*Journal of Stress Physiology & Biochemistry, Vol. 19, No. 1, 2023, pp. 97-104 ISSN 1997-0838*


**ORIGINAL ARTICLE**

# Phytochemical Analysis of Two *Achillea* (*Asteraceae*) Species Using GC/MS Technique

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Received September 29, 2022

Wild *Achillea aleppica* DC and *Achillea arabica* Kotschy flowering, aromatic and perennial herbs, grown in the Middle-Southern regions of Syria were assessed for their ethanolic and acetonic aerial parts extracts phytochemical analysis based on gas chromatography-mass spectrometry (GC/MS) analysis. Overall, GC/MS chromatogram revealed that the 9-Octadecenamide, (Z)- (41.656% and 61.097%) and Hexadecanamide (36.542% and 20.238%) were the most abundant compounds for ethanolic and acetonic *A. aleppica* aerial parts extracts, respectively. Whereas, 9-Octadecenamide, (Z)- (41.280% and 53.990%) and Hexadecanamide (30.828% and 14.445%) were the most abundant compounds for ethanolic and acetonic *A. Arabica* aerial parts extracts, respectively. This study could consider as the first report highlights *A. aleppica* and *A. arabica* extracts phytochemical analysis.

*Key words: Achillea aleppica; Achillea arabica (Achillea biebersteinii); Gas chromatography-mass spectrometry (GC/MS); Phytochemical analysis; 9-Octadecenamide, (Z)-*

*Achillea* genus belongs to Asteraceae family the largest angiosperms's family, comprise approximately 1500 genera and 23000 species. They spilled in three subfamilies and seventeen tribes. This genus involved 115 species of perennial herbs; all of them are native to temperate regions of the northern hemisphere (Moradkhani *et al*. 2012).

*Achillea* species exhibited wide range in medicine and pharmaceutical applications; *e.g*. as antimicrobial (Stojanović *et al*. 2005; Toncer *et al*. 2010; Tabanca *et al*. 2011; Albayrak and Silahtarlıoğlu 2019); antioxidant (Toncer *et al*. 2010; Manayi *et al*. 2012; Polatoglu *et al*. 2013; Albayrak and Silahtarlıoğlu 2019); insecticidal (Toncer *et al*. 2010; Tabanca *et al*. 2011; Polatoglu *et al*. 2013); herbicidal (Toncer *et al*. 2010; Polatoglu *et al*. 2013); cytotoxic (Albayrak and Silahtarlıoğlu 2019); antinociceptive and anti-inflammatory (Toncer *et al*. 2010) properties. Moreover, they used in traditional remedies against rheumatic pain and digestive complaints, fever, common cold, pneumonia and hemorrhage (Manayi *et al*. 2012).

The genus *Achillea* is represented in Syrian Flora with about 9 species (Mouterde 1983), of which *A. aleppica* DC and *A. arabica* Kotschy (Synonyms. *Achillea biebersteinii* Afanasiev) were wild grown in Syria. *A. aleppica* DC has antimicrobial, anti-inflammatory and antinociceptive properties (Toncer *et al*. 2010; Tabanca *et al*. 2011). Whereas, *A. arabica* Kotschy has hepatoprotective, antioxidant, herbicidal and insecticidal properties (Toncer *et al*. 2010; Tabanca *et al*. 2011; Başer 2016; Al-Said *et al*. 2016).

Different analytical methods allowed for long time identifying chemical compounds occurred in plants essential oils (EOs) and extracts. Of which, GC/MS analysis has been extensively employed worldwide for this purpose; *e.g*. in *A. millefolium*, *A. lingulata, A. holosericea* and *A. clavennae* species EOs (Boskovic *et al*. 2005); *A. biebersteinii*, *A. millefolium* and *A. wilhelmsii* EOs (Dehghan and Elmi 2014); *A. biebersteinii* EOs (Al-Said *et al*. 2016; Sevindiki *et al*. 2018); *A. fragrantissima* EOs (Hatem *et al*. 2018); *A. coarctata* EOs (Albayrak and Silahtarlıoğlu 2019) and aqueous ethanolic (40 % v/v) vegetative parts *A. micrantha* extract (Astafyeva *et al*. 2018).

To our knowledge, the majority of researches on *A. aleppica* DC and *A. arabica* Kotschy species phytochemical analysis have been focused on their essential oils composition. However, little is known about their extracts phytochemical analysis. Thereby, the current investigation focused on their ethanolic and acetonic aerial parts extracts phytochemical analysis using GC/MS analysis.

