				10			*S. aureus*	
				8			*K. oxytoca*	
				10			*S. pyogenes*	
				14			*P. aeruginosa*	
EO	*A. formosa* (Boiss.) Sch. Bip. subsp. *amanica* (Rech. f.) Ehrend. & Y.P. Guo		-	-	50.0 µg/ml	-	*E. faecalis*	(Kucukbay et al., 2011)
					25.0 µg/ml		*S. aureus*	
					200.0 µg/ml		*E. coli*	
					200.0 µg/ml		*P. aeruginosa*	
EO	*A. ligustica* All.	FL	-	-	78.0 µg/ml		*B. cereus*	(Cecchini et al., 2012)
					5000 µg/ml		*E. avium*	
					310 µg/ml		*L. acidophilus*	
					310 µg/ml		*S. aureus*	
					625 µg/ml		*S. dysgalactiae*	
					155 µg/ml		*S. mutans*	
					78.0 µg/ml		*S. pyogenes*	
					1250 µg/ml		*S. salivarius*	
		LV			310 µg/ml		*B. cereus*	
					2500 µg/ml		*E. avium*	
					2500 µg/ml		*L. acidophilus*	
					625 µg/ml		*S. aureus*	
					1250 µg/ml		*S. dysgalactiae*	
					155 µg/ml		*S. mutans*	
					155 µg/ml		*S. pyogenes*	
					1250 µg/ml		*S. salivarius*	
		AP [k]			155 µg/ml		*B. cereus*	
					2500 µg/ml		*E. avium*	
					1250 µg/ml		*L. acidophilus*	
					625 µg/ml		*S. aureus*	
					1250 µg/ml		*S. dysgalactiae*	
					38 µg/ml		*S. mutans*	
					78 µg/ml		*S. pyogenes*	
					625 µg/ml		*S. salivarius*	
EO	*A. ageratum* L.	Wild	Leaves	-	27.0	-	-	*S. aureus*	(El Bouzidi et al., 2012)
					59.3			*M. luteus*	
					40.3			*B. subtilis*	
					27.3			*B. cereus*	
					8.8			*E. coli* ATCC 25922	
					9.3			*E. coli* CCMM B4	
					10.7			*E. cloacae*	
					9. 2			*Salmonella sp.*	
					34.8			*C. albicans* CCMM L4	
					18.5			*C. albicans* CCMM L5	
					15.0			*C. krusei*	
					20.7			*C. glabrata*	
					17.3			*C. parapsilosis*	
					29.3			*S. aureus*	

			Flowers		42.3			*M. luteus*	
					26.0			*B. subtilis*	
					26.0			*B. cereus*	
					9.0			*E. coli* ATCC 25922	
					9.0			*E. coli* CCMM B4	
					10.0			*E. cloacae*	
					9.0			*Salmonella sp.*	
					28.0			*C. albicans* CCMM L4	
					15.7			*C. albicans* CCMM L5	
					17.0			*C. krusei*	
					18.3			*C. glabrata*	
					17.7			*C. parapsilosis*	
		Cultivated	Leaves		24.0			*S. aureus*	
					59.3			*M. luteus*	
					40.0			*B. subtilis*	
					24.3			*B. cereus*	
					N.A.			*E. coli* ATCC 25922	
					N.A.			*E. coli* CCMM B4	
					N.A.			*E. cloacae*	
					N.A.			*Salmonella sp.*	
					34.0			*C. albicans* CCMM L4	
					17.0			*C. albicans* CCMM L5	
					12.2			*C. krusei*	
					17.3			*C. glabrata*	
					14.7			*C. parapsilosis*	
			Flowers		28.3			*S. aureus*	
					35.3			*M. luteus*	
					25.3			*B. subtilis*	
					25.0			*B. cereus*	
					N.A.			*E. coli* ATCC 25922	
					N.A.			*E. coli* CCMM B4	
					N.A.			*E. cloacae*	
					N.A.			*Salmonella sp.*	
					26.7			*C. albicans* CCMM L4	
					14.7			*C. albicans* CCMM L5	
					14.3			*C. krusei*	
					18.0			*C. glabrata*	
					17.3			*C. parapsilosis*	
EO	*A. cretica* L.			-	-	>1000 µg/ml	-	*S. epidermidis*	(Kucukbay et al., 2012)
						125 µg/ml		*S. aureus*	
						>1000 µg/ml		*S. hominis*	
						>1000 µg/ml		*S. warneri*	
						62.5 µg/ml		*B. cereus*	
						>1000µg/ml		*E. coli*	
						>1000 µg/ml		*S. flexneri*	
						>1000 µg/ml		*Salmonella*	
EO	*A. umbellata* Sm.			-	-	0.39 mg/ml	-	*S. aureus* isolate	(Radulovic et al., 2012)

				3.12 mg/ml		*E. coli* isolate	
				0.78 mg/ml		*E. coli*	
				1.56 mg/ml		*K. pneumoniae* isolate	
				0.39 mg/ml		*K. pneumoniae*	
				1.56 mg/ml		*Proteus sp.* isolate	
				6.25 mg/ml		*P. aeruginosa* isolate	
				3.12 mg/ml		*S. enterica* isolate	
EO	*A. sieheana* Stapf.	-	9.0	-	-	*A. hydrophila*	(Albayrak, 2013)
			8.0			*E. coli*	
			10.0			*M. morganii*	
			7.5			*K. pneumoniae*	
			8.5			*P. mirabilis*	
			8.0			*P. aeruginosa*	
			9.0			*S. typhimurium*	
			8.0			*Y. enterocolitica*	
			10.5			*B. brevis*	
			10.0			*B. cereus*	
			9.0			*B. subtilis*	
			9.0			*L. monocytogenes*	
			8.0			*S. aureus*	
Extract		Methanol	7.0-9.0 [l]			*A. hydrophila*	
			8.5 [m]			*K. pneumoniae*	
			7.0-9.0 [l]			*P. aeruginosa*	
			7.0 [m]			*Y. enterocolitica*	
			6.5-10.0 [n]			*B. brevis*	
			7.0-13.0 [l]			*B. cereus*	
			10.0-13.0 [o]			*L. monocytogenes*	
			7.0-8.0 [o]			*S. aureus*	
EO	*A. pachycephala* Rech.f.	FL	11.5	-	-	*B. cereus*	(Motavalizadehkakhky et al., 2013b)
			11.0			*B. subtillis*	
			12.0			*S. aureus*	
			19.0			*E. coli*	
			22.5			*K. pneumonia*	
			13.0			*P. vulgaris*	
			25.5			*S. typhi*	
		LV	10.0	-	-	*B. cereus*	
			10.5			*B. subtillis*	
			10.5			*S. aureus*	
			21.0			*E. coli*	
			18.0			*K. pneumonia*	
			11.0			*P. vulgaris*	
			27.0			*S. typhi*	
		ST [p]	7.0	-	-	*B. cereus*	
			7.5			*B. subtillis*	
			8.0			*S. aureus*	
			19.5			*E. coli*	
			20.5			*K. pneumonia*	
			9.5			*P. vulgaris*	
			25.0			*S. typhi*	
Extract		Hexane-ether	15.0	12.5 mg/ml	25.0 mg/ml	*B. cereus*	
			12.5	6.25 mg/ml	25.0 mg/ml	*B. subtillis*	

