doi:10.14720/aas.2021.117.2.1335 Original research article / izvirni znanstveni članek

Chemical components of volatile oil and fatty acids of wild *Bunium persicum* (Boiss.) B. Fedtsch. and cultivated *Cuminum cyminum* L. populations

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Received November 16, 2019; accepted March 18, 2021.
Delo je prispelo 16. novembra 2019, sprejeto 18. marca 2021.

Chemical components of volatile oil and fatty acids of wild *Bunium persicum* (Boiss.) B. Fedtsch. and cultivated *Cuminum cyminum* L. populations

Abstract: Volatile oil and fatty acids components of six various populations of wild *Bunium persicum* Boiss. (Bam and Zirkuh/Iran) and cultivated *Cuminum cyminum* L. (Rayen/Iran; Cukurcak, Taskopru and Asagialicomak/Turkey) species were investigated. The volatile oil content of Bam and Zirkuh populations were 3.9 and 4.7 %, respectively. The analysis of volatile oils by the GC/FID-MSD showed that γ-terpinene (33.62-39.62 %), cuminal (17.9-19.3 %), o-cymene (5.3-11.1 %), benzenemethanol, α-methyl- (7.4-9.5 %), 1-phenyl-1-butanol (6.4-8.4 %) and limonene (6.4-8.6 %) were the major components of *B. persicum* populations. Rayen, Cukurcak, Taskopru and Asagialicomak populations of *C. cyminum* had 2.6, 2.2, 2.0 and 2.5 % of volatile oil, respectively. Cuminal (22.8-37.6 %), benzenemethanol, α-methyl- (5.3-22.6 %), γ-terpinene (16.7-19.4 %), β-pinene (11.2-11.9 %) and 1-phenyl-1-butanol (5.4-12.5 %) were identified as the main components of *C. cyminum*. Fatty acids were detected by the GC/FID. In total, 15 fatty acids were characterised in *B. persicum* populations from Iran. Petroselinic acid (26.3-52.6 %), lauric acid (16.2-37.0 %) and linoleic acid (18.3-33.0 %) were the predominant fatty acids identified in Iranian populations. *C. cyminum* populations were rich in the same fatty acids but, the order was: petroselinic acid (47.5-55.5 %), linoleic acid (22.5-25.4 %) and lauric acid (13.4-24.2 %). Monounsaturated fatty acids (27.4-56.2 %) were the major subgroup. Overall, *B. persicum* populations from Iran and *C. cyminum* from Turkey were almost similar in fatty acids profile although they had wide diversity in the volatile oils compositional profile.

Key words*: Bunium persicum; Cuminum cyminum;* essential oil; fatty acid; GC

Kemijska sestava hlapnih olj in maščobnih kislin samoniklih populacij črne gomoljaste kumine (*Bunium persicum* (Boiss.) B. Fedtsch.) in gojenih populacij rimske kumine (*Cuminum cyminum* L.)

Izvleček: Preučena je bila sestava hlapnih olj in maščobnih kislin dveh samoniklih populacij črne gomoljaste kumine (*Bunium persicum* Boiss.) (Bam and Zirkuh/Iran) in štirih populacij gojene rimske kumine (*Cuminum cyminum L.*); (Rayen/Iran; Cukurcak, Taskopru and Asagialicomak/Turčija). Vsebnost hlapnih olj je v populacijah Bam in Zirkuh znašala 3,9 in 4,7 %. Analiza hlapnih olj z GC/FID-MSD je pokazala, da so bile v populacijah črne gomoljaste kumine njihove glavne sestavine γ-terpinen (33,62-39,62 %), kuminal (17,9-19,3 %), o-cimen (5,3-11,1 %), benzenmetanol, α-metil- (7,4-9,5 %), 1-fenil-1-butanol (6,4-8,4 %) in limonen (6,4-8,6 %). Populacije rimske kumine iz rastišč Rayen, Cukurcak, Taskopru in Asagialicomak so vsebovale 2,6; 2,2; 2,0 in 2,5 % hlapnih olj. Kuminal (22,8-37,6 %), benzenmetanol, α-methyl- (5,3-22,6 %), γ-terpinen (16,7-19,4 %), β-pinen (11,2-11,9 %) in 1-fenil-1-butanol (5,4-12,5 %) so bile glavne sestavine hlapnih olj v rimski kumini. Maščobne kisline so bile analizirane z GC/FID. Celokupno je bilo v populacijah črne gomoljaste kumine iz Irana določenih 15 maščobnih kislin, pri čemer so imele največji delež petršilova (26,3-52,6 %), lovorjeva (16,2-37,0 %) in linolenska kislina (18,3-33,0 %). Populacije rimske kumine so vsebovale enake maščobne kisline, a njihov delež je bil sledeč: petršilova (47,5-55,5 %), linolenska (22,5-25,4 %) in lovorjeva kislina (13,4-24,2 %). Enkrat nenasičene maščobne kisline so bile glavna podskupina (27,4-56,2 %). Nasplošno so imele populacije črne gomoljaste kumine iz Irana in rimske kumine iz Turčije podobno sestavo maščobnih kislin a veliko različnost v sestavi hlapnih olj

