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RESEARCH ARTICLE

Essential oil composition of different parts of *Tanacetum cilicicum* (Boiss.) Grierson

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Abstract
The aim of this study was to investigate and compare the chemical composition of essential oils obtained by Clevenger-type apparatus from capitula (TCC) and aerial parts including leaves and stems (TCA) of *Tanacetum cilicicum* (Boiss.) Grierson from Turkey. TCC and TCA essential oils were separately analysed by GC-FID and GC/MS. Forty and thirty-two compounds were identified, representing 99% and 94.4% of the oils of TCC and TCA essential oils, respectively. The main constituents of the oil of the TCC were camphor (28.8%), (*E*)-nerolidol (16.9%), *trans*-chrysanthenyl acetate (12.8%) and 1,8-cineole (8.9%), whereas the oil from TCA comprised mainly *trans*-chrysanthenyl acetate (22.2%), borneol (19.4%), camphor (11.2%), 1,8-cineole (10.2%) and (*E*)-nerolidol (9.2%). The results showed that TCC and TCA essential oils were rich in oxygenated monoterpenes and oxygenated sesquiterpenes. This study is the first to study the essential oil composition of different parts of *Tanacetum cilicicum* separately. Also, to the our best of our knowledge, (*E*)-nerolidol was found in the *Tanacetum* species as the major compound for the first time.

Keywords: *Tanacetum cilicicum*, essential oil, 1,8-cineole, borneol, camphor, (*E*)-nerolidol, *trans*-chrysanthenyl acetate

Introduction

The genus *Tanacetum* comprises forty-six species in Turkey and nineteen of which are endemic (NGBB, 2019). *Tanacetum* species are used in the treatment of abdominal pain, ulcer, lung diseases, colds, shortness of breath, bronchitis, flu, throat diseases, hoarseness, diabetes, scabies, boils, inflammatory skin diseases, itching, kidney stone, rheumatism, migraine, infertility, menstrual disorders and also as carminative, facilitating digestion appetizing, expectorant, wound healing, antipyretic, tonic, anthelmintic. Some *Tanacetum* species have been reported to possess anticancer, antimicrobial, anti-inflammatory and antioxidant activities (Mantle et al., 2000; Rosselli et al., 2012). *Tanacetum* species contain essential oils (Table 1), flavonoids and sesquiterpene lactones as secondary metabolites (Tabanca et al., 2007; Gören et al., 2002; Polatoğlu et al., 2010a).

Previous phytochemical studies reported that *Tanacetum cilicicum*, known as “Kaba pireotu” in Turkey, contained phenolic compounds [*p*-Coumaric acid, ferulic acid, gallic acid, gentisic acid, chlorogenic acid, chrysin, galangin, quercetin, naringenin, catechin] and essential oils [Bicyclo (3,1,1) hept-2-en-4-ol, camphor, 1,8-cineole, 1,6,10-dodecatrien-3-ol, linalool, sesquisabinene hydrate] (Gecibesler et al., 2016; Ulukanli et al., 2017). Also, this species was found to have antioxidant (Gecibesler et al., 2016; Arıtuluk et al., 2016; Yıldırım et al., 2019), anti-inflammatory (Yıldırım et al., 2019), cholinesterase inhibitory (Orhan et al., 2015), antimicrobial (Ulukanli et al., 2017) and phytotoxic (Ulukanli et al., 2017) activities.

Although there are reports on the chemical composition of essential oil obtained from the aerial parts of *Tanacetum cilicicum*, the current study was aimed to investigate comparatively for the first time the

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chemical composition of essential oils obtained separately from capitulum and aerial parts excluding capitulum.

