Review

Natural Product Communications
July 2019: 1–17

DOI: 10.1177/1934578X19850354
journals.sagepub.com/home/npx

SAGE

Bioactive Compounds and Health Benefits of *Artemisia* Species

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Abstract

Artemisia L. is a genus of small herbs and shrubs found in northern temperate regions. It belongs to the important family Asteraceae, one of the most numerous plant groupings, which comprises about 1000 genera and over 20000 species. *Artemisia* has a broad spectrum of bioactivity, owing to the presence of several active ingredients or secondary metabolites, which work through various modes of action. It has widespread pharmacological activities and has been used as traditional medicine since ancient times as an anthelmintic, antispasmodic, antirheumatic, and antibacterial agent and for the treatment of malaria, hepatitis, cancer, inflammation, and menstrual-related disorders. This review comprises the updated information about the ethnomedical uses and health benefits of various *Artemisia* spp. and general information about bioactive compounds and free radicals.

Keywords

Artemisia, bioactive compounds, artemisinin, essential oils

Received: November 11th, 2018; Revised: February 15th, 2019; Accepted: February 19th, 2019.

Artemisia L. is included in the tribe Anthemideae and comprises over 500 species, which are mainly found in Asia, Europe, and North America.[1-3] A large number of members of the Anthemideae tribe are important as flowers and ornamental crops, as well as medicinal and aromatic plants, many of which produce essential oils used in folk and modern medicine, and in the cosmetics and pharmaceutical industry.[2,4] The genus *Artemisia* comprises a variable number of species found throughout the northern half of the world. The genus may be divided into sections *Artemisia* and *Dracunculus*.[5-7] *Artemisia* comprises over 400 species, many of which have an aromatic, bitter taste. Some say that it is named after the Greek Artemis, who was the goddess of the hunt, of forests, and of childbirth.[5,8,9]

The large genus *Artemisia* from the tribe Anthemideae comprises important medicinal plants, which are currently the subject of phytochemical attention because of their biological and chemical diversity and essential oil production.[2] *Artemisia* generally has a broad spectrum of bioactivity, owing to the presence of several active ingredients or secondary metabolites, which work through various modes of action. Secondary metabolism in a plant not only plays a role in its survival by producing attractants for pollinators, but also acts as a chemical defense against herbivory and disease.[10,11] *Artemisia* essential oils, mostly distilled from the aromatic plants, contain a variety

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of volatile components such as terpenoids, phenylpropanoids, and aliphatic compounds.[12]

The 500 species of *Artemisia* are mostly perennial herbs dominating the vast steppe communities of Asia. Asia has the greatest concentration of species, with 150 accessions for China, 174 in the former Soviet Union, about 50 reported for Japan, 35 species of the genus found in Iran, and about 30 in Italy. *Artemisia* species are frequently utilized for the treatment of different diseases such as malaria, hepatitis, cancer, inflammation, and infections by fungi, bacteria, and viruses.[2,5]

Traditional and Current Uses

One of the most known plants of the genus *Artemisia* is *A. absinthium* L., commonly known as "wormwood," a yellow-flowering perennial plant distributed throughout various parts of Europe, the Middle East, North Africa, and Asia, and several chemotypes have been recognized.[13] The plant is used for its antiparasitic effects and to treat gastrointestinal problems, anorexia, and indigestion.[14] The aerial parts are present in many gastric herbal preparations, in dietary supplements, and in alcoholic beverages, for example, absinthe products, which enjoy a resurgence of popularity all over the world.[2,15] Moreover *A. absinthium* and other plants of this genus were used to control pain in childbirth and to induce abortions.[5-17]

In North African and Middle Eastern countries, *A. abyssinica* Sch. Bip. ex A. Rich. is used in folk medicine as an anthelmintic, antispasmodic, antirheumatic, and antibacterial agent.[18] This plant grows abundantly in various parts of the Arabian peninsula and is locally known as "ather" (Saudi Arabia) and "boitheran" (Yemen).[2,19,20]

Preparations of *A. abrotanum* L. ("southernwood") have been used in traditional medicine for treating a variety of disorders, including upper airway diseases. Moreover it has been found to possess spasmolytic activity on the carbacholine-induced contraction of guinea pig trachea.[6,21] Nowadays, this perennial plant is used mainly for culinary or cosmetic purposes.[2]

Artemisia afra Jacq. ex Willd. is a well-known medicinal plant of South Africa, where it is known as "wilde als." It is widely used for numerous ailments including colds, coughs, diabetes, heartburn, bronchitis, and asthma.[2,22]

Artemisia annua L. ("sweet wormwood," "qinghao") has traditionally been used in China for the treatment of fever and chills. Though originally growing in Asia and Europe, the plant is cultivated in Africa and used as a tea for the treatment of malaria. Artemisinin has been identified as the antimalarial principal of the plant, and artemisinin derivatives are currently established as antimalarial drugs with activity toward otherwise drug-resistant *Plasmodium* infections.[2,23] Most importantly, however, *A. annua* is now known worldwide for its antimalarial properties. Other *Artemisia* species have also been used for the treatment of fevers and malaria. *Artemisia absinthium* and *A. abrotanum* were used to treat malaria in Europe, while *A. afra* in Africa.[5,16,24,25] The species *A. annua* and *A. apiacea* Hance are native to China. There has been some confusion about their ancient Chinese names. In older texts, *qing hao* (blue-green herb) and *cao hao* (herbaceous herb) were used interchangeably. The polymath Shen Gua (1031–1095) of the Song dynasty described two different varieties of *qing hao*, one with blue-green leaves, the other with yellowish-green leaves in autumn. Based partly on his description, the famous physician and natural historian Li Shizhen (1518—1593), whose cyclopedic *Classified Materia Medica* (*Ben cao gang mu*) was published posthumously in 1596, differentiated between *qing hao* (blue-green herb) and *huang hua hao* (yellow blossom herb).[5,26] *Artemisia annua* has been recognized as an important ethnomedicinal herb for 2 millennia. It has been included in ancient pharmacopeias of various Asian and European countries. The World Health Organization has recommended *A. annua* as an antimalarial drug.[27] Its most common ethnobotanical practice involves the use of whole plant decoction for the treatment of malaria, cough, and cold. Its dry leaf powder has been reported in the treatment of diarrhea.[28] The whole flowering plant is known to be anthelminthic, antipyretic, antiseptic, antispasmodic, carminative, stimulant, tonic, and stomachic. The tincture was formally used to treat nervous diseases and crushed plants in liniments.[28] *Artemisia annua* tea infusion has been used for the treatment of malaria in African countries. As mentioned above, *A. annua* contains artemisinin, which provides a structural chemical base for combinatorial treatment therapy for worldwide antimalarial programs. Research studies also report that artemisinin is effective for killing human breast cancer cells.[28] Therefore, isolation and characterization of artemisinin has increased the interest in *A. annua* worldwide. Several ethnobotanical uses in Africa claim that the *A. annua* tea is also effective against human immunodeficiency virus (HIV). Recently, research investigations are more focused to evaluate its antiviral potential against HIV, as it is a highly emerging disease throughout the world.[29]

Artemisia arborescens L. ("great mugwort," "arborescent mugwort") is a morphologically variable species (or mixture of species) with grey-green to silver leaves. It is native to the various habitats of the Mediterranean region, where it occurs as a shrub growing up to 1 m in height. According to popular folklore, it is used as an anti-inflammatory remedy.[2,30]

Artemisia argyi H. Lév. & Vaniot is an herbaceous perennial plant with a creeping rhizome. It is native to China, Japan, and the far eastern parts of the former Soviet Union. In Japan, it is known as "gaiyou" and in China as "ai ye." It is used in herbal medicine for pathologic conditions of the liver, spleen, and kidney.[2]

The powdered leaves of *Artemisia biennis* Willd. are used as spices and in folk remedies as antiseptics. They have been applied externally in salves and washes by the native

Table 1. List of the Chemical Constituents of Various *Artemisia* Spp.