			14.0	6.25 mg/ml	12.5 mg/ml	*S. aureus*	
			24.0	6.5 mg/ml	25.0 mg/ml	*E. coli*	
			26.0	3.12 mg/ml	12.5 mg/ml	*K. pneumonia*	
			12.0	1.56 mg/ml	1.56 mg/ml	*P. vulgaris*	
			24.5	1.56 mg/ml	-	*S. typhi*	
		Methanolic	9.0	25.0 mg/ml	50.0 mg/ml	*B. cereus*	
			7.0	12.5 mg/ml	50.0 mg/ml	*B. subtillis*	
			6.0	12.5 mg/ml	25.0 mg/ml	*S. aureus*	
			10.0	12.5 mg/ml	50.0 mg/ml	*E. coli*	
			9.0	6.25 mg/ml	12.5 mg/ml	*K. pneumonia*	
			10.5	0.39 mg/ml	3.12 mg/ml	*P. vulgaris*	
			9.5	6.25 mg/ml	12.5 mg/ml	*S. typhi*	
EO	*Achillea santolina* L.	FL	12.0	-	-	*B. cereus*	
			14.0			*B. subtillis*	
			9.0			*S. aureus*	
			25.0			*E. coli*	
			23.0			*K. pneumonia*	
			26.0			*P. vulgaris*	
			19.0			*S. typhi*	
		LV	11	-	-	*B. cereus*	
			12.5			*B. subtillis*	
			7.5			*S. aureus*	
			21.0			*E. coli*	
			22.5			*K. pneumonia*	
			27.5			*P. vulgaris*	
			15.0			*S. typhi*	
		ST	9.0	-	-	*B. cereus*	
			12.5			*B. subtillis*	
			6.5			*S. aureus*	
			22.0			*E. coli*	
			21.5			*K. pneumonia*	
			21.0			*P. vulgaris*	
			10.0			*S. typhi*	
Extract		Hexane-ether	13.5	12.5 mg/ml	12.5 mg/ml	*B. cereus*	
			14.0	12.5 mg/ml	25.0 mg/ml	*B. subtillis*	
			7.0	6.25 mg/ml	12.5 mg/ml	*S. aureus*	
			25.0	6.25 mg/ml	12.5 mg/ml	*E. coli*	
			24.0	6.25 mg/ml	12.5 mg/ml	*K. pneumonia*	

			23.5	0.78 mg/ml	3.12 mg/ml	*P. vulgaris*	
			9.0	1.56 mg/ml	-	*S. typhi*	
		Methanolic	8.5	25.0 mg/ml	50.0 mg/ml	*B. cereus*	
			10.0	25.0 mg/ml	50.0 mg/ml	*B. subtillis*	
			5.0	12.5 mg/ml	25.0 mg/ml	*S. aureus*	
			10.5	12.5 mg/ml	50.0 mg/ml	*E. coli*	
			10.0	0.78 mg/ml	6.25 mg/ml	*K. pneumonia*	
			9.0	0.78 mg/ml	3.12 mg/ml	*P. vulgaris*	
			7.0	-	-	*S. typhi*	
Extract	*A. bieberesteinii* Afan.	Water	1.7-3.0 [q]	-	-	*Xanthomonas arboricola pv. juglandis*	(Soltani and Aliabadi, 2013)
	A. millefolium L.						
	A. tenuifolia Lam.						
	A. vermiculatus Trin						
EO	*A. wilhelmsii* Koch.	-	-	2.6 µg/ml	2.6 µg/ml	*B. cereus*	(Kazemi and Rostami, 2015)
				5.5 µg/ml	5.5 µg/ml	*E. cloacea*	
				5.5 µg/ml	5.0 µg/ml	*E. faecalis*	
				5.5 µg/ml	5.5 µg/ml	*L. monocytogenes*	
				15.0 µg/ml	10.0 µg/ml	*S. aureus*	
				5.0 µg/ml	5.0 µg/ml	*A. baumanii*	
				2.0 µg/ml	2.5 µg/ml	*E. coli*	
				5.0 µg/ml	5.0 µg/ml	*K. pneumoniae*	
				15.0 µg/ml	10.0 µg/ml	*P. aeruginosa*	
				5.0 µg/ml	5.0 µg/ml	*P. mirabilis*	
EO	*A. wilhelmsii* Koch.	-	6.25-19 [r]	-	-	MRSA	(Alfatemi et al., 2015)
			11.56 - 22.56 [r]	-	-	MSSA	
EO	*A. biebersteinii* Afan.	-	21.5	-	-	*S. aureus*	(Almadiy et al., 2016)
			16.5			*L. monocytogenes*	
			19.3			*E. coli*	
			15.5			*P. aeruginosa*	
			18.0			*S. enteritidis*	
	A. fragrantissima (Forssk.) Sch. Bip.		18.0	-	-	*S. aureus*	
			15.5			*L. monocytogenes*	
			19.7			*E. coli*	
			14.0			*P. aeruginosa*	
			17.8			*S. enteritidis*	
	A. santolina L.		16.5	-	-	*S. aureus*	
			15.0			*L. monocytogenes*	
			14.0			*E. coli*	
			9.5			*P. aeruginosa*	