Table 1. Previous studies on essential oil of *Tanacetum* species from Turkey

***Tanacetum* species**	**Part distilled**	**Main components (%)**	**Reference**
T. cilicicum (Boiss.) Grierson	Aerial parts	Bicyclo(3,1,1)hept-2-en-4-ol (21.9%) Camphor (15.6%) 1,8-cineole (13.5%) 1,6,10-dodecatrien-3-ol (7.9%)	(Gecibesler et al., 2016)
T. cilicicum (Boiss.) Grierson	Aerial parts	Eucalyptol (5.1%) Linalool (7.0%) Sesquisabinene hydrate (6.9%)	(Ulukanli et al., 2017)
T. mucroniferum Hub.-Mor. & Grierson	Capitula	1,8-cineole (21.9%) Camphor (6.4%)	(Polatoglu et al., 2012a)
T. nitens (Boiss. & Noë) Grierson	Aerial parts	1,8-cineole (27.6%)	(Bagci et al., 2010)
T. argenteum (Lam.) Willd. subsp. *argenteum* (L.) All	Aerial parts	α-pinene (27.9%) Santolinatriene (8.8%) 1,8-cineole (6.8%)	(Bagci et al., 2010)
T. argenteum (Lam.) Willd. subsp. *flabellifolium* (Boiss. & Heldr.) Grierson	Aerial parts	β-thujone (47.1%) α-pinene (19.1%) α-thujone (10.5%)	(Kose et al., 2017)
T. kotschyi (Boiss.) Grierson	Capitula	Artemisia ketone (54.6%) Longiverbenone (vulgarone B) (9.2%)	(Polatoglu et al., 2011a)
	Stem	Artemisia ketone (26.5%) Longiverbenone (vulgarone B) (8.9%) Artemisia alcohol (5.2%) Intermedeol (9.0%)	
T. tomentellum (Boiss.) Grierson	Aerial parts	Camphor (9.4%) Linalool (7.6%) α-terpineol (7.1%) *Trans*-pinocarveol (5.3%)	(Tabanca et al., 2016)
T. zahlbruckneri (Náb.) Grierson	Capitula	Germacrene D (29.7%) Spathulenol (12.0%)	(Polatoğlu et al., 2011b)
T. tabrisianum (Boiss.) Sosn. & Takht.	Capitula	1,8-cineole (17.6%) Hexadecanoic acid (10.3%) Decanoic acid (5.8%) *Trans*-linalooloxide acetate (5.3%)	(Polatoğlu et al., 2011b)
	Stem	1,8-cineole (22.5%) Hexadecanoic acid (8%)	
T. alyssifolium (Bornm.) Grierson	Aerial parts	Borneol (35.2%) α-thujone (24.6%) Camphor (12.4%) β-eudesmol (6.1%)	(Kandemir et al., 2008)
T. argenteum (Lam.) Willd. subsp. *flabellifolium* (Boiss. & Heldr.) Grierson	Aerial parts	α-Pinene (29.0%) (*E*)-sesquilavandulol (16.0%) Camphor (14.0%)	(Tabanca et al., 2007)
T. chiliophyllum (Fisch. & Mey.) Schultz Bip. var. *chiliophyllum* (Fisch. & Mey.) Schultz Bip. from	Capitula	Camphor (32.5%) Chamazulene (9.2%)	(Polatoğlu et al., 2012b)

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Muradiye sample 1	Stem	1,8-Cineole (16.1%) Camphor (36.2%)	
T. chiliophyllum (Fisch. & Mey.) Schultz Bip. var. *chiliophyllum* (Fisch. & Mey.) Schultz Bip. from Muradiye sample 1	Capitula	1,8-Cineole (12%) *p*-Cymene (5.4%) Terpinen-4-ol (10.3%) (*E*)-Sesquilavandulol (5.8%)	(Polatoğlu et al., 2012b)
	Stem	1,8-Cineole (18.4%) *p*-Cymene (5.4%) Terpinen-4-ol (9.0%)	
T. chiliophyllum (Fisch. & Mey.) Schultz Bip. var. *chiliophyllum* (Fisch. & Mey.) Schultz Bip. from Güzeldere	Capitula	α-Pinene (5.3%) 1,8-Cineole (22.1%) Terpinen-4-ol (6.5%)	(Polatoğlu et al., 2012b)
	Stem	1,8-Cineole (28.9%) Terpinen-4-ol (5.6%)	
T. densum (Labill.) Sch.Bip. subsp. *eginense* Heywood	Capitula	Camphor (30.9%) 1,8-Cineole (12.4%) Camphene (10.6%) α-pinene (7.0%) Neodihydrocarveol (5.1%) An unidentified compound (11.5%)	(Polatoğlu et al., 2012c)
	Stem	Camphor (25.7%) Bornyl acetate (9.4%) Borneol (5.1%) An unidentified compound (27.2%)	
	Leaf	Camphor (27.7%) Camphene (7.0%) Bornyl acetate (11.8%) α-pinene (5.3%) Borneol (5.2%) An unidentified compound (20.5%)	
T. parthenium (L.) Sch.Bip. (Sample 1)	Capitula and stem	Camphor (49.0%) *Trans*-chrysanthenyl acetate (22.1%) Camphene (9.4%)	(Polatoğlu et al., 2010b)
T. parthenium (L.) Sch.Bip. (Sample 2)	Capitula and stem	Camphor (60.8%) Camphene (6.8%)	
T. argyrophyllum (C. Koch) Tvzel. var. *argyrophyllum* (C. Koch) Tvzel.	Leaf	1,8-Cineole (11.1%) α-Thujone (51.8%)	(Gören et al., 2001)
T. argyrophyllum (C. Koch) Tvzel. var. *argyrophyllum* (C. Koch) Tvzel.	Capitula	α-Thujone (62.8%)	
T. argenteum (Lam.) Willd. subsp. *canum* (C. Koch) Grierson var. *canum* (C. Koch) Grierson	Leaf	α-Thujone (11.9%) β-Caryophyllene (5.1%) Caryophyllene oxide (12.6%)	
T. praeteritum (Horwood) Heywood subsp. *praeteritum* (Horwood) Heywood	Aerial parts	β-Pinene (5.7%) 1,8-Cineole (12.3%) Bornyl acetate (10.0%) Terpinen-4-ol (7.1%) Borneol (28.1%)	
T. praeteritum (Horwood) Heywood subsp. *massicyticum* Heywood	Aerial parts	α-Thujone (51.1%) β-Thujone (10.0%)	