S. no.	*Artemisia* species	Chemical constituents	References
1.	*A. annua*	Artemisinin, scopoletin, arteannuin B and arteannuic acid, 5-*O*-[(*E*)-caffeoyl]quinic acid, 1,3-di-*O*-caffeoylquinic acid, 4,5-di-*O*-caffeoylquinic acid, 3,5-di-*O*-caffeoylquinic acid, 3,4-di-*O*-caffeoylquinic acid, methyl-3,4-di-*O*-caffeoylquinic acid, methyl-3,5-di-*O*-caffeoylquinic acid, 3,6'-*O*-diferuloylsucrose, 5'-β-D-glucopyranosyloxyjasmonic acid, scoparone, 4-*O*-β-D-glucopyranosyl-2-hydroxyl-6-methoxyacetophenone, chrysosplenol D, casticin, chrysosplenetin, artemisinic acid, deoxy-artemisinin, artemetin, 7,8-dimethylalloxazine (lumichrome), daucosterol, *p*-hydroxybenzoic acid, uracil, nicotinic acid, 3α-hydroxy-1-deoxyartemisinin, salicylic acid, domesticoside (2-*O*-β-D-glucopyranosyl-4-*O*-methylphloroacetophenone, scopolin, β-sitosterol, quercetagetin-6,7,3',4'-tetramethyl ether, quercetagetin-6,7,4'-trimethyl ether	[73–77]
2.	*A. judaica*	Oxygenated monoterpenes, sesquiterpenes, and hydrocarbons	[78]
3.	*A. herba-alba*	Oxygenated monoterpenes, sesquiterpenes and hydrocarbons, chlorogenic acid, 4,5-*O*-dicaffeoylquinic acid, isofraxidin 7-*O*-β-D-glucopyranoside, 4-*O*-β-D-glucopyranosylcaffeic acid, rutin, schaftoside, isoschaftoside, and vicenin-2	[78]
4.	*A. vulgaris*	Eudesmane-type sesquiterpene, morin, luteolin, triterpenes, coumarin, flavonoids, eriodictyol	[79–81]
5.	*A. rupestris*	Citrusin A, alaschanioside A, coniferin, citrusin B, syringaresinol-β-D-glucoside, (6*R*,9*S*)-3-carbonyl-α-ionolglucopyranoside, byzantionoside B, 6-demethoxy-4'-*O*-methylcapillarisin-7-*O*-β-D-glucopyranoside, catechin, kaempferide, artemetin, kaempferol 3,3',4'-trimethylether, umbelliferone, stigmasterol, rupestonic acid, artemetin, casticin, chlorogenic acid, 7-hydroxycoumarin, rupestonic acid, 12-hydroxy-4,11(13)-guaiadien-3-one, luteolin, 5,7-dihydroxy-3',4'-dimethoxyflavone, luteolin 7-*O*-β-D-glucoside, luteolin 7-*O*-[β-D-xylopyranosyl-(1→6)-β-D-glucopyranoside], linarin, quercetin, nevadensin, gardenin D, skimmin, stigmasterol-3-*O*-β-D-glucopyranoside, 1,2-isopropylidene-α-D-glucopyranose, tianshic acid, β-sitosterol, daucosterol, rupestonic acid, chrysosplenetin B, herniarin, isokaempferide, vanillic acid, kaempferol 3,3',4'-trimethyl ether, and ermanin	[82–84]
6.	*A. capillaris*	Neochlorogenic acid, chlorogenic acid, cryptochlorogenic acid, caffeic acid, 1,3-dicaffeoylquinic acid, 3,4-dicaffeoylquinic acid, 3,5-dicaffeoylquinic acid, 4,5-dicaffeoylquinic acid, chlorogenic acid analogs and phenolic acids, 7-hydroxy-coumarin, 5,7-dimethoxy-coumarin, 7-hydroxy-8-methoxy-coumarin, 7,8-dihydroxy-coumarin, quercetin, kaempferol, isorhamnetin-3-*O*-β-D-galactopyranoside, 7-methoxycoumarin, 4-hydroxyacetophenone, nicotinic acid, 3(*R*)-deca-4,6,8-triyne-1,3-diol, 3(*R*)-deca-4,6,8-triyne-1,3-diol-1-*O*-β-D-glucopyranoside, 3(*R*)-9-decene-4,6-diyne-1,3,8-triol, 4-hydroxyacetophenone-4-*O*-β-D-glucopyranoside, phenylcarbinol-*O*-β-D-glucopyranoside, thymidine, isoquercitrin, isorhamnetin-3-*O*-glucoside, ursolic acid, oleanolic acid, and β-sitosterol	[85–89]
7.	*A. ordosica* Krasch	3,5,3',4'-Tetrahydroxy-6,7-dimethoxyflavone, 5,3',4'-trihydroxy-7-methoxyflavanone, 5,7,4'-trihydroxy-6-methoxyflavone, 5,7,4'-trihydroxyflavanone, 3,5,4'-trihydroxy-7-methoxyflavanone, 3,5,7-trihydroxy-4'- methoxyflavanone, isosakuranetin, 7,4'- dimethylaromadendrin, acacetin, cirsimaritin, rhamnetin, eupatolitin, 5,7,2',4'-tetrahydroxy-6,5'-dimethoxyflavone, hyperoside	[90,91]
8.	*A. absinthium*	Absinthin, anabsinthin, 5,6,3',5'-tetramethoxy-7,4'-hydroxyflavone, 5-hydroxy-3,3',4',6,7-pentamethoxyflavone, artemitin, rutin, glycosides of quercetin, chlorogenic, caffeic acids, artamarin, artamaridin, artamaridinin, artamarinin, quebrachitol	[92–94]
9.	*A. sphaerocephala* Krasch.	Caffeic acid, 5,7,2',4'-tetrahydroxy-6,5'-dimethoxyflavone, quercetagetin, 4'-hydroxywogonin, quercetagetin-4'-methyl ether, 5,6,3'-trihydroxy-7,4'-dimethoxyflavanone, eriodictyol-7-methyl ether, quercetin-7-methyl ether, sakuranetin, isosakuranetin, 3,5-dihydroxy-7,4'-dimethoxy-flavanone, 5-hydroxy-7,4'-dimethoxyflavanonol, 5,3'-dihydroxy-7,4'-dimethoxyflavanone, 5,7-dihydroxy-6,4'-dimethoxyflavone, hesperetin, naringenin, acacetin, chrysoeriol, 5,7-dihydroxy-4'-methoxyflavone-6,8-di-*C*-glucopyranoside, didymin, acacetin-7-*O*-rutinoside, piceine, capillarin, ethyl linoleate, sakuranetin, isosakuranetin, artocarpanone	[90,95,96]
10.	*A. turanica*	3,5-Dicaffeoylquinic acid, 4,5-dicaffeoylquinic acid, 3,5,3',4'-tetrahydroxy and 7,5'-methoxy flavones	[97,98]
11.	*A. campestris*	Catechin, vanillic acid, caffeic acid, syringic acid, *p*-coumaric acid, and gallic acid	[99]
12.	*A. gmelinii*	Genkwanin, hispidulin, 3'-hydroxy-genkwanin, chrysoeriol, apigenin, 5,7,3',4'-tetrahydroxy-6,5'-dimethoxy-flavone, kumatakenin, quercetin, patuletin, quercetagetin-3,6,7-trimethylether, and 7,3',4'-trihydroxy-3-methoxy-flavone	[100]