				13.0			*S. enteritidis*	
	A. millefolium L.			15.7	-	-	*S. aureus*	
				16.0			*L. monocytogenes*	
				14.5			*E. coli*	
				8.0			*P. aeruginosa*	
				12.7			*S. enteritidis*	
Extract	*A. millefolium* L.		Methanol	10.0	62.5 mg/ml	-	*S. aureus*	(Bobis et al., 2015)
				8.0	70.42		*B. cereus*	
				NA	NA		*E. coli*	
				NA	NA		*P. aeruginosa*	
				NA	NA		*S. typhimurium*	
EO	*A. ligustica* All.	IF	-	-	155 µg/ml	-	*S. mutans*	(Freires et al., 2015)
					1250 µg/ml	-	*S. salivarius*	
					310 µg/ml	-	*L. acidophilus*	
		LV			155 µg/ml	-	*S. mutans*	
					1250 µg/ml	-	*S. salivarius*	
					2500 µg/ml	-	*L. acidophilus*	
		AP [s]			38 µg/ml	-	*S. mutans*	
					625 µg/ml	-	*S. salivarius*	
					1250 µg/ml	-	*L. acidophilus*	
Extract	*A. millefolium* L.		Ethanol	8-11 [t]	-	-	*S. aureus*	(Jesionek et al., 2015)
				6-8 [t]			MRSA	
				8-10 [t]			*S. epidermidis*	
EO	*A. collina* (Becker ex Wirtg.) Heimerl		-	11.05	-	-	*S. flexneri*	(Jianu et al., 2015)
				10.94			*K. pneumoniae*	
				10.14			*S. typhimurium*	
				8.98			*S. aureus*	
				12.97			*E. coli*	
EO	*A. millefolium* L.		-	-	2.5 µg/ml	5.0 µg/ml	*B. cereus*	(Kazemi, 2015a)
					5.0 µg/ml	10.0 µg/ml	*E. faecalis*	
					5.0 µg/ml	10.0 µg/ml	*S. aureus*	
					2.5 µg/ml	5.0 µg/ml	*E. coli*	
					2.5 µg/ml	5.0 µg/ml	*P. aeruginosa*	
					2.5 µg/ml	5.0 µg/ml	*P .mirabilis*	
					5.0 µg/ml	10.0 µg/ml	*S. typhimurium*	
					5.0 µg/ml	10.0 µg/ml	*C. freundii*	
EO	*A. hamzaoglui* Arabaci & Budak.		-	-	625 µg/ml	-	*E. coli*	(Turkmenoglu et al., 2015)
					312.5 µg/ml		*S. typhimurium*	
					156.25 µg/ml		*P. aeruginosa*	
					78.12 µg/ml		*S. aureus*	
					156.25 µg/ml		*P. acnes*	
					312.5 µg/ml		*S. mitis*	
Extract			Methanol		625 µg/ml		*E. coli*	
					625 µg/ml		*S. typhimurium*	
					156.25 µg/ml		*P. aeruginosa*	
					625 µg/ml		*S. aureus*	
					625 µg/ml		*P. acnes*	
					625 µg/ml		*S. mitis*	
EO	*A. santolinoides* subsp *wilhelmsii* (K. Koch) Greuter		-	-	128 µg/ml	-	*S. aureus*	(Fahed et al., 2016)
					>512 µg/ml		*P. aeruginosa*	
EO	*A. millefolium* L.		-	21.0	-	-	MRSA	(Sevindik et al., 2016)
				14.0			*S. aureus*	
				10.0			*P. aeruginosa*	
				11.0			*E. coli*	
				12.0			*B. cereus*	

*EO: Essential oil; **NA: Not active; [a] IDZ: inhibition zone diameter; [b] Water-insoluble parts of the methanolic extracts were found to have moderate activity against *C. perfringens* (IZD: 12.0 mm), while the corresponding water soluble parts were inactive againts all the tested bacterial strains.; [c] The essential oil was inactive against *E. coli*, while the water insoluble methanolic extract was not active against *S. pneumonia*, *C. perfringen* and *M. smegmatis*; [d] Water-insoluble parts ($CHCl_3$) of the methanolic extracts were found to have moderate activity against *C. perfringens* (IZD-12.0 mm); [e] LV: Leaves; [f] FL: Flower; [g] At oil concentrations 1.5%-100%; [h] Mentioned as minimal lethal concentration (MLC); [i] VP: Vegetative parts (stems/leaves); [j] IF: Inflorescences; [x] Bactericidal effect was observed; [k] AP: Aerial parts; [l] Over the methanol extract (%) 1-10%; [m] At the methanol extract (%) of 10.0%; [n] Over the methanol extract (%) 2.5-10%; [o] Over the methanol extract (%) 5.0-10.0%; [p] ST: Stem; [q] *A. vermiculatus* showed the highest antibacterial effects on *Xanthomonas arboricola* pv. Juglandis; [r] Over the essential oil volume of 25-100 µl; [s] AP: Aerial parts; [t] When using 5-10 µl of the extracts

Table 5
Antifungal activities of the extracts and essential oils of some species of *Achillea* genus.

Sample	*Achillea* species	Extracting solvent(s)	Fungi	Antifungal activity				Ref.
				Activity	MIC *	MLC **	IZD (mm)***	
EO****	*A. atrata* L.	-	*A. alternata*	4.0 µl/ml	-	-	-	(Ristic et al., 2004)
			A. niger	4.0 µl/ml	-	-	-	
			A. ochraceus	4.0 µl/ml	-	-	-	
			A. versicolor	5.0 µl/ml	-	-	-	
			A. flavus	5.0 µl/ml	-	-	-	
			A. terreus	4.0 µl/ml	-	-	-	
			C. cladosporioides	3.0 µl/ml	-	-	-	
			F. tricinctum	4.5 µl/ml	-	-	-	
			P. ochrochloron	7.0 µl/ml	-	-	-	
			P. funiculosum	7.0 µl/ml	-	-	-	
			P. helianthi	2.0 µl/ml	-	-	-	
			T. viride	7.0 µl/ml	-	-	-	
			T. mentagrophytes	2.0 µl/ml	-	-	-	
			T. rubrum	3.0 µl/ml	-	-	-	
			T. tonsurans	3.0 µl/ml	-	-	-	
			M. canis	6.0 µl/ml	-	-	-	
			M. gypseum	6.0 µl/ml	-	-	-	
			E. floccosum	6.0 µl/ml	-	-	-	
EO	*A. clavennae* L.	-	*A. niger*	21 (20 µl/disc)	-	-	-	(Bezic et al., 2003)
			A. fumigatus	22 (20 µl/disc)	-	-	-	
			C. albicans	24 (20 µl/disc)	-	-	-	
EO	*A. millefolium* L.	-	*C. albicans* ATCC 1023	-	2.5 [a]; 2.5 [b]	2.5 [a]; 2.5-5.0 [b]	-	(Falconieri et al., 2011)
			C. tropicalis ATCC 13803	-	2.5 [a]; 2.5 [b]	2.5 [a]; 5.0 [b]	-	
			C. krusei H9	-	2.5 [a]; 2.5 [b]	2.5 [a]; 5.0 [b]	-	
			C. guillermondii MAT23	-	1.25 [a]; 1.25 [b]	1.25 [a]; 2.5 [b]	-	
			C. parapsilosis ATCC 90018	-	2.5 [a]; 2.5 [b]	2.5 [a]; ≥20 [b]	-	
			C. neoformans CECT 1078	-	1.25 [a]; 0.64 [b]	1.25 [a]; 1.25 [b]	-	