T. argenteum (Lam.) Willd. subsp. *argenteum* (L.) All	Leaf	α-Pinene (36.7%) β -Pinene (27.5%) 1,8-Cineole (9.8%)	(Polatoğlu et al., 2010a)
T. densum (Labill.) Sch.Bip. subsp. *amani* Heywood	Leaf	α-Pinene (9.7%) β -Pinene (27.2%) 1,8-Cineole (13.1%) *p*-Cymene (8.9%) Lavandulyl acetate (8.1%)	
T. macrophyllum (Waldst. & Kit.) Sch. Bip.	Aerial parts	β-eudesmol (89.5%)	(Javidnia et al., 2010)
T. armenum (DC.) Sch.Bip.	Leaves	1,8-Cineole (31.3%) Camphor (8.6%) α-Terpineol (5.5%)	(Başer et al., 2001)
T. armenum (DC.) Sch.Bip.	Aerial parts	1,8-Cineole (11.3%) Camphor (26.7%) Borneol (10.6%) γ-Eudesmol (5.5%)	
T. balsamita L.	Aerial parts	α-Thujone (11.7%) Carvone (52.4%)	
T. chiliophyllum Fisch. & Mey.) Schultz Bip. var. *chiliophyllum* Fisch. & Mey.) Schultz Bip.	Capitula	α-Thujone (12.5%) Camphor (16.8%) *cis*-Chrysanthenyl acetate (16.3%)	
T. haradjani (Rech.fil.) Grierson	Leaves	1,8-Cineole (10.0%) Camphor (15.9%) Terpinen-4-ol (6.7%)	
T. cadmeum (Boiss.) Heywood (using Direct Thermal Desorption Technique- DTD)	Leaves	*p*-Cymene (11.9%) Eucalyptol (27.0%) Ascaridol (22.4%) Unknown (5.0%)	(Gogus et al., 2009)
T. cadmeum (Boiss.) Heywood (using Direct Thermal Desorption Technique- DTD)	Capitula	2-Carene (6.2%) *p*-Cymene (9.3%) γ-Terpinene (15.3%) Ascaridol (39.8%)	
T. cadmeum (Boiss.) Heywood (using hydrodistillation-HD)	Leaves and capitula	*p*-Cymene (7.2%) Eucalyptol (12.0%) Verbenone (5.7%) Ascaridol (46.0%) Unknown (5.2%)	
T. cadmeum (Boiss.) Heywood subsp. *orientale* Grierson	Aerial part	1,8-Cineole (18.9%) *p*-cymene (15.7%) Terpinen-4-ol (14.8%) Borneol (9.8%)	(Özek et al., 2007)
T. macrophyllum (Waldst. & Kit.) Sch.Bip.	Aerial part	Camphor (5.8%) *cis*-chrysanthenol (12.0%) Copaborneol (5.6%) β−eudesmol (21.4%)	(Demirci et al., 2007)
T. argyrophyllum (C. Koch) Tvzel. var. *argyrophyllum* (C. Koch) Tvzel.	Capitula	1,8-Cineole (8.4%) Camphor (29.7%) Bornyl acetate (6.1%) Borneol (12.0%)	(Polatoğlu et al., 2010c)
T. argyrophyllum (C. Koch) Tvzel. var. *argyrophyllum* (C. Koch) Tvzel.	Stem	1,8-Cineole (17.5%) Camphor (26.6%)	

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		Borneol (15.0%)	
T. macrophyllum (Waldst. & Kit.) Sch.Bip.	Capitula	(*E*)-Sesquilavandulol (20.3%) γ-Eudesmol (21.5%) Copaborneol (8.5%)	(Polatoğlu et al., 2015)
	Leaf	1,8-Cineole (11.0%) β-Thujone (9.0%) Bornyl acetate (9.6%) Borneol (6.3%) Copaborneol (14.1%)	

Materials and Methods

Plant material

Aerial parts of plant were collected in the flowering period from Pülümür district of Tunceli province of Turkey in 2017 and identified by one of us (AD). Voucher specimens were deposited in the Herbarium of the Faculty of Pharmacy, Marmara University (MARE No: 17768).

Isolation of essential oil

Capitula (100 g) and aerial parts including leaves and stem (200 g) were separately hydrodistilled for 4 hours using a Clevenger apparatus. The essential oils obtained were stored at 4°C in the dark until analysed.