Ključne besede: *Bunium persicum; Cuminum cyminum*; eterična polja; maščobne kisline; plinska kromatografija (GC)

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1 INTRODUCTION

Bunium persicum (Boiss.) B. Fedtsch. [syn: *Elwendia persica* (Boiss.) Pimenov & Kljuykov] as a member of the Apiaceae family is a perennial and herbaceous plant that grows in a limited area of Central to West Asia. The fruits (seeds) of *B. persicum* have been widely used as medicinal, aromatic and spice plants in food and cosmetic industries (Azizi et al., 2009; Omidbeigi, 2013). The active ingredients of this plant are volatile oils extracted from the ripe fruits (*Kan et al., 2007*). Based on numerous studies, *B. persicum* has biological and pharmacological properties including antimicrobial (Rustaie et al., 2016), antioxidant (Sharafati Chaleshtori, 2018), antifungal (Takayuki et al., 2007; Khaledi and Hassani, 2018), antibacterial (Demirci et al., 2008; Oroojalian et al., 2010), hypoglycaemic and anti-inflammatory activities (Hajhashemi, 2011). The *B. persicum* fruit samples from different locations of Kerman province/Iran contained 3.5, 4, 7 and 8.5 % of volatile oil (Omidbaigi and Arvin, 2009). ρ-cuminaldehyde (23.50 %), α-methylbenzenemethanol (14.59 %), γ-terpinene (13.10 %) and β-cymene (8.48 %), sabinene (5.82 %) and α-pinene (4.03 %) were reported as major constituents of *B. persicum* essential oil (Sanei Dehkordi et al., 2016).

Cuminum cyminum L. is a valuable medicinal and aromatic plant that originated from Egypt, Central Asia and Eastern Mediterranean regions (Omidbeigi, 2013). The fruits of *C. cyminum* are applied as a popular spice in the kitchen and food industries (Hajlaoui et al., 2010). This plant possesses anti-inflammatory, diuretic, carminative and antispasmodic characteristics. It is also used to treat toothache, epilepsy, dyspepsia, jaundice, diarrhea, flatulence, and indigestion (Evanse et al., 1996; Dhandapani et al., 2002; Rebey et al., 2012). Also, *C. cyminum* has high antioxidant and antibacterial activities (Guo et al., 2018). The volatile oil content of this plant has been reported from 1 to 5 % (Lee, 2005; Ladan Moghadam, 2016). The main components of the volatile oil are monoterpenes and sesquiterpene derivatives such as cuminal (36.31 %), cuminic alcohol (16.92 %), γ-terpinene (11.14 %), safranal (10.87 %), p-cymene (9.85 %) and β-pinene (7.75 %) (Li and Jiang, 2004).

Another valuable by-product of the Apiaceae family is their fatty oil which is widely used in various industries (Kooti et al., 2015). Petroselinic acid is the major component of *C. cyminum* fatty oil (Dubey et al., 2018). Also, petroselinic acid, oleic acid, linoleic acid, lauric acid and palmitic acid were introduced as the main components of *B. persicum* fatty oil (Khalid et al., 2009). Although comprehensive information on cumin oil is available in the literatures, there are a few available scientific records about *B. persicum*. The production and accumulation of secondary metabolites and their qualities are affected by various biotic and abiotic factors such as genetic characteristics, climatic conditions (light, temperature, rainfall, irrigation, soil, height, location, etc.), environment organisms, applied agro-techniques and post-production processing (Soltanbeigi & Sakartepe, 2020).

The aim of this investigation was the comparison of volatile oil content and the volatile and fatty oils chemical component and its diversity in various populations of *B. persicum* and *C. cyminum* from different locations of Iran and Turkey.