			T. mentagrophytes FF7	-	0.64 [a]; 0.32	0.64 [a]; 0.64 [b]	-	
			M. canis FF1	-	0.32 [a]; 0.64 [b]	0.32 [a]; 0.64-1.25 [b]	-	
			T. rubrum CECT 2794	-	0.32 [a]; 0.32 [b]	0.64 [a]; 1.25 [b]	-	
			M. gypseum CECT 2905	-	0.64 [a]; 0.64 [b]	0.64 [a]; 0.64-1.25 [b]	-	
			E. floccosum FF9	-	0.64 [a]; 0.64 [b]	0.64 [a]; 0.64 [b]	-	
			T. mentagrophytes var. *interdigitale* CECT 2958	-	0.64 [a]; 0.64 [b]	1.25 [a]; 1.25 [b]	-	
			T. verrucosum CECT 2992	-	1.25 [a]; 0.64 [b]	1.25 [a]; 1.25 [b]	-	
			A. niger ATCC16404	-	5.0 [a]; 1.25 [b]	>20 [a]; >20 [b]	-	
			A. fumigatus ATCC 46645	-	2.5-5.0 [a]; 1.25 [b]	>20 [a]; >20 [b]	-	
			A. flavus F44	-	10.0 [a]; 1.25 [b]	>20 [a]; >20 [b]	-	
EO		*A. clavennae* L.	-	*A. niger* ATCC 16404	-	-	-	14.2	(Stojanovic et al., 2005)
				C. albicans ATCC 10231	-	-	-	17.7	
		A. holosericea Sm.	-	*A. niger* ATCC 16404	-	-	-	7.4	
				C. albicans ATCC 10231	-	-	-	7.6	
EO		*A. fragrantissima* (Forssk.) Sch. Bip.	-	*C. albicans*	-	-	-	35	(Barel et al., 1991)
EO		*A. taygetea* Boiss. & Heldr.	-	*C. albicans*	-	1.67 mg/ml	-	-	(Magiatis et al., 2002)
				C. tropicalis	-	1.23 mg/ml	-	-	
				C. glabrata	-	1.17 mg/ml	-	-	
EO		*A. millefolium* L.	-	*C. albicans*	-	4.50 mg/ml	-	21.0	(Candan et al., 2003)
				C. krusei	-	18.0 mg/ml	-	16.0	
Extract			Methanol [c]	*C. albicans*	-	-	-	12.0	
				C. krusei	-	-	-	12.0	
EO		*A. sintenisii* Hub. Mor.	-	*C. albicans*		9.0 mg/ml	-	18.0	(Sokmen et al., 2003)
				C. krusei		9.0 mg/ml	-	15.0	
Extract			Methanol	*C. albicans*	-	-	-	16.0	
EO		*A. fragrantissima* (Forssk.) Sch. Bip.	-	*C. albicans*	-	-	-	30.0	(El-Shazly et al., 2004)
Extract			*n*-hexane-ether		-	-	-	15.0	
EO		*A. santolina* L.	-		-	-	-	27.0	
Extract			*n*-hexane-ether		-	-	-	13.0	
EO	CO [d]	*A. biebersteinii* Afan.	-	*C. albicans*	-	0.15 mg/ml	-	>60.0	(Sokmen et al., 2004)

	OF [e]					-		11->60.0	
Extract			Methanol		-	-	-	12.0	
EO		*A. ligustica* All.	-	*C. albicans*	-	>900 µg/ml	-	20.0	(Tuberoso et al., 2005)
EO		*A. schischkinii* Sosn.	-	*C. albicans*	-	125 µg/ml	-	-	(Iscan et al., 2006)
		A. aleppica DC. subsp. *aleppica*			-	62.5 µg/ml	-	-	
EO		*A. ligustica* All.	-	*C. albicans*	-	-	-	24.3 and 23.7 [f]	(Bader et al., 2007)
EO	*A. ligustica* All.	FP [g]	-	*C. albicans*	-	625 µg/ml	625 µg/ml	-	(Maggi et al., 2009)
		VP [h]				625 µg/ml	625 µg/ml		
EO		*A. coarctata* Poir.	-	*C. albicans*	-	3.25 [i] µg/ml	6.5 [i] µg/ml	-	(Tzakou et al., 2009)
Extract		*A. teretifolia* Willd.	Chloroform	*C. albicans*	-	-	-	14.0	(Turkoglu et al., 2010)
Extract		*A. aleppica* D.C. subsp. *aleppica*	Ethanol	*C. albicans*	-	-	-	8.0	(Baris et al., 2011)
		A. aleppica D.C. subsp. *zederbaueri* (Hayek) Hub.-Mor						10.0	
		A.biebersteinii Afan.						10.0	
EO		*A. formosa* (Boiss.) Sch. Bip. subsp. *amanica* (Rech. f.) Ehrend. & Y.P. Guo	-	*C. albicans*	-	12.5 µg/ml	-	-	(Kucukbay et al., 2011)
				C. tropicalis	-	12.5 µg/ml	-	-	
EO		*A. umbellata* Sm.	-	*C. albicans*	-	1.56 µg/ml	-	-	(Radulovic et al., 2012)
				C. albicans ATCC 10231	-	0.39 µg/ml	-	-	
EO		*A. sieheana* Stapf.	-	*S. cerevisiae*	-	-	-	14.0	(Albayrak, 2013)
EO		*A. aleppica* D.C. subsp. *zederbaueri* (Hayek) Hub.-Mor	-	*C. albicans*	-	1.0 µg/ml	1.0 µg/ml	-	(Kazemi and Rostami, 2015)
				C. parapsilosis		1.5 µg/ml	1.5 µg/ml		
				A. niger		2.5 µg/ml	2.0 µg/ml		
				A. fumigatus		2.2 µg/ml	2.5 µg/ml		
EO		*A. hamzaoglui* Arabaci & Budak.	-	*C. krusei*	-	312.5 µg/ml	-	-	(Turkmenoglu et al., 2015)
				C. albicans					
				C. tropicalis					
				C. parapsilosis					
Extract			Methanol	*C. krusei*	-	312.5 µg/ml	-	-	
				C. albicans					
				C. tropicalis					
				C. parapsilosis		156.25 µg/ml			
EO		*A. nobilis* L.	-	*C. tropicalis*	-	0.5 mg/ml	-	-	(Demirci et al., 2009)
		A. teretifolia Willd.		*C. tropicalis*		>2.0 mg/ml			
EO		*A. santolinoides* subsp *wilhelmsii* (K. Koch) Greuter	-	*C. albicans* ATCC 10231	-	256 µg/ml	-	-	(Fahed et al., 2016)
				T. rubrum SNB-TR1		32 µg/ml			