GC and GC-MS conditions

The oils were analysed by Gas Chromatography-Flame Ionization Detector (GC-FID) and Gas Chromatography-Mass Spectrometry (GC/MS) using an Agilent GC-MSD system (Mass Selective Detector-MSD).

GC-MS analysis

The GC-MS analysis was carried out with an Agilent 5975 GC-MSD system (Agilent, USA; SEM Ltd., Istanbul, Turkey). Innowax FSC column (60m x 0.25mm, 0.25μm film thickness) was used with helium as carrier gas (0.8 mL/min). GC oven temperature was kept at 60°C for 10 min and programmed to 220°C at a rate of 4°C/min, and kept constant at 220°C for 10 min and then programmed to 240°C at a rate of 1°C/min. Split ratio was adjusted 40:1. The injector temperature was at 250°C. The interphase temperature was at 280°C. MS were taken at 70 eV. Mass range was from *m/z* 35 to 450.

GC-FID analysis

GC-FID analyses were performed using an Agilent 6890N GC system. FID temperature was set to 300°C and the same operational conditions were applied to a triplicate of the same column used in GC–MS analyses. Simultaneous auto injection was done to obtain equivalent retention times. Relative percentages of the separated compounds were calculated from integration of the peak areas in the GC-FID chromatograms.

Identification of compounds

The components of essential oils were identified by comparison of their mass spectra with those in the Baser Library of Essential Oil Constituents, Adams Library (Adams, 2007), MassFinder Library (Hochmuth, 2008), Wiley GC/MS Library (McLafferty & Stauffer, 1989) and confirmed by comparison of their retention indices. These identifications were accomplished by comparison of retention times with authentic samples or by comparison of their relative retention index (RRI) to a series of n-alkanes. Alkanes (C_8-C_{29}) were used as reference points in the calculation of relative retention indices (RRI) (Curvers et al., 1985). Relative percentage amounts of the separated compounds were calculated from FID chromatograms. The analysis results are expressed as mean percentage ± standard deviation (SD) (*n* = 3) as listed in Table 2 and 3.

Results and Discussion

The aim of our study was to comparatively investigate the chemical composition of water-distilled essential oils obtained from capitula (TCC) and aerial parts including leaves and stems (TCA) of *Tanacetum cilicicum* (Boiss.) Grierson from Turkey.

Forty and thirty-two compounds were identified, representing 99% and 94.4% of the oils of TCC and TCA, respectively. The main compounds of the oil of the TCC were identified as camphor (28.8%), (*E*)-nerolidol (16.9%), *trans*-chrysanthenyl acetate (12.8%) and 1,8-cineole (8.9%), whereas *trans*-chrysanthenyl acetate (22.2%), borneol (19.4%), camphor (11.2%), 1,8-cineole (10.2%) and (*E*)-nerolidol (9.2%) were found as major compounds in the essential oil of TCA (Table 2 and 3).

Table 2. Essential oil composition of capitula of *Tanacetum cilicicum*

No	RRI	Compounds	%	IM Identification method
1	1014	Tricyclene	0.1 ± 0.0	MS
2	1032	α-Pinene	0.9 ± 0.1	t_R, MS
3	1035	α-Thujene	0.2 ± 0.0	MS
4	1076	Camphene	2.0 ± 0.1	t_R, MS
5	1118	β-Pinene	0.4 ± 0.0	t_R, MS
6	1132	Sabinene	0.8 ± 0.0	t_R, MS
7	1188	α-Terpinene	0.1 ± 0.0	t_R, MS
8	1203	Limonene	0.6 ± 0.0	t_R, MS
9	1213	1,8-Cineole	8.9 ± 0.1	t_R, MS
10	1255	γ-Terpinene	0.3 ± 0.0	t_R, MS
11	1280	*p*-Cymene	0.7 ± 0.0	t_R, MS
12	1445	Filifolone	0.2 ± 0.0	MS
13	1484	*trans*-Chrysanthenol	2.7 ± 0.0	MS
14	1532	Camphor	28.8 ± 0.1	t_R, MS
15	1538	*trans*-Chrysanthenyl acetate	12.8 ± 0.1	MS
16	1553	Linalool	2.7 ± 0.0	t_R, MS
17	1590	Bornyl acetate	0.3 ± 0.1	t_R, MS
18	1611	Terpinen-4-ol	1.6 ± 0.0	t_R, MS
19	1667	*cis*-Verbenol	0.4 ± 0.1	MS
20	1683	*trans*-Verbenol	1.5 ± 0.0	MS
21	1706	α-Terpineol	2.9 ± 0.1	t_R, MS
22	1719	Borneol	3.9 ± 0.1	t_R, MS
23	1747	*p*-Mentha-1,5-dien-8-ol	0.6 ± 0.1	MS
24	1772	δ-Cadinene	0.4 ± 0.0	t_R, MS
25	1783	Campholene alcohol	0.4 ± 0.0	MS
26	1875	Benzyl 2-methylbutyrate	0.4 ± 0.0	MS
27	1916	Benzyl isovalerate	0.6 ± 0.0	t_R, MS
28	1988	Nerolidol oxide I	0.5 ± 0.0	MS