(Continued)

Table 1. Continued

S. no.	*Artemisia* species	Chemical constituents	References
13.	*A. selengensis*	(*E*)-Resveratrol, (*E*)-cinnamic acid, caffeic acid, chlorogenic acid, gallic acid, luteolin, isorhamnetin, 7-methoxy coumarin, quercetin, acteoside, 7-methoxy-4'-hydroxyisoflavone, 1',3'-propanediol,2'-amino-1'-(1,3-benzodioxol-5-yl), artanomaloide, canin, eupatilin, quercetin-3-*O*-β-D-glucoside-7-*O*-α-L-rhamnoside, isoquercitrin, 1,3-di-*O*-caffeoylquinic acid, pinoresinol-4-*O*-β-D-glucoside, scopolin, isofraxidin-7-*O*-β-D-glucopyranoside, β-farnesene , *N*-(α-methylnaphthalene)-3- (*ortho*-cresyl) propionamide, *N*-(α-methylnaphthalene)-3-(contra-cresyl) propionamide, α-pinene oxide, α-humulene, α-cedrene, β-curcumene, zingiberene, sesquisabinene hydrate, isocaryophyllene, β-sesquiphellandrene, 4',7-dimethylluteolin, 11,13-dihydromatricarin, chrysoerid-7-*O*-β-D-glucoside, luteolin-4'-*O*-β-D-glucoside, quercetin-3-*O*-β-D-xyloside, daucosterol	101–105
14.	*A. scoparia*	4-Pyridone glucoside, polyacetylene glucosides, 2-(5-acetyl-2,3-dihydro-benzofuran-2-yl)-propyl ester, 2-(3'-methoxyl-3'-methyl-*trans*-but-1'-enyl)-*p*-methoxylacetophenone, 5,8-dimethoxy-6,7-methylenedioxycoumarin (Artemicapin A), 8-methoxy-6,7-methylenedioxycoumarin, 6-demethoxycapillarisin, 2,4-dihydroxyl-6-methoxy-acetophenone, β-sitosterol, 6,7- dimethoxy-coumarin, capillartemisin B, kumatakenin and isoscoploletin-β-D-glucoside, 7-methoxycoumarine, isosabandin, 6,7-dimethylesculetin, 7-methylesculetin, scopoletin, capillarisin, chlorogenic acid butyl ester, isoscopoletin-β-D-glucoside (magnolioside), hyperin, eupafolin, pedalitin, 5,7,2',4'-tetrahydroxy-6,5'-dimethoxyflavone, capillone, capillin, jaceosidin, chrysoeriol, arcapillin, luteolin, chrysoeriol-7-*O*-β-D-glucopyranoside, cacticin, isorhamnetin-3-*O*-β-D-glucopyranoside, quercetin-7-*O*-α-L-rhamnopyranoside, hyperin and *n*-butyl-β-D-fructopyranoside, cirsilineol, cirsimaritin, arcapillin, cirsilio, quercetin-3-*O*-β-D-glucoside 3,5-dihydroxy-5-methoxycinnamic acid, caffeic acid, 6,7-dimethoxycoumarin	86,106-111
15.	*A. frigida*	Kaempferol, ferulic acid, cinnamic acid, daucosterol, 5,7,3',4'-tetrahydroxy-6,5'-dimethoxyflavone, 5,7-dihydroxy-6,3',4'-trimethoxyflavone, 5,7,4'-trihydroxy-6,3'-dimethoxyflavone, 5,7,4'-trihydroxy-6-methoxyflavone, 5,7,3',4'-tetrahydroxy-6-methoxyflavone, rutin , 3'-methoxy-luteolin-4'-*O*-β-D-glucoside, 5-hydroxy-3',4'-dimethoxyflavone-7-*O*-β-D-glucuronide	112
16.	*A. lactiflora*	7-Hydroxycoumarin, 7-methoxycoumarin, balanophonin, aurantiamide, aurantiamide acetate, isovitexin, kaempferol-3-*O*-β-D-rutinoside, rutin, caffeic acid ethyl ester, quercetin, methyl 3,5-di-*O*-caffeoyl quinate, methyl 3,4-di-*O*-caffeoyl quinate, dehydrovomifoliol, 3-hydroxy-1-(4-hydroxy-3,5-dimethoxy-phenyl)-1-propanone, chrysindin D, camelliagenin A, 4'-*O*-methylalpinumisoflavone, 5-hydroxy-3',4',6,7,8-pentamethoxyflavone, armexifolin, 3β-hydroxy-5α,6α-epoxy-7-megastigmen-9-one, carissone, and (*E*)-3β,4α- dihydroxyl-(2',4'-hexadiynylidene)-1,6-dioxaspiro [4,5] decane, 4-(2-hydroxyethoxy) acetophenone, loliolide, isololiolide, isovanillic acid, *p*-hydroxybenzoic acid, (*E*)-*p*-coumaric acid, ethyl (*E*)-*p*-coumarate, (+)-pinoresinol, (+)-medioresinol, (+)-syringaresinol, 4-hydroxy-3,5-dimethoxy-benzoic acid, dihydroisoferulic acid	113-115
17.	*A. indica*	5-Hydroxy-3,7,4'-trimethoxyflavone, ludartin, maackiain, lupeol, *cis*-matricaria ester, *trans*-matricaria ester, and 6-methoxy-7,8-methylenedioxy coumarin	116
18.	*A. leucophylla*	Lupeol, apigenin, luteolin, isorhamnetin, monoheptadecanoin, scopoletin, umbelliferone, kaempferol-3-*O*-α-LL-rhamnoside, kaempferol-3-*O*-glucoside, kaempferitrin and D-mannitol	117
19.	*A. myriantha*	Arglabin, 13-acetoxy-3β-hydroxyl-germacra- 1(10)*E*,4*E*,7(11)-trien-12,6α-olide, eupatorin, 8α-acetoxyarglabin, artemyriantholide B, artemyriantholide A, 4',5,7-trihydroxy-6,3'-dimethoxy flavone, casticin, 5,4'-dihydroxy-6,7,3',5'-tetramethoxyflavone, arborescin, arlatin	74

(Continued)