			T. mentagrophytes SNB-TM1		32 µg/ml			
			T. soudanense SNB-TS1		16 µg/ml			
			T. violaceum SNB-TV1		16 µg/ml			
			T. tonsurans SNB-TT1		16 µg/ml			

*MIC: Minimal inhibitory concentration; **MLC: Minimal lethal concentration; ***IDZ: inhibition zone diameter (mm); ****EO: Essential oil; [a, b]: From Portugal and Italy, respectively (MIC and MLC were determined by a microdilution method and expressed in µl/ml: V/V); [c] Partitioned with chloroform ($CHCl_3$) to separate less polar, water-insoluble compounds; [d] CO: Crude oil; [e] OF: Oil fractions;
[f] For flowers and leaves, respectively; [g] FL: Flowers; [h] VP: Vegetative parts; [i] For both inflorescence and leaf oils.

Table 6
Herbicidal activities of essential oils and extracts of *A. gypsicola* Hub-Mor. and *A. biebersteinii* Afan. against some of the most common weeds (Kordali et al., 2009).

Weed	Germination (%)				Root length (mm)				Radicle length (mm)			
	A. gypsicola Hub-Mor.		*A. biebersteinii* Afan.		*A. gypsicola* Hub-Mor.		*A. biebersteinii* Afan.		*A. gypsicola* Hub-Mor.		*A. biebersteinii* Afan.	
	EO	Extract	EO	Extract	EO	Extract	EO	Extract	EO	Extract	EO	Extract
Amaranthus retroflexus	0.0±0.0	1.3 ± 0.7	0.0 ± 0.0	8.7 ± 1.8	0.0 ± 0.0	2.3 ± 1.5	0.0 ± 0.0	6.7 ± 0.7	0.0 ± 0.0	9.3 ± 2.0	0.0 ± 0.0	9.6 ± 1.2
Chenopodium album	48.0 ± 4.0	28.7 ± 0.7	28.0 ± 3.1	38.0 ± 2.3	2.4 ± 0.1	6.3 ± 0.6	2.5 ± 0.1	12.5 ± 0.8	4.0 ± 0.2	9.2 ± 1.2	4.1 ± 0.2	7.5 ± 0.4
Cirsium arvense	0.0±0.0	19.3 ± 1.3	3.3 ± 0.7	46.0 ± 1.2	0.0 ± 0.0	9.7 ± 1.0	2.0 ± 0.0	15.2 ± 0.8	0.0 ± 0.0	8.3 ± 0.5	2.4 ± 0.4	10.7 ± 0.6
Lactuca serriola	0.0±0.0	31.3 ± 1.8	0.7 ± 0.7	17.3 ± 1.8	0.0 ± 0.0	9.5 ± 1.0	0.7 ± 0.7	12.7 ± 1.5	0.0 ± 0.0	5.1 ± 0.4	0.7 ± 0.7	5.7 ± 0.4
Rumex crispus	57.3 ± 1.8	56.0 ± 3.1	50.7 ± 8.2	76.7 ± 2.4	2.9 ± 0.2	17.9 ± 1.8	2.6 ± 0.2	23.5 ± 1.7	3.5 ± 0.2	6.5 ± 0.2	3.3 ± 0.1	8.5 ± 0.2

Table 7
Antioxidant activities of diverse essential oils and extracts of *Achillea* genus worldwide.

Sample	Plant name	Plant organ	Antioxidant assay	Antioxidant activity		Ref.
				IC_{50}	RSA (%)	
EO*	*A. millefolium* L.	Aerial parts	DPPH [a]	1.56 µg/ml	NR [p]	(Candan et al., 2003)
			FEHD (HRSA) [b]	407.30µg/ml		
			ILPA [c]	892.67µg/ml		
			ISRA [d]	304.00µg/ml		
Extract			DPPH	45.60µg/ml		
			FEHD (HRSA)	2.70µg/ml		
			ILPF	13.50 µg/ml		
			ISRA	NT		
EO	*A. biebersteinii* Afan.	Aerial parts	DPPH	4500 µg/ml	NR	(Sokmen et al., 2004)
			ISRA	NT		
			IHRA [e]	2.10 µg/ml		
			ILPA	18.50 µg/ml		
Extract			DPPH	49.5 µg/ml		
			ISRA	231.0 µg/ml		
			IHRA	433.3 µg/ml		
			ILPA	783.6 µg/ml		
EO	*A. collina* (Becker ex Wirtg.) Heimerl	NR	DPPH	0.62 mg/ml	17.48%-90.21% [q]	(Bozin et al., 2008)
	A. pannonica Scheele			0.52 mg/ml	0.000%-97.99% [q]	
EO	*A. teretifolia* Willd.	Aerial parts	DPPH	Both> 0.500 mg/ml	NR	(Demirci et al., 2009)
	A. nobilis L.					
Extract	*A. schischkinii* Sosn.	Aerial parts	ABTS [f]	NR	ME [r]: 87.3%	(Turkoglu et al., 2010)
					WE [s]: 80.9%	
					CH [t]: 50%	
			DPPH		ME: 68.0%	
					WE: 69.2%	
					CH: 59.2%	
			ISRA		ME: 77.1%	
					WE: 93.2%	
					CH: 45.0%	
			MSC [g]		ME: 89.0%	
					WE: 50.8%	
					CH: 4.0%	
	A. teretifolia Willd.		ABTS	NR	ME: 91.5%	
					WE: 91.2%	
					CH: 49.0%	
			DPPH		ME: 75.9%	
					WE: 69.6%	
					CH: 60.1%	
			ISRA		ME: 79.9%	
					WE: 93.6%	
					CH: 48.0%	
			MSC		ME: 55.5%	