## MATERIALS AND METHODS

### *Plant materials and preparation of extracts*

Aerial parts of *A. aleppica* and *A. arabica* (10 plants for each species) were collected and bulked as representative for each *Achillea* sp. Samples have been collected during blooming stage from two wild *Achillea* species grown in their natural habitat from Middle-Southern regions in Syria. *Achillea aleppica* DC was collected from rural Damascus regions - Syria; whereas, *Achillea arabica* Kotschy was collected from rural Homs regions - Syria (Table 1).

Samples were shade dried for two weeks, and were milled to fine powder by special electric mill and stored separately in glass bowls for ethanolic and acetonic extracts preparation.

The fine powder for each sample was extracted with ethanol and acetone solvents, separately as flowing: 1 g of fine powder was extracted with 10 ml solvent overnight, filtrated with filter papers (Whatman no.1). Then, all extracts were kept in tightly fitting stopper bottles and stored at 4 °C. The final obtained extracts were then subjected to GC/MS analysis.

### GC/MS analysis

GC Chromatec-Crystal 5000 system, supported with Chromatec Crystal Mass Spectrometry Detector (Chromatec, Russia) has been employed to investigate phytochemical ethanolic and acetonic *A. aleppica* and *A. arabica* aerial parts extracts analysis. GC/MS analysis has been performed according to the following conditions: The range scan was 42-850 MU, the column [(BP-5-MS (30 m × 0.25 mm × 0.25 μm)], carrier gas (0.695 ml/min flow of Helium gas). Oven temperature was programmed initially at 35 °C for 1 min, then an increase by 10°C /1 min till 220 °C, then increase to 230 °C by 1°C /1 min followed by 10 °C /1 min increasing till 255 °C (hold for 5 min). Injector temperature was 275 °C and detector temperature was 280 °C and ionization energy was 70 ev. Each extract component was identified by comparing retention time values of gas chromatography on polar columns and by comparing mass spectrum and NIST-17 library databases.

## RESULTS AND DISCUSSION

In the current study, GC/MS chromatogram revealed 11 and 23 compounds in ethanolic and acetonic *A. aleppica* aerial parts extracts, respectively (Tables 2 & 3). Of which, 9-Octadecenamide, (Z)- (41.656%), Hexadecanamide (36.542%) and Tetradecanamide (9.965%) were the most abundant compounds in ethanolic *A. aleppica* aerial parts extracts (Table 2). Whereas, 9-Octadecenamide, (Z)- (61.097%), Hexadecanamide (20.238%) and Nonadecanamide (5.601%) were the most abundant compounds in acetonic *A. aleppica* aerial parts extracts (Table 3). As for *A. Arabica,* they were 8 and 34 compounds in ethanolic and acetonic *A. aleppica* aerial parts extracts, respectively (Tables 4 & 5). Of which, 9-Octadecenamide, (Z)- (41.280%), Hexadecanamide (30.828%) and Dodecanamide (8.940%) were the most abundant compounds in ethanolic *A. Arabica* aerial parts extracts (Table 4). Whereas, 9-Octadecenamide, (Z)- (53.990%), Hexadecanamide (14.445%) and 13-Docosenamide, (Z)- (7.829%) were the most abundant compounds in acetonic *A. Arabica* aerial parts extracts (Table 5).

Overall, GC/MS chromatogram revealed that the 9-Octadecenamide, (Z)- (41.656% and 61.097%) and Hexadecanamide (36.542% and 20.238%) were the most abundant compounds for ethanolic and acetonic *A. aleppica* aerial parts extracts, respectively. Whereas, 9-Octadecenamide, (Z)- (41.280% and 53.990%) and Hexadecanamide (30.828% and 14.445%) were the most abundant compounds for ethanolic and acetonic *A. Arabica* aerial parts extracts, respectively.