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29	2008	Caryophyllene oxide	0.6 ± 0.1	t_R, MS
30	2016	Nerolidol oxide II	0.5 ± 0.1	MS
31	2041	(*E*)-nerolidol	16.9 ± 0.2	t_R, MS
32	2096	Elemol	1.0 ± 0.1	MS
33	2174	Fokienol	0.3 ± 0.0	MS
34	2187	γ-Eudesmol	1.0 ± 0.1	MS
35	2191	T-Cadinol	1.1 ± 0.1	MS
36	2246	α-Eudesmol	0.5 ± 0.0	MS
37	2255	α-Cadinol	0.6 ± 0.1	t_R, MS
38	2256	β-Eudesmol	0.5 ± 0.1	MS
39	2273	Selina-11-en-4α-ol	0.6 ± 0.1	MS
40	2296	Decanoic acid	0.2 ± 0.0	MS
		Total identified compounds (%)	99.5	
		Monoterpene hydrocarbons	6.1	
		Oxygenated monoterpenes	67.7	
		Sesquiterpene hydrocarbons	0.4	
		Oxygenated sesquiterpenes	24.1	
		Aromatic ester	1.0	
		Saturated fatty acid	0.2	

RRI; Relative retention indices calculated against n-alkanes C8-C29. %; calculated from the FID chromatograms and expressed as mean ± SD (n = 3). tr; Trace (<0.1 %); t_R, identification based on the retention times (t_R) of genuine compounds on the HP Innowax column; MS, identified on the basis of computer matching of the mass spectra.

Table 3. Essential oil composition of aerial parts including leaves and stem of *Tanacetum cilicicum*

No	**RRI**	**Compounds**	**%**	**IM Identification Method**
1	1014	Tricyclene	0.1 ± 0.0	MS
2	1032	α-Pinene	1.1 ± 0.0	t_R, MS
3	1035	α-Thujene	0.2 ± 0.0	MS
4	1076	Camphene	1.8 ± 0.0	t_R, MS
5	1118	β-Pinene	1.9 ± 0.0	t_R, MS
6	1132	Sabinene	0.7 ± 0.0	t_R, MS
7	1203	Limonene	0.5 ± 0.0	t_R, MS
8	1213	1,8-Cineole	10.2 ± 0.1	t_R, MS
9	1255	γ-Terpinene	0.4 ± 0.1	t_R, MS
10	1280	*p*-Cymene	0.6 ± 0.0	t_R, MS
11	1484	*trans*-Chrysanthenol	1.7 ± 0.0	MS
12	1532	Camphor	11.2 ± 0.1	t_R, MS
13	1538	*trans*-Chrysanthenyl acetate	22.2 ± 0.1	MS
14	1553	Linalool	0.5 ± 0.0	t_R, MS
15	1586	Pinocarvone	tr	MS
16	1590	Bornyl acetate	2.2 ± 0.1	t_R, MS
17	1611	Terpinen-4-ol	1.4 ± 0.0	t_R, MS
18	1667	*cis*-Verbenol	tr	MS
19	1683	*trans*-Verbenol	1.5 ± 0.0	MS
20	1706	α-Terpineol	2.9 ± 0.0	t_R, MS
21	1719	Borneol	19.4 ± 0.1	t_R, MS

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22	1772	δ-Cadinene	0.4 ± 0.1	t_R, MS
23	1786	*ar*-Curcumene	0.4 ± 0.1	MS
24	1988	Nerolidol oxide I	tr	MS
25	2008	Caryophyllene oxide	1.8 ± 0.0	t_R, MS
26	2016	Nerolidol oxide II	tr	MS
27	2041	(*E*)-Nerolidol	9.2 ± 0.2	t_R, MS
28	2191	T-Cadinol	1.6 ± 0.0	MS
29	2246	α-Eudesmol	tr	MS
30	2255	α-Cadinol	0.3 ± 0.1	t_R, MS
31	2256	β-Eudesmol	0.7 ± 0.1	MS
32	2273	Selina-11-en-4α-ol	1.1 ± 0.1	MS
		Total identified compounds (%)	96.0	
		Monoterpene hydrocarbons	7.3	
		Oxygenated monoterpenes	73.2	
		Sesquiterpene hydrocarbons	0.8	
		Oxygenated sesquiterpenes	14.7	

RRI; Relative retention indices calculated against *n*-alkanes C8-C29. %; calculated from the FID chromatograms and expressed as mean ± SD (*n* = 3). tr; Trace (<0.1 %); t_R, identification based on the retention times (t_R) of genuine compounds on the HP Innowax column; MS, identified on the basis of computer matching of the mass spectra.