					WE: 82.3%	
					CH: 72.9%	
Extract	*Achillea wilhelmsii* C. Koch	Aerial parts	DPPH	58.9 µg/ml	NR	(Fathi et al., 2011)
Extract	*A. aleppica* D.C. subsp. *aleppica*	Aerial parts	DPPH	33.0 µg/ml	85.0%	(Baris et al., 2011)
	A. aleppica D.C. subsp. *zederbaueri* (Hayek) Hub.-Mor			33.0 µg/ml	81.0%	
	A.biebersteinii Afan.			32.0 µg/ml	73.0%	
	A. aleppica D.C. subsp. *aleppica*		FEHD (HRSA)	NR	~70.0%	
	A. aleppica D.C. subsp. *zederbaueri* (Hayek) Hub.-Mor				~70.0%	
	A.biebersteinii Afan.				67.0%	
	A. aleppica D.C. subsp. *aleppica*		FTC [h] and TBA [i]	NR	45.0%	
	A. aleppica D.C. subsp. *zederbaueri* (Hayek) Hub.-Mor				38.0%	
	A.biebersteinii Afan.				51.0%	
Extract	*A. sieheana*	Aerial parts	PM [j], DPPH; BCLBA [k]	87.04 µg/ml	131.71[u]	(Albayrak, 2013)
Extract	*A. aucherii* Boiss.	Leaves	DPPH; FTC; BCLBA	844 µg/ml	0.00%-80.0% [v]	(Gharibi et al., 2013)
	A. pachycephalla			248 µg/ml		
	A. kellalensis Boiss.			518 µg/ml		
EO	*A. phrygia* Boiss. & Balansa	Aerial parts	DPPH	NR	40.4%	(Akcin et al., 2014)
EO	*A. ageratum* L.	Aerial parts	DPPH	7.49 mg/ml	NR	(Kasrati et al., 2015)
			RP [l]	40.00 mg/ml		
			BCLBA	0.46 mg/ml		
			ABTS	1.19 mg/ml		
EO	*A. wilhelmsii* Koch.	Aerial parts	DPPH	15 µg/ml	NR	(Kazemi and Rostami, 2015)
			BCLBA	19 µg/ml		
Extract	*A. eriophora* DC.	Aerial parts	DPPH	89.3 µg/ml [w]	0.00%-90.0% [y]	(Mottaghipisheh et al., 2015)
				245.2 µg/ml [x]		
Extract	*A. coarctata* Poir.	Aerial parts	DPPH; BCLBA	94.1 µg/ml	74.1%	(Agar et al., 2015)
	A. kotschyi Boiss.			32.6 µg/ml	60.1%	
	A. lycaonica Boiss. & Heldr.			70.0 µg/ml	81.5%	
EO	*A. wilhelmsii Koch.*	Aerial parts	DPPH	0.01 mg/ml	0.08 mg/ml (Scavenging ability)	(Alfatemi et al., 2015)
EO	*A. millefolium* L.	Inflorescences	DPPH	1.8 mg/l	NR	(Fierascu et al., 2015)
			CLA [m]	NR	89.61-96.11% [z]	
Extract			DPPH	NR	82.14%	
			CLA	NR	89.29% [1]	
Extract	*A. vermicularis*	Leaves	DPPH; BCLBA; FTC	309.7 µg/ml [2]	30.0-90.0% [3, 4]	(Gharibi et al., 2015)
	A. nobilis L.			289.5 µg/ml		
	A. wilhelmsii Koch.			609.0 µg/ml		

	A. millefolium L.			809.0 µg/ml		
	A. filipendulina Lam.			340.6 µg/ml		
	A. tenuifolia Lam.			193.5 µg/ml		
	A. biebersteinii Afan.			179 µg/ml		
	A. eriophora DC.			1172 µg/ml		
Extract	*A. millefolium* L.	Leaves	DPPH; BCLBA; FTC	NR	40.00%-70.0%[5-7]	(Gharibi et al., 2016)
	A. nobilis L.					
	A. filipendulina Lam.					
EO	*A. filipendulina* Lam.	Aerial parts	DPPH	NR	55.3%	(Hasimi et al., 2015)
EO	*A. collina* (Becker ex Wirtg.) Heimerl	Inflorescences	DPPH	25.03 µg/ml	NR	(Jianu et al., 2015)
EO	*A. millefolium* L.	Aerial parts	DPPH	22.11 mg/ml	NR	(Kazemi, 2015a)
			BCLBA	1.1 µl/ml		
			FRAP [n]	360.16 µmol Fe^{2+}/g EO		
EO	*A. millefolium* L.	Aerial parts	DPPH	20.06 µg/ml	NR	(Kazemi, 2015c)
EO	*A. tenuifolia* Lam.	Aerial parts	DPPH	15.12 µg/ml	NR	(Kazemi, 2015b)
Extract	*A. millefolium* L.	Waste yarrow	DPPH	7.89 µg/ml	MAE [8]: 71.72%	(Milutinovic et al., 2015)
					SLE [9]:51.54%	
					Maceration:21.58%	
			FRAP		MAE: 2.023 mmol/l	
					SLE: 1.544 mmol/l	
					Maceration: 0.977 mmol/l	
Extract	*A. millefolium* L.	Aerial parts	DPPH	NR	AMM [10]: 23.7%	(Sevindik et al., 2015)
					AMP [11]: 20.3%	
					AMC [12]: 7.2%	
					AME [13]: 55.1%	
					AMB [14]: 28.3%	
					AMA[15]: 2.9%	
			ABTS	NR	AMM: 34.2%	
					AMP: 30.0%	
					AMC: 32.5%	
					AME: 97.0%	
					AMB: 31.1%	
					AMA: 3.9%	
			ISRA	NR	AMM: 54.0%	
					AMP: 51.0%	
					AMC: 49.5%	
					AME: 85.5%	
					AMB: 75.8%	
					AMA: 10.9%	
			ILPA	NR	AMM: 22.2%	
					AMP: 21.5%	
					AMC: 5.3%	
					AME: 36.6%	
					AMB: 31.0%	
					AMA: 0.0%	
Extract	*A. hamzaoglui* Arabaci & Budak.	Aerial parts	DPPH	32.09 µg/ml	NR	(Turkmenoglu et al., 2015)
Extract	*A. tenorii* (Grande)		ABTS	22.49 µg/ml	TAC [16]: 1.50 Tr eq/g	

		Aerial parts	DPPH	31.41 µg/ml	TAC: 3.13 Tr eq/g	(Venditti et al., 2015)
			FRAP-FZ [o]	21.56 FRAP unit	TAC: 0.53 Tr eq/g	
EO	*A. fragrantissima* (Forssk.) Sch. Bip.	Aerial parts	H_2O_2-astrocytes	0.50 ± 0.04 [17]	-	(Eissa, T.F. et al., 2014)
Extract	*A. schurii* Schultz Bip.	Flowers	DPPH	58.87 µg/ml	-	(Benedec et al., 2016)
Extract	*A. santolina* L.	Aerial parts	DPPH	55 µg/ml	-	(Ardestani and Yazdanparast, 2007)
			ISRA	39 µg/ml		
			FEHD (HRSA)	416 and 519 µg/ml [18]		
EO	*A. millefolium* L.	Aerial parts	DPPH	32.75 mg/ml	-	(Vidic et al., 2016)
			ABTS	0.34 mg/ml	-	