It has been reported the presence of camphor (9-30%), 1,8-cineole (9-42%), p-cymene (5-27%) and piperitone (3-50%) as a main components in *A. biebersteinii* EOs (Toncer *et al*. 2010; Tabanca *et al*. 2011). Whereas, α-terpinen (41.42%), 2-carene (13.96%), m-cymene (13.41%) and 1,8-cineole (8.91%) were mainly presented in *A. biebersteinii* EOs using GC/MS analysis (Dehghan and Elmi 2014). While, Al-Said et al. (2016) reported 44 compounds in *A. biebersteinii* EOs; of which α-Terpinene (29.2%), p-Cymene (22.9%), Terpinen-4-ol (4.7%) and 1,8-Cineole (4.3%) were mainly detected in their EOs using GC/MS analysis. Moreover, Sevindiki *et al*. (2018) reported 29 components in *A. biebersteinii* EOs, of which 1,8-cineole (20.36%), cyclohexanone (8.39%), 2-cyclohexen-1-one (5.38%) and spathulenol (4.19%) were presented as a main components using GC/MS analysis.

Whereas, camphor (33-34%), 1,8-cineole (20-26%), p-cymene (14%), α-pinene (4%), α-terpineol (9%), α-bisabolol oxide (4%), T-cadinol (4%), caryophyllene oxide (3%) and spathulenol (3%) as a main components in *A. aleppica* EOs (Toncer *et al*. 2010).

GC/MS analysis has been extensively also used to investigate of other *Achillea* species for their EOs composition. In this regards, Boskovic *et al*. (2005) reported that β-pinene in *A. millefolium*, τ-cadinol in *A. lingulata,* 1,8-cineole in *A. holosericea* and camphor in *A. clavennae* were the main constituents in their EOs. Moreover, Astafyeva *et al*. (2018) reported that aldehydes (41.93%), alcohols (21.24%), hydrocarbons (14.45%), aromatic hydrocarbons (7.78%), esters (3.21%) and ketones (2.37%) functional groups, were mainly recorded in the aqueous ethanolic (40 % v/v) vegetative parts *A. micrantha* extract. Whereas, Hatem *et al*. (2018) reported 51 compounds of which artemisia ketone (29.97%), α-thujone (13.34%), germacrene (11.5%) followed by α-cubebene (6.25%), spathulenol (3.63%), β-sesquiphellandrene (3.52%) and γ-muurolene (3.27%) were mainly components in the fresh aerial parts of *A. fragrantissima* EOs. Moreover, Albayrak and Silahtarlıoğlu (2019) reported 45 compounds were presented in *A. coarctata* EOs; of which Camphor (29.44%), 1,8-cineole (19.87%), borneole (8.25%), β-eudesmol (7.65%) and caryophyllene oxide (7.29%) were mainly occurred using GC/MS analysis. Whereas, other compounds were presented in minor amounts (0.17%–2.91%).

Whereas, Dehghan and Elmi (2014) reported 20 compounds in *A. millefolium* EOs of which 1,8-cineole (28.0%), camphor (19.2%), borneol (98.8%) and β-pinene (6.3%) were mainly presented. While, 23 compounds in *A. wilhelmsii* EOs of which carvacrol (29.2%), linalool (10.3%), 1,8-cineole (11.0%), (E)-nerolidol (8.4%) and borneol (5.04%) were mainly presented in their EOs. Whereas, Farajpour ett al. (2017) reported that the 1,8-Cineole, 1.2–19.8%; β-thujone, 0.4–55.3%; camphor, 0.6–25.5%; germacrene-D, 2–20.6%; trans-nerolidol, 0.4–48.1%; isospathulenol, 0.5–36%; and cubenol, 0.1–42.9% were mainly detected in the *A. millefolium* EOs. Recently, Yener *et al*. (2020) reported that α-terpinene, β-eudesmol, piperitone, endo-borneol, artemisia ketone, verbenol, eucalyptol and camphor were the main constituents in *Achillea* species EOs.

In the current study, caryophyllene oxide was recorded to be 0.264% in acetonic *A. aleppica* aerial parts extract; whereas, it was recorded to be 1.01% in *A. biebersteinii* EOs (Baris *et al*. 2006); 3% in *A. aleppica* EOs (Toncer *et al*. 2010); 2% in *A. tenuifolia* EOs (Manayi *et al*. 2014); 0.52% in *A. fragrantissima* EOs (Choucry 2017) and ranged between 0.76-11.9% in *A. millefolium* EOs (Farajpour *et al*. 2017). Otherwise, in the current study, oleic acid was recorded to be 41.656% and 61.097% for ethanolic and acetonic *A. aleppica* aerial parts extracts, respectively and to be 41.280% and 53.990% for ethanolic and acetonic *A. Arabica* aerial parts extract's, respectively. Whereas, it was 9.7% in *A. tenuifolia* EOs (Manayi *et al*. 2014). These differences could be attributed to the fact that geographical distribution, species, plant phynological stages and extraction type (solvents or EOs) affect *Achillea* sp. chemical composition (Dehghan and Elmi 2014; Al-Said *et al*. 2016; Farajpour *et al*. 2017).