Table 1. Continued

S. no.	*Artemisia* species	Chemical constituents	References
20.	*A. anomala*	β-Sitosterol, β-daucosterol, schleicheol 2, α-spinasterol, 5α,8α-epidioxy-ergosta-6,22-dien-3β-ol, 5α,8α-epidioxy-ergosta-6,9(11),22-trien-3β-ol, 22*E*-3β,5α-dihydroxyergosta-7,22-dien-6-one, naringenin, luteolin, kaempferol, chrysoeriol, diosmetin, jaceosidin, isorhamnetin 3-*O*-glucoside, hesperetin-7-*O*-β-D-glucopyranoside, methyl (4a*S*,7*S*,7a*R*)-7-hydroxy-7-methyl-1,4a,5,6,7,7a-hexahydrocyclopenta[c]pyran-4-carboxylate, rehmaglutin D, (*E*)-6-hydroxy-2,6-dimethylocta-2,7-dienoic acid, chrysoeriol, luteolin, apigenin, *p*-coumaric acid, 3β- ethoxytanapartholide, (4*S**,5*S**)-dihydro-5-[(1*R**,2*S**)-2-hydroxy-2-methyl-5-oxo-3-cyclopenten-1-yl]-3-methylene-4-(3-oxobutyl)-2(3H)-furanone, ligucyperonol, cyperusol C, santamarin, 1α,2α,3α,4α,10α- pentahydroxyguaia-11(13)-ene-12,6α-olide, balanophonin, methyl 3-(2'-hydroxy-4'-methoxyphenyl) propanoate, acceroic acid, simiarenol, α-amyrin, β-sitosterol, 4-methoxysalicylic acid, *m*-hydroxybenzoic acid, 2'-hydroxycinnamaldehyde, cinnamic acid, isoferulic acid, 7-methoxycoumarin, indolyl-3-carboxylic acid, dihydrophaseic acid 4'-*O*-β-D-glucopyranoside, citroside A, (6*S*,9*R*)-roseoside, cyclobalanone, friedelin, sorghumol, pseudoneolinderane, herniarin, scopoletin, isofraxidin and caffeic acid	118-122
21.	*A. argyi*	Lemaphenol A, aurantiamide acetate, camelliagenin A, japonica acid, labd-13(*E*)-ene-8α,15-diol, 3β-acetoxy-20-oxo-21-nordammaran-23-oic acid, apigenin, jaceosidin, luteolin, eupatilin, β-sitosterol, quercetin, isotanciloide, umbelliferone, daphnetin, eriodictyol, rhamnetin, hispidulin, L-2-*O*-methyl-chiro-inositol, stigmasterol, daucosterol, and 4-methoxy-3-hydroxyphenol	123,124 125
22.	*A. rupestris*	5,4'-Dihydroxy-3,6,7-trimethoxy flavone, *R*-(-)-vestitol, tricin, chrysoeriol, 3-indole carboxylic acid, esculetin, apigenin, luteolin, luteolin-7-glucoside, (*E*)-caffeic acid, casticin, chrysosptertin B, artemetin, robinin, quercetin, linearin, sucrose, tilianin, 3'-methoxy-4'-*O*-*p*-coumaroyl-β-D-glucoside, hirsutine, ethyl *p*-methoxycinnamate, rutin	126,127
23.	*A. sacrorum*	β-Sitosterol, acacetin, 7-methoxy-6-hydroxycoumarin, 5-hydroxy-7,4'-dimethoxyflavone, 1,4-dicaffeoylquinic acid, salicylic acid, veratric acid, scopoletin, isofraxidin, succinic acid, sugereoside, sacroside C, *o*-hydroxycinnamoyl-β-D-glucopyranoside, 6-methoxycoumarin-7-hydroxylprimeveraside	128,129
24.	*A. amygdalina*	Ergostadien-3β-ol, ludartin, 5-hydroxy-6,7,3',4'-tetramethoxyflavone, *trans*-matricaria ester, diacetylenic spiroenol ether, and *cis*-matricaria ester	130
25.	*A. lavandulaefolia*	Kaempferol, formononetin, isorhamnetin, apigenin, tricin, quercetin-7-*O*-β-D-glucopyranoside, quercetin-7-*O*-α-L-rhamnopyranoside, quercetin-3-*O*-β-D-glucopyranoside, kaempferol-3-*O*-β-D-glucopyranoside, apigenin-7-*O*-β-D-glucopyranoside, kaempferol-3-*O*-β-D-rutinoside, 7-methoxycoumarin, *m*-hydroxybenzoic acid, isoferulic acid, loliolide, medioresinol, (+)-syringaresinol, syringic acid, friedelinol, caffeic acid, vanillic acid, stigmasterol, sitosterol-3-*O*-glucopyranoside, β-amyrin, β-sitosterol, ursolic acid, eupatilin, naringenin, apigenin, luteolin, quercetin	131,132
26.	*A. dubia*	Calotropoleanyl ester, α-amyrin, nonacosanoic acid, docosanoic acid, tetracosanoic acid, 1-(*O*-tricosanoyl) glycerol, 1-(*O*-pentacosanoyl) glycerol, and β-sitosterol	133
27.	*A. dracunculus*	1-Monopalmitin, methyl α- linolenate, 1-monoolein, 3-*O*-acetylursolic acid, 3β,22β,24-trihydroxy-olean-12-ene, oleic acid, palmitic acid, 1-monolinolein, vanillic acid, hesperetin, naringenin, quercetin, rutin, scoparone, scopoletin, 7-hydroxycoumarin, daphnetin, caffeic acid, chlorogenic acid, 7-methoxycoumarin, 7-hydroxyartemidin	134,135
28.	*A. iwayomogi*	Coumarins, phenolics, flavonoids, caffeoylquinic acids, diterpene glycosides, hispidulin, 6-methoxytricin, arteanoflavone, quercetin-3-gentiobioside, 1,3-di-*O*-caffeoylquinic acid, suavioside A, turpinionoside A, (*Z*)-3-hexenyl-*O*-α-arabinopyranosyl-(1→6)-*O*-β-D-glucopyranoside, (*Z*)-5'-hydroxyjasmone 5'-*O*-β-D-glucopyranoside, (-)-syringaresinol-4-*O*-β-D-glucopyranoside, and methyl 3,5-di-*O*-caffeoyl quinate	136,137
29.	*A. halodendron*	Arcapillin, isorhamnetin-3-*O*-glucopyranoside, *p*-hydroxyacetophenone, caffeic acid, *p*-coumaric acid, isorhamnetin, palmitic acid, cirsilineol, pentacosanol	138
30.	*A. waldst*	1-Dotriacontanol, palmitic acid, hexacosyl eicosanoate, β-daucosterol	139
31.	*A. inculta*	Germacrene D, phytol, santolin alcohol, a hydroperoxide, 4,5-dihydroxysantolin-1,8-diene, a sesquiterpene lactone, flavone artemetin	140
32.	*A. vestita*	Taurin, 1,11-bis-*epi*-artesin, yomogin, 5,7,3',4'-tetrahydroxy-6, 8-dimethoxy flavone, 5,7,3',4'-tetrahydroxy-6-methoxy flavone,5,6,3',4'-tetrahydroxy-7-methoxy flavone, taraxerol-3β-acetate, friedelin, α-amyrin, β-sitosterol, daucosterol, scoplatin, 7-hydroxy-6,8-dimethoxycoumarin, isoferulic acid, caffeic acid	141

(Continued)