*EO: Essential oil; [a] DPPH: 1,1-diphenyl-1-picrylhydrazil or 2,2-diphenyl-1-picrylhydrazil; [b] FEHD (HRSA): Fe^{3+}-EDTA-H_2O_2 deoxyribose (Hydroxyl radical scavenging activity); [c] ILPA: Inhibition of lipid peroxidation assay; [d] ISRA: Inhibition of superoxide radicals assay; [e] IHRA: Inhibition of hydroxyl radicals assay; [f] ABTS: 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulphonic acid); [g] MSC: Metal scavenging capacity; [h] FTC: Ferric thiocyanate; [i] TBA: Thiobarbituric acid; [j] PM: Phosphomolybdenum; [k] BCLBA: β-Carotene-linoleic acid bleaching assay; [l] RP: Reducing power; [m] CLA: Chemiluminescence assay; [n] FRAP: Ferric reducing antioxidant power; [o] FRAP-FZ: Ferric reducing antioxidant power-ferrozine; [p] NR: Not reported; [q] Over the concentration range 0.25-7.50 mg/ml; [r] ME: Methanol extract; [s] WE: Water extract; [t] CH: Chloroform extract; [u] mg AAE/g extract and a high reducing effect (71.08%) on the oxidation of β-carotene; [v] Over the concentration range 50-500 ppm; [w] Ethanol extract; [x] Ethyl acetate extract; [y] Over the concentration range 25-100 ppm; [z] Being diluted over the dilution factors (DF) of 10-40; [1] For the diluted extract over the range 2-8: 88.08-89.02; [2] Using the DPPH assay; [3] Using β-carotene-linoleic acid bleaching assay (BCLBA); [4] Using FTC assay reducing power of the *Achillea* extracts fall within the range: 0.306-2.311 µg/ml; [5] DPPH radical scavenging activity of the three *Achillea* species extracts (500 ppm) in four irrigation regimes: 100 % field capacity (Control), low drought stress (LDS) (75% FC), moderate drought stress (MDS) (50% FC), and severe drought stress (SDS) (25% FC); [6] Reducing power of the *Achillea* extracts compared to BHT in four irrigation regimes: 0.8-1.9; [7] In the BCLBA system % inhibition was in the range 2.5%-25%; [8] MAE: Microwave assisted extraction; [9] SLE: Solid-liquid extraction; [10] AMM: *A. millefolium* methanol extract; [11] AMP: *A. millefolium* petroleum ether extract; [12] AMC: *A. millefolium* chloroform extract; [13] AME: *A. millefolium* ethyl acetate extract; [14] AMB: *A. millefolium n*-butanol extract; [15] AMA: *A. millefolium* aqueous fractions; [16] TAC: Total antioxidant capacity; [17] µmol Trolox equivalents (TE) /mg sample; For nonsite-specific and site-specific assays, respectively.

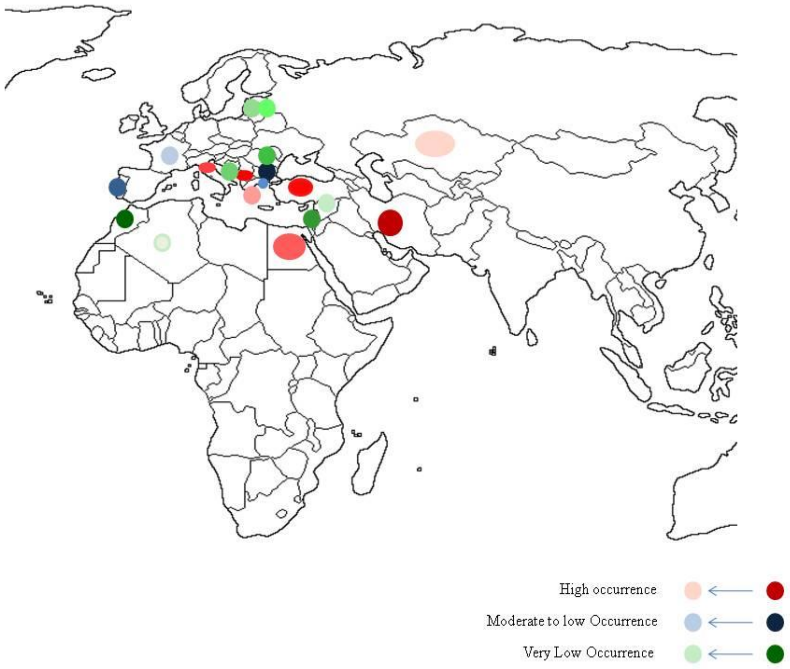
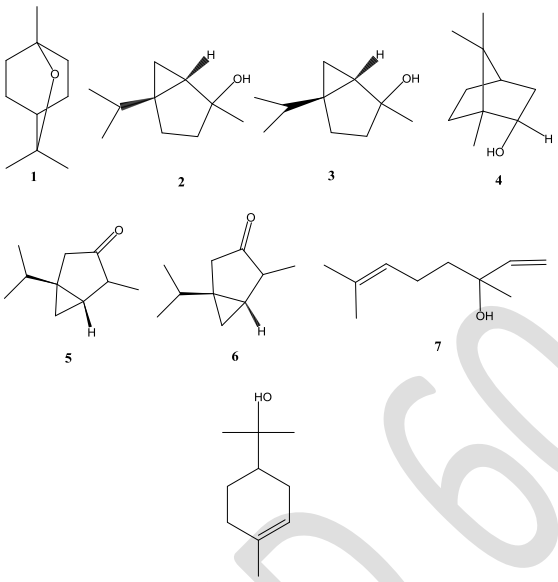


Fig. 1. Distribution of different *Achillea* species worldwide



1 2 3 4 5 6 7 8

Fig. 2. Molecular structures of the most frequently occurring oxygenated monoterpenes in the chemical profiles of the essential oils and extracts of *Achillea* species (**1**: 1,8-Cineole: $C_{10}H_{18}O$; **2**: *cis*-Sabinene hydrate: $C_{10}H_{18}O$; **3**: *trans*-Sabinene hydrate: $C_{10}H_{18}O$; **4**: Borneol: $C_{10}H_{18}O$; **5**: α-Thujone: $C_{10}H_{16}O$; **6**: β-Thujone: $C_{10}H_{16}O$; **7**: Linalool: $C_{10}H_{18}O$; **8**: α-Terpineol: $C_{10}H_{18}O$).