**Table 1**. Collection sites of *A. aleppica* and *A.arabica* species.

| Species | Collection site | Code | Altitude (m) | Annual rainfall (mm) |
|---|---|---|---|---|
| *A. aleppica* | Damascus | A.A | 950 | 260 |
| *A. arabica* | Homs | A.R | 265 | 400 |

**Table 2**. GC/MS analysis of ethanolic *A. aleppica* aerial parts extracts.

| Peak No | RT (min) | Name of Compound | Peak area (%) |
|---|---|---|---|
| 1 | 9.482 | Eucalyptol | 1.002 |
| 2 | 11.745 | endo-Borneol | 1.523 |
| 3 | 20.611 | Hexadecanenitrile | 0.748 |
| 4 | 22.259 | Pentadecanal | 2.027 |
| 5 | 24.126 | Dodecanoic acid, 3-hydroxy- | 3.314 |
| 6 | 24.982 | Hexadecanamide | 36.542 |
| 7 | 29.404 | 9-Octadecenamide, (Z)- | 41.656 |
| 8 | 30.084 | Tetradecanamide | 9.965 |
| 9 | 32.232 | 9-Octadecenenitrile, (Z)- | 0.803 |
| 10 | 33.743 | 13-Docosenamide, (Z)- | 1.431 |
| 11 | 33.881 | 9-Octadecenoic acid (Z)-, tetradecyl ester | 0.988 |

**Table 3**. GC/MS analysis of acetonic *A. aleppica* aerial parts extracts.

| Peak No | RT (min) | Name of Compound | Peak area (%) |
|---|---|---|---|
| 1 | 7.038 | Styrene | 0.142 |
| 2 | 9.491 | Eucalyptol | 0.777 |
| 3 | 10.087 | p-Menth-8-en-1-ol, stereoisomer | 0.260 |
| 4 | 10.599 | Cyclohexanol, 1-methyl-4-(1-methylethenyl)-,cis | 0.383 |
| 5 | 10.674 | Thujone | 0.428 |
| 6 | 11.749 | endo-Borneol | 0.689 |
| 7 | 17.412 | Caryophyllene oxide | 0.264 |
| 8 | 18.430 | Eicosane | 0.325 |
| 9 | 18.510 | Nonadecane | 0.832 |
| 10 | 18.596 | Heptanoic acid, heptyl ester | 0.263 |
| 11 | 19.693 | Tetradecanal | 0.608 |
| 12 | 20.199 | Benzaldehyde, 4-(dimethylamino)- | 0.183 |
| 13 | 20.622 | Octadecanal | 1.170 |
| 14 | 20.885 | Dodecyl nonyl ether | 0.803 |
| 15 | 21.381 | 10-Octadecenal | 0.833 |
| 16 | 22.270 | Pentadecanal | 1.676 |
| 17 | 23.211 | Z,Z-4,16-Octadecadien-1-ol acetate | 1.016 |
| 18 | 23.621 | 9-Hexadecenoic acid | 0.549 |
| 19 | 24.994 | Hexadecanamide | 20.238 |
| 20 | 25.500 | Palmitoleic acid | 0.627 |
| 21 | 29.434 | 9-Octadecenamide, (Z)- | 61.097 |
| 22 | 30.101 | Nonadecanamide | 5.601 |
| 23 | 32.240 | 9-Octadecenenitrile, (Z) | 1.238 |

**Table 4**. GC/MS analysis of ethanolic *A.arabica* aerial parts extracts.

| Peak No | RT (min) | Name of Compound | Peak area (%) |
|---|---|---|---|
| 1 | 13.654 | 4-Hydroxy-α-Thujone | 5.002 |
| 2 | 14.894 | 4-Hydroxy-ß-Thujone | 5.913 |
| 3 | 20.618 | Dodecanoic acid, 3-hydroxy- | 0.925 |
| 4 | 24.124 | Palmitoleamide | 5.608 |
| 5 | 24.984 | Hexadecanamide | 30.828 |
| 6 | 27.163 | Humulenol-ll | 1.505 |
| 7 | 29.405 | 9-Octadecenamide, (Z)- | 41.280 |
| 8 | 30.088 | Dodecanamide | 8.940 |