Table 1. Continued

S. no.	*Artemisia* species	Chemical constituents	References
33.	*A. arborescens*	Artemitin, arborescin, sesamin, (+)-lirioresinol β-dimethyl ether, chrysoeriol, apigenin, β-sitosteryl glucoside, dihydroridentin, and chrysoeriol 4-glucoside	142
34.	*A. roxbugiana*	Riedelin, α-amyrin acetate, α-amyrin, β-amyrin acetate, β-sitosterol, dotriacontanoic acid, octacosanol, octacosanoic acid, triacontanoic acid, daucosterol, friedelan-3-one, multiflorenone, stigmastanone, 8-hydroxydotriacontan-27-one	143
35.	*A. tangutica*	β-Sitosterol, α-amyrin acetate, α-amyrin, β-amyrin, β-amyrin acetate, 2- oxo-desoxyligustrin, estafiatin, 4α-hydroxyguaia-10(14),11(13)-dien-12,6α-olide, 1-*epi*-reynosin, and 9β-acetoxy-4,5-dehydro-4(15)-dihydrocostic acid	144
36.	*A. japonica*	β-Amyrin, triacontanoic acid, β-sitosterol, stigmasterol, 7,8- dimethoxycoumarin, 6,7-dimethoxycoumarin, capillarisin, 8,4'-dihydroxy-3,7,2'-trimethoxyflavone, 3,5-dihydroxy-6,7,3',4'-tetramethoxyflavone, cinnamic acid, *p*-methoxybenzoic acid, and ferulic acid	145
37.	*A. subdigitata*	5,8,3',5'-Tetrahydroxyflavanone, 5,8,2'-trihydroxy-5'-methoxyflavanone, 5,7,4'- trihydroxy-3',5'-dimethoxyflavanone, 3-(3-hydroxy)-phenoxy-2-propenal, tricin, quercetin-3-rhamnoside, ethyl 2,5- dihydroxycinnamate, 8-hydroxy-6,7-dimethoxycoumarin, 2,4-hexadiyn-1-one, α-amyrin, β-amyrin, α-amyrin acetate, α- amyrone, friedelin, β-sitosterol, tetracosanoic acid, and *n*-butyl palmitate	146
38.	*A. montana*	Ezoartemin, ezomontanin, 11,13-dihydroezomontanin, yomogiartemin, yamayomoginin	147
39.	*A. myriantha*	Blumenol A, (+)-dehydrovomifoliol, (+)-3-hydroxy-β-ionone, (3*R*,6*R*,7*E*)-3-hydroxy-4, 7-megastigmadien-9-one, (-)-10-oxo-isodauc-3-en-15-oic acid, isoerivanin, eudesmafraglaucolide, artanomalide A, 13-acetoxy-3β-hydroxy-germacra-1*E*,4*E*,7(11)-trien-12,6α-olide, 13-acetoxy-3β-tigloyl- germacra-1*E*,4*E*,7(11)-trien-12,6α-olide, 13-acetoxy-3β-(3-methylbutanoyl)-germacra-1*E*,4*E*,7(11)-trien-12,6α-olide, 3,9-diacetoxy-13-hydroxy-1(10),4,7(11)-germacratrien-12,6α-olide, and 8α-angeloyloxycostunolide	148

inhabitants of North America for treating sores and wounds, and internally to treat chest infections.[2,31]

Artemisia campestris L. is a perennial faintly aromatic herb, widespread in the south of Tunisia, commonly known as "tgouft." The leaves of this plant are widely used in traditional medicine as a decoction for their antivenin, anti-inflammatory, anti-rheumatic, and antimicrobial properties.[32] *Artemisia cana* Pursh is used as a spice and in folk remedies as an antiseptic.[2]

Artemisia douglasiana Besser ("*California mugwort*") is a perennial herb that is native to the western United States, especially northern California, Oregon, and Washington. *Artemisia douglasiana* is used to promote menstruation, as a stimulant, tonic, to treat nervous disorders, and as a diuretic. The essential oil has been used for aromatherapy, inhaled for mental clarity and ease of mental distress; used as a massage for aching muscles and pain on the surface of the body; and as a bath or tonic.[33] In Argentina, *A. douglasiana*, which is adventitious and cultivated in the Cuyo region, is used in folk medicine and known under the common name of "matico.". The popular use of the infusion of leaves of "matico" is to treat peptic ulcers and gastrointestinal disorders.[34]

Artemisia dracunculus L. ("tarragon") is a perennial herb, which has a long history of use in culinary traditions. It also possesses a wide range of health benefits and has therefore been widely used as an herbal medicine. For example, in the Himalayas, extracts of *A. dracunculus* are used to relieve toothache, reduce fever, and as a treatment for gastrointestinal problems.[35] Two well-described cultivars (Russian and French) are used widely and differ in ploidy level, morphology, and chemistry. The botanical and chemical constituents are closely detailed in the literature, the latter mainly focusing on its essential oil composition, which give its distinctive flavor.[2,36]

Artemisia dubia Wall. ex Besser is native to Bhutan, China, India, Japan, Nepal, and Thailand.[37] In Nepal, the leaf juice of *A. dubia* is used to treat cuts and wounds while the plant paste is used against fever.[38]

Artemisia echegaray Hieron is commonly known in Argentina as "ajenjo" and is used as a natural food additive.[2] Decoctions of leaves and stems of *A. frigida* Willd. are used for coughs and diabetes[2]; several native American tribes have used decoctions of *A. frigida* for menstrual irregularities.[39]

Artemisia fukudo Makino is distributed along the shorelines of South Korea's Jeju Island and in the south of the Korean Peninsula, Japan, and Taiwan. This plant is used as a flavoring agent and in a variety of cosmetics in Korea. It also has various biological effects, including anti-inflammatory, antitumor, and antibacterial properties.[40]

Artemisia gmelinii Weber ex Stechm. is a plant of the high-altitude regions of Asia. In Nepal, the fresh plant is ground into a paste and applied externally for headaches, boils, and pimples.[35] *Artemisia haussknechtii* Boiss. is used in dyspepsia and other gastrointestinal disorders by local people in the Western part of Iran (province of Kermanshah).[41] In Nepal, *A. indica* Willd. is used to treat ringworm, cuts, and wounds, and as an anti-leech treatment.[35,38] *Artemisia iwayomogi* Kitamura is a perennial herb easily found around Korea. It is called "haninjin" or "dowijigi" in Korean and is traditionally used for the treatment of various liver diseases, including hepatitis.[2]

Table 2. List of the Constituents of Essential Oils in Various *Artemisia* Spp.