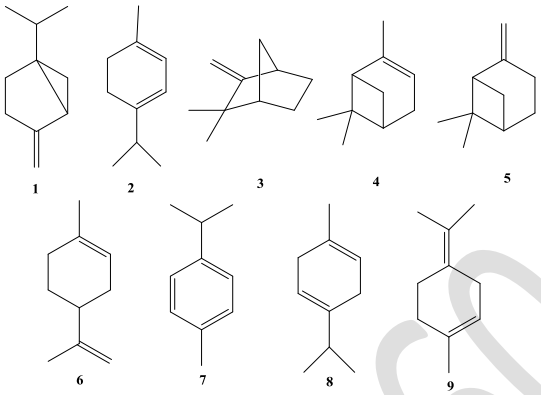


Fig. 3. Chemical structures of the main monoterpene hydrocarbons in the profiles of the essential oils and extracts of *Achillea* species (**1**: Sabinene: $C_{10}H_{16}$; **2**: α-Terpinene: $C_{10}H_{16}$; **3**: Camphene: $C_{10}H_{16}$; **4**: α-Pinene: $C_{10}H_{16}$; **5**: β-Pinene: $C_{10}H_{16}$; **6**: Limonene: $C_{10}H_{16}$; **7**: *p*-Cymene: $C_{10}H_{14}$; **8**: γ-Terpinene: $C_{10}H_{16}$; **9**: Terpinolene: $C_{10}H_{16}$).

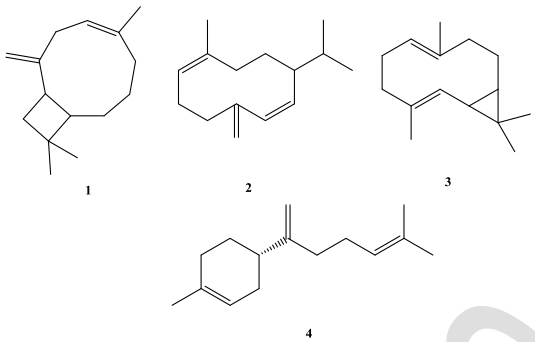


Fig. 4. Chemical structures of the sesquiterpene hydrocarbons having most frequencies in the profiles of the essential oils and extracts of *Achillea* species (**1**: (*E*)-Caryophyllene: $C_{15}H_{24}$; **2**: Germacrene D: $C_{15}H_{24}$; **3**: Bicyclogermacrene: $C_{15}H_{24}$; **4**: β-Bisabolene: $C_{15}H_{24}$).

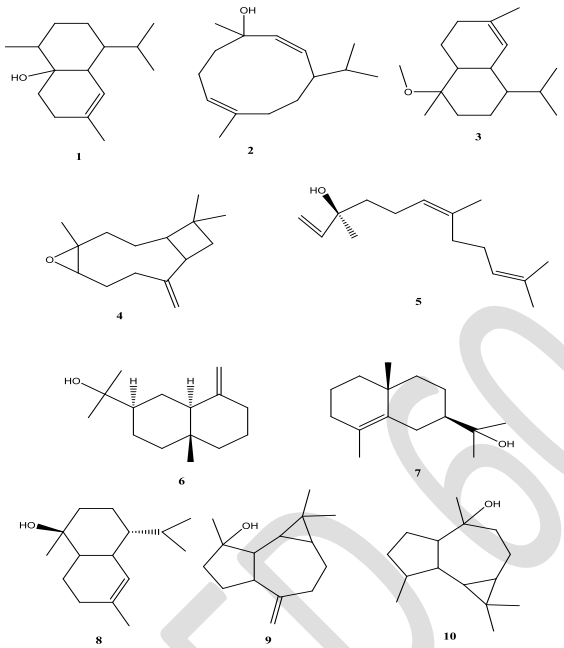


Fig. 5. Chemical structures of the main oxygenated sesquiterpenes in the profiles of the essential oils and extracts of *Achillea* species (**1**: *epi*-Cubenol: $C_{15}H_{26}O$; **2**: Germacrene-D-4-ol: $C_{15}H_{26}O$; **3**: T-cadinol: $C_{15}H_{26}O$; **4**: Caryophyllene oxide: $C_{15}H_{24}O$; **5**: (*E*)-Nerolidol: $C_{15}H_{26}O$; **6**: β-Eudesmol: $C_{15}H_{26}O$; **7**: γ-Eudesmol: $C_{15}H_{26}O$; **8**: α-Cadinol: $C_{15}H_{26}O$; **9**: Spathulenol: $C_{15}H_{24}O$; **10**: Viridiflorol: $C_{15}H_{26}O$).

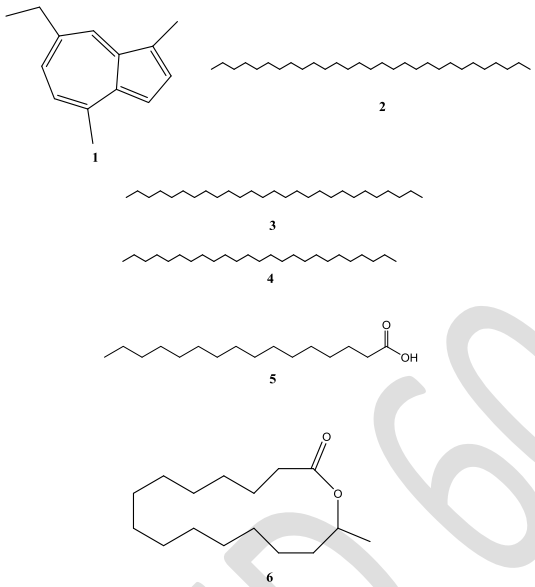


Fig. 6. Chemical structures of the prevalent non-terpene hydrocarbons in the profiles of the essential oils and extracts of *Achillea* species (**1**: Chamazulene: $C_{14}H_{16}$; **2**: Nonacosane: $C_{29}H_{60}$; **3**: Heptacosane: $C_{27}H_{56}$; **4**: Pentacosane: $C_{25}H_{52}$; **5**: Hexadecanoic acid: $C_{16}H_{32}O_2$; **6**: 15-Hexadecanolide: $C_{16}H_{30}O_2$).

Fig. 7. Schematic representation of versatile medicinal and phytochemical activities of essential oils and extracts from different species of the *Achillea* genus.

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