The terpenoids consist of the main portion of essential oils and oxygenated monoterpenes (67.7%) were the main group of constituents of TCC oil, followed by oxygenated sesquiterpenes (24.1%), monoterpene hydrocarbons (6.1%), aromatic ester (1%), sesquiterpene hydrocarbons (0.4%), saturated fatty acid (0.2%). The major groups of compounds of TCA oil were oxygenated monoterpenes (73.2%), followed by oxygenated sesquiterpenes (14.7%), monoterpene hydrocarbons (7.3%), sesquiterpene hydrocarbons (0.8%) (Table 2 and 3).

There are only two reports on the composition of essential oil of *Tanacetum cilicicum*. In these studies, the chemical content of the essential oils obtained from the aerial parts containing the capitulum, stem and leaves of the plants was studied. Gecibesler et al. (2016) found bicyclo (3,1,1) hept-2-en-4-ol (21.9%), camphor (15.6%), 1,8-cineole (13.5%), 1,6,10-dodecatrien-3-ol (7.9%) as major compounds in oil, while Ulukanli et al. (2017) reported 1,8-cineole (eucalyptol) (5.1%), linalool (7.0%), sesquisabinene hydrate (6.9%) as major compounds. Contrary to these studies, in our current study, the chemical analysis of the essential oils *T. cilicicum* was performed separately for capitula and aerial parts (stem and leaves). However, similar to previous studies, camphor and 1,8-cineole were found to be major compounds in the essential oils (Gecibesler et al.,2016). The plant materials used in both studies were collected from the same areas. This may explain the similarity of chemical compositions of both oils.

In addition, the major components of *T. cilicicum* essential oils have also been previously reported from other *Tanacetum* species. Briefly, camphor in the essential oils of *T. mucroniferum* (Polatoglu et al., 2012a), *T. tomentellum* (Tabanca et al., 2016), *T. alyssifolium* (Kandemir et al., 2008), *T. argenteum* subsp. *flabellifolium* (Tabanca et al., 2007), *T. chiliophyllum* var. *chiliophyllum* (Polatoğlu et al., 2012b; Başer et al., 2001), *T. densum* subsp. *eginense* (Polatoğlu et al., 2012c), *T. parthenium* (Polatoğlu et al., 2010b), *T. armenum* (Başer et al., 2001), *T. haradjani* (Başer et al., 2001), *T. macrophyllum* (Demirci et al., 2007), *T. argyrophyllum* var. *argyrophyllum* (Polatoğlu et al., 2010c); *trans*-chrysanthenyl acetate in the essential oil of *T. parthenium* (Polatoğlu et al., 2010b); 1,8-cineole in the essential oil of *T. mucroniferum* (Polatoğlu et al., 2012a), *T. nitens* (Bagci et al., 2010), *T. argenteum* subsp. *argenteum* (Bagci et al., 2010), *T. tabrisianum*

(Polatoğlu et al., 2011b), *T. chiliophyllum* var. *chiliophyllum* (Polatoğlu et al., 2012b), *T. densum* subsp. *eginense* (Polatoglu et al., 2012c), *T. argyrophyllum* var. *argyrophyllum* (Gören et al., 2001), *T. praeteritum* subsp. *praeteritum* (Gören et al., 2001), *T. argenteum* subsp. *argenteum* (Polatoğlu et al., 2010a), *T. densum* subsp. *amani* (Polatoğlu et al., 2010a), *T. armenum* (Başer et al., 2001), *T. haradjani* (Başer et al., 2001), *T. cadmeum* (Gogus et al., 2009), *T. cadmeum* subsp. *orientale* (Özek et al., 2007), *T. argyrophyllum* var. *argyrophyllum* (Polatoğlu et al., 2010c), *T. macrophyllum* (Polatoğlu et al., 2015); borneol in the essential oils of *T. alyssifolium* (Kandemir et al., 2008), *T. densum* subsp. *eginense* (Polatoglu et al., 2012c), *T. praeteritum* subsp. *praeteritum* (Gören et al., 2001), *T. armenum* (Başer et al., 2001), *T. cadmeum* subsp. *orientale* (Özek et al., 2007), *T. argyrophyllum* var. *argyrophyllum* (Polatoğlu et al., 2010c), *T. macrophyllum* (Polatoğlu et al., 2015) have been found in previous studies. On the other hand, although (E)-nerolidol was found as a minor compound in the essential oil of different *Tanacetum* species (Ulukanli et al., 2017; Polatoğlu et al., 2012a; Polatoğlu et al., 2012b; Başer et al., 2001; Özek et al., 2007; Demirci et al., 2007; Polatoğlu et al., 2010c; Başer et al., 2001), it was found to be a major compound in the current study. Generally, essential oils of *Tanacetum* species are characterized by high amounts of monoterpene compounds (Table 1). The essential oil of *T. cilicicum* in our current study was found to be rich in monoterpene compounds.