S. no.	*Artemisia* species	Essential oil components	References
1.	*A. giraldi*	1,8-Cineole, camphor, terpinen-4-ol, α-terpineol	149
2.	*A. rubripes*	β-Farnesene, 1,8-cineole , β-caryophyllene, germacrene D, camphor	149,150
3.	*A. judaica*	β-Eudesmol, palmitic acid, spathulenol, eudesma-4 (15),7-dien-1-β-ol, carvacrol, thymol, piperitone, camphor and ethyl (*E*)-cinnamate	78,151
4.	*A. herba-alba*	Piperitone, ethyl (*E*)-cinnamate, ethyl (*Z*)-cinnamate, thymol, isophorone, 1,8-cineole, *cis*-pinocarveol, artemisia ketone, α-thujone, germacrene D, camphor and β-thujone	78,152,153
5.	*A. ciniformis*	Camphor, 1,8-cineole and *trans*-pinocarveol	154
6.	*A. vulgaris*	Sabinene, 1,8-cineole, artemisia ketone, both thujone isomers (α- and β-diastereoisomers), camphor, *cis*-chrysanthenyl acetate, davanone, davanone B, chrysanthenone, borneol, germacrene D, α-pinene, menthol, β-eudesmol, spathulenol, (*Z*,*Z*)-3,5-octadiene, 2,5-octadiene, 3,4,5-trimethyl-1-hexene, pulegone, 3-methyl-2-cyclohexene-1-one, decahydro-1,1,7-trimethyl-4-methylene-1*H*-cyclopropazulene	79,155,156 157
7.	*A. asiatica*	Piperitone, davanone, *p*-cymene and 1,8-cineole	158
8.	*A. anethoides*	1,8-Cineole, 2-isopropyl-5-methyl-3-cyclohexen-1-one, terpinen-4-ol, *o*-cymene and pinocarveol	159
9.	*A. dubia*	Terpinolene, limonene, 2,5-etheno [4.2.2] propella-3,7,9-triene, isoelemicin and *p*-cymene-8-ol	160
10.	*A. aucheri*	Camphor, 1,8-cineole, verbenone, camphene, β-myrcene, α-pinene	161,162
11.	*A. nilagirica*	α-Thujone, germacrene D, β-thujone, β-caryophyllene, caryophyllene oxide, borneol	163
12.	*A. campestris*	Germacrene D, β-pinene, α-pinene, α-cadinol, limonene, β-myrcene, falcarinol, α-terpenyl acetate, camphor, spathulenol, camphene, limonene, and borneol	62,99
13.	*A. absinthium*	β-Thujone, 1,8-cineole, *cis*-chrysanthenol, sabinene, camphor, isoascaridol, β-pinene *o*-cymene, α-phellandrene, myrcene , *cis*-chrysanthenyl acetate, dihydrochamazulene isomer , germacrene D, linalool acetate, linalool, 2-methyl-5-(1-methyl-ethenyl)-2-cyclohexen-1-one, β-caryophyllene, 1,2-dihydro-1,4,6-trimethyl-naphthalene, elemol, 6-methyl-2,2,dipyridine *N*-oxide	13,164-168
14.	*A. dracunculus*	1,8-Cineole, camphor, camphene, borneol, thymene, terpinen-4-ol, γ-terpinene, α-terpineol, caryophyllene oxide, β-pinene, α-pinene, β-myrcene, limonene, (*Z*)-β-ocimene, (*E*)-β-ocimene, α-terpinolene, 5-phenyl-1,3-pentadiyne, methyleugenol, capillene, elemicin, bicyclogermacrene, iso-elemicin, germacrene B, *p*-cymene, linalool, β-thujone, camphor, methylchavicol, iso-menthol, bornyl acetate, carvacrol, α-terpinyl acetate, hexyl hexanoate, α-copaene, β-caryophyllene, β-phellandrene, 3,7-dimethyl-1,3,7-octatriene, 1*S*-α-pinene, l-methoxy-4-(2-propenyl)-benzene, limonene, 1*R*-α-pinene	169-171
15.	*A. annua*	Selina-3,11-dien-6α-ol, artemisia ketone, α-pinene, 1,8-cineole, camphor, bisabolol, bisabolol oxide B, bisabolol oxide A, (*E*)-nerolidol, L-borneol, α-copaene, β-caryophyllene, β-bisabolene, germacrene D, germacrene B, (−)-neoclovene-(II), isoaromadendrene epoxide, *cis*-lanceol, caryophyllene oxide, (*E*)-β-farnesene, 2,5-dihydro-3-methylfuran, β-myrcene, (*Z*)-caryophyllene, santolina triene	166,172-176
16.	*A. montana*	*n*-Palmitic acid	166
17.	*A. millefolium*	Oxygenated monoterpenes	166
18.	*A. arborescens*	α-Thujone	177
19.	*A. mongolica*	1,8-Cineole, (*S*)-*cis*-verbenol, terpinen-4-ol, (-)-camphor, α-terpineol, and verbenol	178
20.	*A. capillaris*	α-Pinene, β-pinene, limonene, 1,8-cineole, piperitone, β-caryophyllene, capillin, palmitic acid, 9,12,15-octadecatrienoic acid, falcarinol, *trans*-(*Z*)-α-bisabolene epoxide, and germacrene D	179,180
21.	*A. diffusa*	Camphor, 1,8-cineole, and β-thujone	181
22.	*A. rupestris*	α-Terpinyl acetate, spathulenol, α-terpineol, linalool, terpinen-4-ol, β-elemene, β-sesquiphellandrene, α-guaiene, linalyl 3-methyl-butyrate, 1-hexadecanol, palmitic acid, linoleic acid	182,183
23.	*A. scoparia*	Palmitic acid, caryophyllene oxide, spathulenol, β-myrcene, (+)-limonene, (*Z*)-β-ocimene, γ-terpinene, α-pinene, furfuraldehyde, methylheptenone, 1,8-cineole, carvone, β-thujone, 3-thujanol, geranyl acetate, eugenol, δ-cadinene, γ-cadinene, dihydrocarvyl acetate	184-187
24.	*A. parviflora*	Camphor, germacrene D, germacrene B, artemisia ketone, 1,8-cineole, α-copaene linalool, lavandulol, santalyl acetate, lavandulyl acetate, β-caryophyllene, spathulenol, caryophyllene oxide, cubenol, α-humulene, limonene, bicyclogermacrene, and α-cadinol	188-190
25.	*A. myriantha*	α-Eudesmol, β-eudesmol, germacrene D, 1,8-cineole, β-pinene oxide, δ-cadinene, chrysanthenone, camphor, β-caryophyllene, α-humulene, caryophyllene oxide, terpinen-4-ol, and (+)-α-terpineol	191

(Continued)

Table 2. Continued

S. no.	*Artemisia* species	Essential oil components	References
26.	*A. argyi*	Sesquiterpenes, esters, monoterpenes, ketones, 1,8-cineole, 4-hydroxy-4-methyl-2-pentanone, borneol, thujone, β-caryophyllene, 2,2'-bithiophene, 3,3,6,8-tetramethyl-1-tetralone and selina-6-en-4-ol, artemisia alcohol, camphor, artemisia ketone, L-borneol, absinthol, 1*R*-α-pinene, globulol, 3,3,6-trimethyl-1,5-heptadien-4-ol, isobornyl formate, spathulenol, seychellene, santolina triene, chamazulene, *p*-mentha-1,8-dien-10-ol	192-195
27.	*A. monosperma*	β-Pinene, α-terpinolene, limonene, α-pinene, β-maaliene, shyobunone	196
28.	*A. sieberi*	α-Terpineol, 1,8 cineole, β-thujone, *cis*-sabinol, linalool, dihydrocarveol, geranyl acetate, camphor, camphene, and α-pinene	197,198
29.	*A. fukudo*	α-Thujone, β-thujone, camphor, β-caryophyllene and β-elemene	199
30.	*A. frigida*	α-Pinene, camphene, 1,8-cineol, camphor, borneol, terpinen-4-ol, bornyl acetate, germacrene D, α- and β-thujones	200
31.	*A. argyrophylla*	Yomogi alcohol, artemisia ketone, artemisia alcohol, camphor, borneol, and bornyl acetate	200
32.	*A. imponens*	Monoterpene and sesquiterpene and vulgarone B, 1,8-cineol, and camphor	201
33.	*A. selengensis*	1,8-Cineol, (*Z*)-β-farnesene, β-thujone, α-humulene, γ-elemene, (*E*)-β-farnesene, valeranone, (2*E*,13*Z*)-octadecadien-1-ol, α-bisabolol, bornyl acetate, germacrene D	202,203
34.	*A. indica*	β-Caryophyllene, germacrene D, caryophyllene oxide, *cis*-β-elemenone, and selin-11-en-4α-ol	204
35.	*A. lavandulaefolia*	β-Caryophyllene, (*E*)-β-farnesene, and chrysanthenone	205
36.	*A. rutifolia*	1,8-Cineol, camphor, terpenen-4-ol, and 4-isobutylphenol	206
37.	*A. pallens*	Pentanol, hexanol, (*E*/*Z*)-hexenol, 2-furaldehyde/myrcene, benzyl alcohol, caprylic acid, geranyl acetone, α-ionone	207
38.	*A. glauca*	Anisole, methyl oleate, palmitic acid, and methyleugenol	208
39.	*A. vestita* Wall	Monoterpenes, monoterpenic derivatives, sesquiterpenes, 1,8-cineol, camphor, and borneol	209
40.	*A. mongolica* Fisch	Sesquiterpenes and sesquioxides, carvone, piperitone, elemol, 2-methyl-2-butene, methylene cyclopentane, β-pinene, α-thujene, α-pinene, camphene, 1-octen-3-ol, β-thujene, β-pinene, α-phellandrene, bornylene, *p*-cymene, terpinen-1-ol, artemisia ketone, γ-terpinene, β-terpineol, myrtanol, α-terpinolene, verbenone, linalool, α-thujone, β-thujone, camphor, isopulegone, isoborneol, terpinen-4-ol, α-terpineol, myrtenol, and *trans*- and *cis*-carveol	210,211
41.	*A. lactiflora* Wall	δ-3-Carene, myrcene, limonene, *p*-cymene, δ-elemene, α-copaene, β-elemene, β-caryophyllene, α-humulene, *ar*-curcumene, γ-cadinene, δ-cadinene, calamenene, (*E*)-β-farnesene, caryophyllene oxide, β-guaiene, lactiflorenol, spathulenol, *S*-guaiazulene, herniarin, α-pinene, β-pinene, borneol, palmitic acid	212
42.	*A. subdigitata*	α-Thujone, α-pinene, camphene, sabinene, β-pinene, myrcene, δ-3-carene, β-ocimene, *p*-isopropylphenol, limonene, γ-terpinene, terpinen-4-ol, estragole, geraniol, methyl eugenol	213