2 MATERIALS AND METHODS

2.1 PLANT MATERIALS

The fruits of two populations of wild *Bunium persicum* were collected from the mountains of Bam (Kerman Province/Iran) and Zirkuh (Khorasan Province/Iran). Also, four cultivated *Cuminum cyminum* fruits samples were obtained from Rayen county (Kerman Province/Iran), Cukurcak (Çukurcak/Sultandağı), Taskopru (Taşköprü/Sultandağı) and Asagialicomak (Aşağıaliçomak/Emirdağ) villages (Afyonkarahisar/Turkey). The geographical and climatic conditions of the sampling regions are outlined in Table 1. The plants were taxonomically identified by a senior expert from the Agricultural Research, Education and Extension Organization of West Azerbaijan Province of Iran and Afyonkarahisar Directorate of Provincial Agriculture and Forestry, Republic of Turkey.

2.2 ISOLATION OF VOLATILE OILS

50 g of powdered dried fruits of plant samples were subjected to hydro-distillation by using a Clevenger type apparatus for 3 hours and volatile oil content of the samples was calculated as:

Oil content (v/M) = observed volume of oil (ml)/ mass of sample (g) × 100

The volatile oil samples were dried over anhydrous sodium sulfate and were stored at 4 °C in ambered vials till GC-MS analysis.

2.3 DETERMINATION OF VOLATILE OIL COMPONENTS

A gas chromatography (GC) system (Agilent Technologies, 7890B) equipped with a flame ionization detector (FID) and coupled to a mass spectrom-

Table 1: The geographical and some climatic data of the plants sampling locations

	Bam[1]	Zirkuh[1]	Rayen[1]	Cukurcak[2]	Taskopru[2]	Asagialicomak[2]
Coordinates	29°04′N 58°21′E	33°36′N 59°59′E	29°35′N 57°26′E	38°42′N 31°22′E	38°34′N 31°18′E	38°58′N 31°42′E
Elevation (m)	1050	1330	2201	1309	953	980
Climate Type	Hot and dry climate	Normal tropical climate	Moderate mountainous/ dry	Continental climate	Continental climate	Continental climate
Rainfall (mm/ year)	68	150	93.8	501	501	421

1: Iran Meteorological Organization, 2: Turkish State Meteorological Service

etry detector (MSD) (Agilent Technologies, 5977A) was used. An HP-Innowax column (Agilent 19091N-116: 60 m × 0.320 mm internal diameter and 0.25 µm film thickness) was used for the separation of the components. Samples were analyzed with the column held initially at 70 °C with 5 min hold time. Then, the temperature increased to 160 °C with 3 °C min-1 heating ramp. Finally, the temperature was raised to 250 °C with 6 °C min-1 heating ramp with 5 min hold time. Helium (99.999 % purity) was the carrier gas at 1.3 ml min-1 flow rate. The injection volume was 1µl (20 µl of volatile oil was dissolved in 1 ml of n-hexane). The solvent delay time was 8.20 min. The injection was in split mode (40 : 1). Detector, injector and ion source temperatures were 270 °C, 250 °C and 230 °C, respectively. MS scan range was (m z-1): 50-550 atomic mass units (AMU) under electron impact (EI) ionization of 70 eV.

Retention indices were determined by the co-injection of C7-C30 n-alkanes (Sigma-Aldrich) to (GC/FID) system (Agilent Technologies, 7890B) under the same conditions mentioned above. The volatile oils constituents were identified by the comparison of their retention indices and mass spectra by the computer library search database of US National Institute of Standards and Technology (NIST), Wiley libraries, other published mass spectra data (Adams, 2007) and the available data from our database.

2.4 LIPID EXTRACTION

50 g of grinded fruit samples were dissolved in 150 ml n-hexane at laboratory temperature for 12 h. n-hexane was removed with a rotary evaporator (40 °C) and the residue was stored at -10 °C until the fraction of the fatty acids could be determined. During the lipid extraction, evaporation and storage steps, the samples were kept away from light (Özgul Yücel, 2005).

2.5 ESTERIFICATION OF FATTY ACIDS

Methyl esters of samples were prepared by a cold transmethylation using 2 ml KOH in methanol and n-hexane with minor modifications (IUPAC, 1987). The extracted oil (0.5 g) was dissolved in 10 ml n-hexane followed by the addition of 1 ml of 2 ml methanolic KOH. The tubes were vortexed for 2 min. Finally, 1 ml of n-hexane layer was taken for GC analysis.