Conclusion

The present study showed that essential oils of TCC and TCA were rich in oxygenated monoterpenes and oxygenated sesquiterpenes. Also, the results showed that (*E*)-nerolidol was found, for the first time, as a major compound in the *Tanacetum* oils.

REFERENCES

Adams, R.P. (2007). Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry. Allured Publ. Corp, Carol Stream, IL.

Arıtuluk, Z.C., Çankaya, İ.İ.T., & Gençler Özkan, A.M. (2016). Antioxidant activity, total phenolic and flavonoid contents of some *Tanacetum* L. (Asteraceae) taxa growing in Turkey. FABAD *Journal of Pharmaceutical Sciences*, *41*, 17–25.

Bagci, E., & Kocak, A. (2010). Essential oil composition of two endemic *Tanacetum* (T. *nitens* (Boiss.&Noe) Grierson and *T. argenteum* (Lam.) Willd. subsp. *argenteum*) (Asteraceae) taxa, growing wild in Turkey. *Industrial Crops and Products*, *31*, 542–545.

Başer, K.H.C., Demirci, B., Tabanca, N., Özek, T. & Gören, N. (2001). Composition of the essential oils of *Tanacetum armenum* (DC.) Schultz Bip., *T. balsamita* L., *T. chiliophyllum* (Fisch. & Mey.) Schultz Bip. var. *chiliophyllum* and *T. haradjani* (Rech. fil.) Grierson and the enantiomeric distribution of camphor and carvone. *Flavour and Fragrance Journal*, *16*, 195–200.

Curvers, J., Rijks, J., Cramers, C., Knauss, K., & Larson, P. (1985). Temperature programed retention indexes: calculation from isothermal data. Part 1: Theory. *Journal of High Resolution Chromatography*, *8*, 607–610.

Demirci, B., & Başer, K.H.C. (2007). The essential oil composition of *Tanacetum macrophyllum* (Waldst. et Kit.) Schultz. Bip. *Journal of Essential Oil Research*, *19*, 255–257.

Gecibesler, I.H., Kocak A., & Demirtas, I. (2016). Biological activities, phenolic profiles and essential oil components of *Tanacetum cilicicum* (Boiss.) Grierson. *Natural Product Research*, *30*(24), 2850–2855.

Gogus, F., Celik, A., Lewis, A.C., Ozel, M.Z. (2009). Analysis of volatile components from *Tanacetum cadmium* by hydrodistillation and direct thermal desorption methods using GC×GC-TOF/MS. *Chemistry of Natural Compounds*, *45*(4), 471–473.

Gören, N., Arda, N., & Caliskan, Z. (2002). Chemical characterization and biological activities of the genus *Tanacetum* (Compositae). *Studies in Natural Products Chemistry*, *27*, 547–658.

Gören, N., Demirci, B., Başer, K.H.C. (2001). Composition of the essential oils of *Tanacetum* spp. from Turkey. *Flavour and Fragrance Journal*, *16*, 191–194.

Hochmuth, D.H. (2008). MassFinder-4, Hochmuth Scientific Consulting, Hamburg, Germany.

Javidnia, K., Gholami, M., Firuzi, O., Özer, H., Kandemir, A. (2010). Antimicrobial and antioxidant activity and chemical composition of the essential oil of *Tanacetum macrophyllum* (Waldst. et Kit.) Schultz. Bip. *Journal of Essential Oil Research*, *22*(2), 186–188.

Kandemir, A., Ozer, H., Kilic, H., Cakir, A., & Demir, Y. (2008). Essential oil composition of *Tanacetum alyssifolium*, an endemic species from Turkey. *Chemistry of Natural Compounds*, *44*(4), 530–531.

Kose, Y.B., Iscan, G., Goger, F., Demirci, B., Elmacı, C. (2017). Antibacterial, anticandidal and antioxidant properties of *Tanacetum argenteum* (Lam.) Willd. subsp. *flabellifolium* (Boiss. & Heldr.) Grierson. *Pakistan Journal of Pharmaceutical Sciences*, *30*(6), 2047–2052.

Mantle, D., Eddeb, F., & Pickering, A.T. (2000). Comparison of relative antioxidant activities of British medicinal plant species *in vitro*. *Journal of Ethnopharmacology*, *72*, 47–51.

McLafferty, F.W., Stauffer, D.B. (1989). The Wiley/NBS Registry of Mass Spectral Data, J. Wiley and Sons, New York.

Nezahat Gökyiğit Botanik Bahçesi (NGBB) (2019). https://www.bizimbitkiler.org.tr/v2/ hiyerarsi.php?c=Tanacetum (Date of access: 15.05.2020).

Orhan, I.E., Tosun, F., Gülpınar, A.R., Kartal, M., Duran, A., Mihoglugil, F., & Akalgan, D. (2015). LC-MS quantification of parthenolide and cholinesterase inhibitory potential of selected *Tanacetum* L. (Emend. Briq.) taxa. *Phytochemistry Letters*, *11*, 347–352.