Artemisia japonica Thunb. is distributed throughout continental Asia and Japan.[37] In northern Pakistan, the leaf extract is used to treat malaria and a paste of leaves is used externally on skin diseases.[35] *Artemisia judaica* L. is a perennial fragrant shrub that grows widely in the deserts and on the Sinai Peninsula in Egypt, and is a very common anthelmintic drug in most North African and Middle-Eastern countries where it is known by the Arabic name of "shih."[2,22]

The genus *Artemisia* is known to contain many bioactive compounds; artemisinin exerts not only antimalarial activity but also profound cytotoxicity against tumor cells[6,42] and arglabin is employed for treating certain types of cancer in the former Soviet Union.[43] Over the past decade *Artemisia* species have been used traditionally in various populations; thus, *A. keiskeana* Miq. has been used as a traditional Chinese drug for the treatment of gynecopathy, amenorrhea, bruise, and rheumatic disease.[6,44]

The inhabitants of northeastern Mexico use an infusion of leaves from *A. ludoviciana* Nutt. as an antidiarrheal remedy,[2] while several Native American tribes of North America have used infusions for coughs, sore throats, and colds.[39] *Artemisia nilagirica* (C.B. Clarke) Pamp., commonly called "Indian wormwood," is widely found in the hilly areas of India, where it is used as insecticide.[45] A paste from the leaves of *A. nilagirica* is used externally to treat cuts and wounds and the leaves chewed to treat oral ulcers.[35]

Artemisia princeps Willd. ("Japanese mugwort" or "yomogi") is the best-known *Artemisia* in Japan, where it is a fundamental ingredient of the Japanese confection "kusa-mochi." This plant has also been used in traditional Asian medicine for the treatment of inflammation, diarrhea, and many circulatory disorders.[2]

Artemisia rubripes Nakai has been used as a traditional Korean medicine for stomach ache, vomiting, diarrhea, and as a

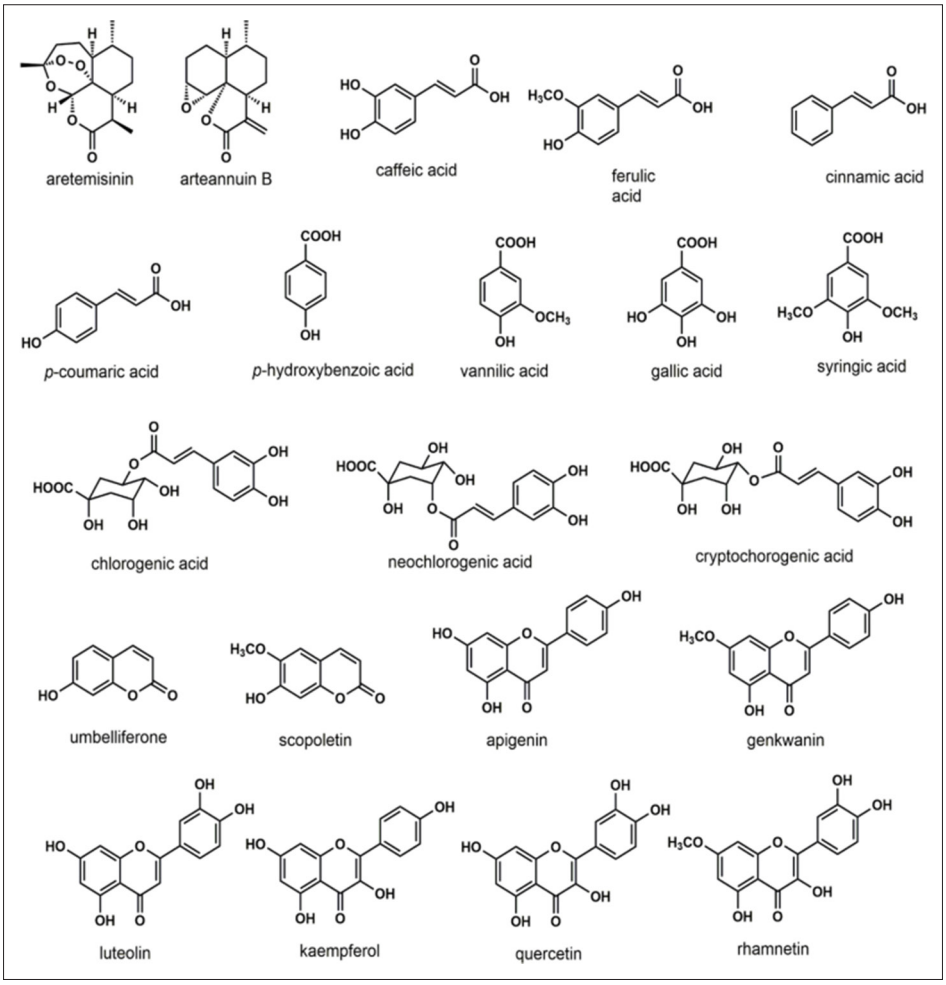

Figure 1. Some nonvolatile constituents of *Artemisia* spp.

hemostatic agent.[46] *Artemisia rutifolia* Stephan ex Spreng. is distributed in Afghanistan, China, India, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan, Russian Federation, and Tajikistan. A tea from the herb is taken to treat asthma, as an anti-inflammatory and diuretic; the fresh herb is used as an analgesic for toothache; a decoction of the herb is gargled for treatment of angina, stomach problems, and heart problems.[14,47]