**Table 5**. GC/MS analysis of acetonic *A.arabica* aerial parts extracts.

| Peak No | RT (min) | Name of Compound | Peak area (%) |
|---|---|---|---|
| 1 | 7.038 | Styrene | 0.375 |
| 2 | 9.322 | Benzoic acid, 2,4-dimethyl-, (2,4-dimethylpheny)methyl ester | 0.145 |
| 3 | 11.866 | Octanoic acid, 7-oxo- | 0.358 |
| 4 | 12.724 | Isopulegol acetate | 0.599 |
| 5 | 13.430 | 1,4-dihydroxy-p-menth-2-ene | 0.269 |
| 6 | 14.415 | Dimethylmuconic acid | 0.082 |
| 7 | 14.512 | Ricinoleic acid | 0.170 |
| 8 | 14.712 | Arginine | 0.160 |
| 9 | 14.896 | 1,6-Octadiene, 3-ethoxy-3,7-dimethyl- | 1.526 |
| 10 | 17.201 | 1-Eicosanol | 0.080 |
| 11 | 18.508 | Tetradecane | 0.559 |
| 12 | 18.836 | Benzeneacetic acid, 4-tetredecyl ester | 0.191 |
| 13 | 19.185 | Cyclobuta[a]dibenzo[c.f]cycloheptadiene, 7-oxo- | 0.847 |
| 14 | 19.677 | Tetradecanal | 0.426 |
| 15 | 20.197 | Didodecyl phthalate | 0.222 |
| 16 | 20.620 | Hexadecanenitrile | 0.744 |
| 17 | 20.887 | Nonadecane | 0.580 |
| 18 | 21.373 | trans-2-Hexadecenoic acid | 0.835 |
| 19 | 22.265 | Tridecanal | 1.007 |
| 20 | 23.200 | 9-Octadecenenitrile, (Z) | 0.691 |
| 21 | 23.604 | Hexadecanal | 0.350 |
| 22 | 24.162 | 13-Docosenamide, (Z)- | 7.829 |
| 23 | 24.582 | 9-Hexadecenoic acid | 0.680 |
| 24 | 24.992 | Hexadecanamide | 14.445 |
| 25 | 25.502 | Octadecanenitrile | 0.606 |
| 26 | 27.156 | Phthaloylaspartic acid | 0.506 |
| 27 | 27.648 | α-Amyrin | 0.327 |
| 28 | 29.427 | 9-Octadecenamide, (Z)- | 53.990 |
| 29 | 30.095 | Deoxyspergualin | 5.003 |
| 30 | 31.556 | 4-((2-Amino-phenylthio)-1-benzyl-6-methylpiperidin-2-thione | 0.933 |
| 31 | 32.238 | Palmitoleonitrile | 1.011 |
| 32 | 33.344 | Carnegine | 1.276 |
| 33 | 33.628 | Benzen,1,1-[2-methyl-2-(phenylthio)cycloprppylidene]bis- | 1.505 |
| 34 | 33.748 | Cis-11-Eicosenamide | 1.668 |

## CONCLUSION

Ethanolic and acetonic *A. aleppica* and *A. arabica* aerial parts extracts have been investigated for their chemical composition using GC/MS analysis. Among different compounds detected in GC/MS ethanolic and acetonic *A. Arabica* and *A. aleppica* aerial parts extracts, 9-Octadecenamide, (Z)- and Hexadecanamide were the most abundant compounds. The two studied *Achillea* species showed some differences in their chemical composition of their extracts. The observed differences in their extracts composition could be attributed to the tested solvents, studied *Achillea* species and their geographical distribution.

## ACKNOWLEDGMENT

I thank I. Othman (Director General of AECS) and N. MirAli (Head of Molecular Biology and Biotechnology Department in AECS) for their support.

## CONFLICTS OF INTEREST

The authors declare that they have no potential conflicts of interest.

## REFERENCES

Albayrak S., Silahtarlıoğlu N., (2019) Determination of biological activities of essential oil and extract obtained from *Achillea coarctata* Poir. *Adv. Tradit. Med*., 20, 77–88.

Al-Said M.S., Mothana R.A., Al-Yahya M.M., Rafatullah S., Al-Sohaibani M.O., Khaled J.M., Alatar A., Alharbi N.S., Kurkcuoglu M., Baser H.C. (2016) GC-MS analysis: *In Vivo* hepatoprotective and antioxidant activities of the essential oil of *Achillea biebersteinii* Afan. growing in Saudi Arabia. *Evid. Based. Complement. Alternat. Med*., 2016, Article ID 1867048.