Özek, G., Özek, T., İşcan, G., Başer, K.H.C., Hamzaoglu, E., & Duran, A. (2007). Composition and antimicrobial activity of the essential oil of *Tanacetum cadmeum* (Boiss.) Heywood subsp. *orientale* Grierson. *Journal of Essential Oil Research*, *19*, 392–395.

Polatoğlu, K., Demirci, F., Demirci, B., Gören, N., & Başer, K.H.C. (2010a). Essential oil composition and antibacterial activity of *Tanacetum argenteum* (Lam.) Willd. ssp. *argenteum* and *T. densum* (Lab.) Schultz Bip. ssp. *amani* Heywood from Turkey. *Journal of Oleo Science*, *59*(7), 361–367.

Polatoğlu, K., Demirci, F., Demirci, B., Gören, N., & Başer, K.H.C. (2010b). Antibacterial activity and the variation of *Tanacetum parthenium* (L.) Schultz Bip. essential oils from Turkey. *Journal of Oleo Science*, *59*(4), 177–184.

Polatoğlu, K., Demirci, F., Demirci, B., Gören, N., & Başer, K.H.C. (2010c). Antimicrobial activity and essential oil composition of a new *T. argyrophyllum* (C. Koch) Tvzel var. *argyrophyllum* chemotype. *Journal of Oleo Science*, *59*(6), 307–313.

Polatoglu, K., Demirci, B., Goren, N., Baser, K.H.C. (2011a). Essential oil composition of *Tanacetum kotschyi* from Turkey. *Chemistry of Natural Compounds*, *47*(2), 297–299.

Polatoğlu, K., Demirci, B., Gören, N., & Başer, K.H.C. (2011b). Essential oil composition of endemic *Tanacetum zahlbruckneri* (Náb.) and *Tanacetum tabrisianum* (Boiss.) Sosn. and Takht. from Turkey. *Natural Product Research*, *25*(6), 576–584.

Polatoglu, K., Sen, A., Kandemir, A., & Gören, N. (2012a). Essential oil composition and DPPH scavenging activity of endemic *Tanacetum mucroniferum* Hub.–Mor. & Grierson from Turkey, *Journal of Essential Oil Bearing Plants*, *15*(1), 66–74.

Polatoğlu, K., Demirci, B., Demirci, F., Gören, N., & Başer, K.H.C. (2012b). Biological activity and essential oil composition of two new *Tanacetum chiliophyllum* (Fisch. & Mey.) Schultz Bip. var. *chiliophyllum* chemotypes from Turkey. *Industrial Crops and Products*, *39*, 97–105.

Polatoglu, K., Demirci, B., Demirci, F., Gören, N., & Baser, K.H.C. (2012c). The Essential oil composition of *Tanacetum densum* (Labill.) Heywood ssp. *eginense* Heywood from Turkey. *Records of Natural Products*, *6*(4), 402–406.

Polatoğlu, K., Karakoç, Ö.C., Demirci, B., Gören, N. & Başer, K.H.C. (2015). *Sitophilus granarius* L. (Coleoptera) toxicity and biological activities of the essential oils of *Tanacetum macrophyllum* (Waldst. & Kit.) Schultz Bip. *Journal of Oleo Science*, *64*(8), 881–893

Rosselli, S., Bruno, M., Raimondo, F.M., Spadaro, V., Varol, M., Koparal, A.T., & Maggio, A. (2012). Cytotoxic effect of eudesmanolides isolated from flowers of *Tanacetum vulgare* ssp. *siculum*. *Molecules*, *17*, 8186–8195.

Tabanca, N., Başer, K.H.C., Aytaç, Z., Jacob M.R., Khan, S.I., & Demirci, B. (2016). Chemical composition and antimicrobial activity of *Tanacetum tomentellum* (Boiss.) Grierson essential oil from Turkey. *Natural Volatiles and Essential Oils*, *3*(2), 1–8.

Tabanca, N., Demirci, F., Demirci, B., Wedge, D.E., & Baser, K.H.C. (2007). Composition, enantiomeric distribution, and antimicrobial activity of *Tanacetum argenteum* subsp. *flabellifolium* essential oil. *Journal of Pharmaceutical and Biomedical Analysis*, *45*, 714–719.

Ulukanli, Z., Demirci, S., & Yilmaztekin, M. (2017). Essential oil constituents of *Tanacetum cilicicum*: Antimicrobial and phytotoxic activities. *Journal of Food Quality*, *2017*, 1–11.

Yıldırım, A., Şen, A., Doğan, A., & Bitiş L. (2019). Antioxidant and anti-inflammatory activity of capitula, leaf and stem extracts of *Tanacetum cilicicum* (Boiss.) Grierson. *International Journal of Secondary Metabolite*, *6*(2), 211–222.