Artemisia scoparia Waldst. & Kit. ("red stem worm wood") is a faintly scented annual herb which is widespread and common throughout the world, particularly in southwest Asia and central Europe. The success of *A. scoparia* may be attributed to the presence of phytotoxins, the volatile essential oils, in addition to other nonvolatile secondary products. It has been established that aerial parts of *A. scoparia* yield a volatile essential oil that has medicinal value. It possesses insecticidal, antibacterial, anticholesterolemic, antipyretic, antiseptic, cholagogue, diuretic, purgative, and vasodilatory activities and is also used for the treatment of gall bladder inflammation, hepatitis, jaundice, malaria, and diabetes.[2,35,48]

Artemisia spicigera K. Koch, named locally as "yavs¸an," is widespread in Central and Eastern Anatolia in Turkey, at an altitude between 1000 and 2500 m.[49]

Artemisia tridentata Nutt. "big sagebrush" is one of the most widely distributed and ecologically important shrub species in Western North America. This species serves as a critical habitat and food resource for many animals and invertebrates.[32] Several North American native tribes have used infusions of *A. tridentata* to treat bronchitis and pneumonia.[39]

Artemisia vestita Wall ex Besser has been utilized for the treatment of fungal infections such as tinea, tympanitis, and thrush.[2,6,23]

Artemisia vulgaris L., commonly known as "mugwort," is a perennial weed growing wild native in temperate and cold-temperature zones of the world such as in Asia, Europe, and North America.[50,51] The plant is widely used in the Philippines, where it is locally known as "herbaka," for its antihypertensive actions. It has also been suggested to have

other medicinal activities such as anti-inflammatory, antispasmodic, carminative, and anthelmintic properties, and has been used in the treatment of painful menstruation (dysmenorrhea) and in the induction of labor or miscarriage.[50] *Artemisia vulgaris* has been known not only as an edible plant but also as a folk medicine resource. Mugwort is used to flavor tea and rice dishes in Asia and as a culinary herb for poultry and pork in Western cultures.[51] In Oriental medicine, mugwort has been employed as an analgesic agent and in conjunction with acupuncture therapy.[51,52] Considered an emmenagogue, an inducing agent of menstrual flow, mugwort has been traditionally employed to bring about regular menses in cases of amenorrhea or menorrhagia.[51]

Artemisia mongolica (Fisch. ex Besser) Nakai has been used as a folk medicine for generations to cure inflammations and colds in Northwest China.[53]

Artemisia pontica L. is well known in Bulgarian folk medicine as a sedative and an appetizer.[54]

In the western Himalayas of northern Pakistan, *A. roxburghiana* Besser extract is used to treat fever, malaria, and intestinal worms. In Uttarakhand, India, *A. roxburghiana* is used in ethnoveterinary medicine to treat eye diseases, wounds, cuts, and external parasites.[35]

Artemisia herba-alba Asso (syn. *Artemisia maritima* L., *Artemisia brevifolia* Wall.) is used in the traditional medicine of the Northern Badia region of Jordan, in the form of a decoction, against fever and menstrual and nervous problems.[55] *Artemisia herba-alba*, known also as desert wormwood (known in Arabic as "shih," and French as "armoiseblanche"),[56] has been used in folk medicine by many cultures since ancient times and in Moroccan folk medicine to treat arterial hypertension and/or diabetes.[57-59] *Artemisia herba-alba* is widely distributed in North Africa and used traditionally by the Egyptians as a vermifuge in addition to its other medical and veterinary uses.[60] Herbal tea from this species has been used as analgesic, antibacterial, antispasmodic, and hemostatic agents.[61] During an ethnopharmacological survey carried out among the Bedouins of the Negev Desert, it was found that *A. herba-alba* relieved stomach disorders.[60] This plant is also suggested to be important as a fodder for sheep and for livestock in the plateau regions of Algeria where it grows abundantly.[62]

Artemisia sieberi Besser is a famous medicinal plant in Middle East traditional medicine as an anthelmintic. In external use, the flowering shoots and leaves were boiled in normal saline and the extracted solution was used for treatment of gangrenous ulcers, infectious ulcers, and inflammations. *Artemisia sieberi* is used as fodder for sheep and it is believed that it can increase weight and fleece of sheep. It was used as carminative, to relieve inflammation and abscesses and to prevent leprosy.

Bioactive Compounds From *Artemisia*

Bioactive compounds are experiencing a growing interest in wide range of applications: geo-medicine, plant science, modern pharmacology, agrochemicals, cosmetics, food industry, nano-bio-science, and so on.[63-65]

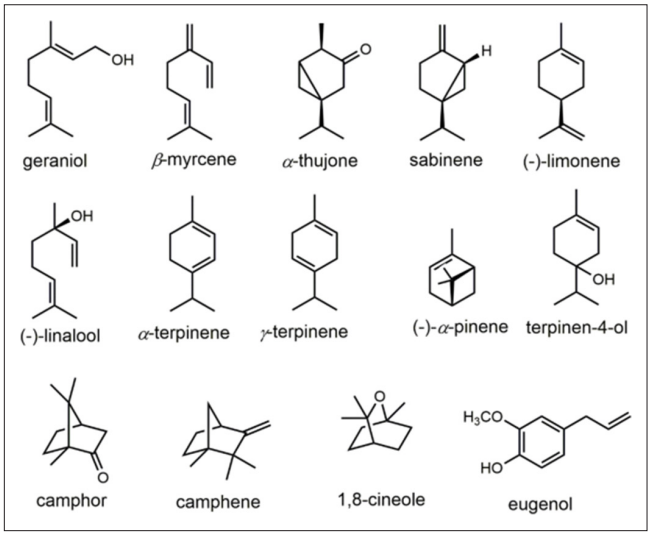

Figure 2. Structure of some volatile constituents of *Artemisia* spp.

Bioactive compounds in plants are classified according to different criteria. A presentation based on clinical function–their pharmacological or toxicological effects–is relevant for the clinician, pharmacist, or toxicologist. An approach based on biological effects is complicated by the fact that the clinical outcome is not exclusively connected to biochemically closely related compounds; even biochemically different molecules might produce similar clinical effects. A botanical categorization based on families and genera of the plants producing the bioactive compounds might also be relevant, as closely related plant species most often produce the same or chemically similar bioactive compounds. However, there are also ranges of examples that species even genetically less related produce similar secondary compounds. The main focus are the bioactive chemical compounds; therefore, it is useful to categorize them according to biochemical pathways and chemical classes.[66-68]

Artemisia species represent rich sources of various types of biologically active compounds accountable for numerous pharmacological activities. Differences in qualitative and quantitative composition of bioactive compounds might be correlated with environmental conditions, species variation, geographic, climatic, and genetic conditions, plant age, soil, phase of vegetation, anatomical part of plant, harvesting season, and method of harvesting.[69-72]

Tables 1 and 2 present detailed list of the chemical constituents and essential oil components of various *Artemisia* sp., respectively (Figures 1 and 2).

Conclusion

Artemisia species are widely used in traditional medicine all over the world with different and well-known therapeutic applications. They exhibit anti-inflammatory, antitumor, antioxidant,

antispasmodic, antimicrobial, insecticidal, antimalarial, antifungal, and antioxidant activities. These diverse biological activities are manifested by different compounds whose main components are essential oils and polyphenols. *Artemisia* holds a great potential for human health and its therapeutic effects should be more strictly and intensively analyzed. Preclinical and clinical research needs to be done on the use of these plants and further indepth investigations are urgently necessary to study all bioactive compounds and their biomolecular mechanisms at the cellular and tissue levels.

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Acknowledgments

The authors are very thankful to all the authors whose work has been cited in this paper.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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