Astafyeva O., Kurashov S.E., Krylova J., Egorov M., Bataeva Y., Baimukhambetova A., (2018) Chemical composition and antibacterial properties of *Achillea micrantha. Indian J. Pharm. Sci*., 80, 434-441.

Başer K.H.C., (2016) Essential oils of *Achillea* species of Turkey. *Nat. Volatiles. Essent. Oils*., 3, 1-14.

Baris O., Güllüce M., Şahın F., Ozer H., Kilic H., Ozkan H., Sökmen M., Ozbek T., (2006) Biological activities of the essential oil and methanol extract of *Achillea biebersteinii* Afan. (Asteraceae). *Turk. J. Biol*., 30, 65-73.

Boskovic Z., Radulovic N. Stojanovic G. (2005) Essential oil composition of four *Achillea* species from the Balkans and its chemotaxonomic significance. *Chem. Nat. Comp*., 41, 674–678.

Choucry M.A. (2017) Chemical composition and anticancer activity of *Achillea fragrantissima* (Forssk.) Sch. Bip. (Asteraceae) essential oil from Egypt. *J. Pharmacogn. Phytotherapy*., 9, 1-5.

Dehghan G., Elmi F., (2014) Essential oil combination of three species of *Achillea* growing wild in East Azarbayjan- Iran. *Adv. Herb. Med*., 1, 22-28.

Dev P., Ramappa V.K., Gopal R ., Sangeeta., (2017) Analysis of chemical composition of *Mulberry Silkworm* pupal oil with fourier transform infrared spectroscopy (FTIR), gas chromatography/mass spectrometry (GC/MS) and its antimicrobial property. *Asian J. Agric. Res*., 11, 108-115.

Farajpour M., Ebrahimi M., Baghizadeh A., Aalifar M., (2017) Phytochemical and yield variation among Iranian *Achillea millefolium* accessions. *HortScience*., 52, 827–830.

Hatem N., Lara H.W., Safaa B., Nabil N., Nelly A-A., (2018) Antimicrobial activity of essential oil from Achillea fragrantissima (Forssk.) Sch.Bip. (Astracreas) growing wild in North Bekaa, Lebanon. *Int. J. Eng. Sci. Technol*., 7, 115-124.

Kumar V., Roy B.K., (2018) Population authentication of the traditional medicinal plant *Cassia tora* L. based on ISSR markers and FTIR analysis. *Sci. Rep*., 8, 10714.

Manayi A., Kurepaz-mahmoodabadi M., Gohari A.R., Ajani Y., Saeidn S., (2014) Presence of phthalate derivatives in the essential oils of a medicinal plant *Achillea tenuifolia*. *DARU J. Pharm. Sci*., 22,78.

Moradkhani S., Kobarfard F., Ayatollahi S.A. (2014) Phytochemical investigations on chemical constituents of *Achillea tenuifolia* Lam. *Iran. J. Pharm. Sci*.., 13,1049-1054.

Mouterde P. (1983) *Nouvelle Flore du Liban et de la Syrie. Dar El- Machreck, Beyrouth*., Vol. 3, Pp. 398-402.

Sevindiki E., Aydin S., Apaydin E.E., Surmen M., (2018) Essential oil composition and antimicrobial activity of *Achillea biebersteinii* Afan. (Asteraceae) from Erzincan region, Turkey. *Not. Sci. Biol*., 10, 328-332.

Tabanca N., Demirci B., Gurbuz I., Demirci F., Becnel J.J., Wedge D.E., Baser K.H.C., (2011) Essential oil composition of five collections of *Achillea biebersteinii* from central Turkey and their antifungal and insecticidal activity. *Nat. Prod. Commun*., 6, 701-706.

Toncer O., Basbag S., Karaman S., Diraz E., Basbag M. (2010) Chemical composition of the essential oils of some *Achillea* species growing wild in Turkey. *Int J. Agric. Biol*., 12:,527-530.

Yener I., Yilmaz M.A., Olmez O.T., Akdeniz M., Tekin F., Hasimi N., Alkan M.H., Ozturk M., Ertas A., (2020) A Detailed biological and chemical investigation of sixteen *Achillea* species essential oils via chemometric approach. *Chem. Biodivers*., 17, e1900484.