2.6 DETERMINATION OF FATTY ACIDS

Gas Chromatography analyses were carried out on a GC-2025 (Shimadzu Co., Kyoto, Japan) equipped with a flame ionization detector (FID). A capillary column DB-23 (60 m, 0.25 mm ID and 0.25 µm film thickness, J & W Scientific, Folsom, USA) was used. The oven temperature was scheduled as follows: 180 °C for 5 min, increased to 200 °C with 10 °C min^{-1} heating ramp with 18 min hold time. Further, raised to 240 °C at the rate of 10 °C min-1 for 20 min. Helium (99.999 %) was used as the carrier gas at 40 ml min-1 flow rate. The injection was performed in split mode (100 : 1). Detector and injector temperatures were 250 °C. Fatty acids standards had linear calibration curves (R^2 = 0.99). The GC method used was validated for fatty acids determination of cumin seed oil samples with 95 % confidence limits. Mean analytical recoveries from the individual fatty acids in the oil samples were changed from 99.7 % to 100 %. The results were calculated as percentage peak area. The identification of FAMEs of samples was performed using a standard FAMEs mixture (Sigma-Aldrich Chemicals 189-

19). In addition, some parameters including the sum of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) as well as petroselinic acid : linoleic acid ratio (PS : L), linoleic acid : linolenic acid (L : LN) ratio, iodine values (IV), oxidative susceptibility (OS) and theoretical oxidative stability (TOSI) were determined. Iodine values were calculated from the fatty acid percentages by using the formula given by Maestri et al. (1998):

IV = palmitoleic % × 1.001) + (oleic % × 0.899) + (linoleic % × 1.814) + (linolenic % × 2.73)

Oxidative susceptibility (OS) was estimated from fatty acid values by using the formula given by Cert et al. (1996):

Oxidative Susceptibility (OS) = MUFA + (45 × linoleic) + (100 × linolenic)

Theoretical oxidative stability (TOSI) was calculated from fatty acids data by using the formula given by Chu and Kung, (1998):

TOSI(h) = 7.5125 + palmitic % × (0.2733) + stearic % × (0.0797) + petroselinic % × (0.0159) + linoleic % × (-0.1141) + linolenic % × (-0.3962)

3 RESULTS AND DISCUSSION

3.1 VOLATILE OIL COMPONENTS

The volatile oils from wild *B. persicum* and *C. cyminum* were pale yellow to brown and pale yellow, respectively. As shown in Tables 1 and 2, location and climate significantly influenced the quantity and quality of volatile oils. The volatile oil content of Bam and Zirkuh *B. persicum* populations were 3.9 and 4.73 %, respectively. Volatile oil content for cultivated Rayen, Cukurcak, Taskopru and Asagialicomak populations of *C. cyminum* were 2.65, 2.2, 2 and 2.5 % (Table 2). According to the results, the volatile oil content of *B. persicum* populations was higher than that of *C. cyminum* populations. Various studies have reported similar results. Mazidi et al. (2012) reported that the volatile oil content of *B. persicum* was about 4.18 % and yellow. Another study on wild *B. persicum*, reported that the volatile oil content of plants collected from seven locations of Khorasan Province/Iran were about 3.1, 6.4, 6.7, 7.1, 7.5, 7.7 and 7.9 % (Talebi et al., 2018). Overall, the chemical differences between species are inevitable, and the yield and chemical constituents of medicinal and aromatic plants (like other types of plants) are responsive to the genetic, geographical, climatic and seasonal conditions, agronomic practices, and harvest time (Yanive and Palevitch, 1982; Omidbaigi and Arvin, 2009). Elevation and temperature are the most important of these factors (Talebi et al., 2018). The essential oil is made gradually from the beginning of the fruit, but its amount is low. The highest amount of essential oil is at a stage when the fruits are not yet fully mature. At the full maturity stage, a small amount of essential oil is reduced (Hornok, 1978).

Monoterpenes were found as the main chemical group components in both species (Table 3). The levels of monoterpene hydrocarbons in *B. persicum* (57.17-64.53 %) were significantly higher than *C. cyminum* (39.37-39.5 %). Maximum monoterpene hydrocarbons in *B. persicum* and *C. cyminum* were recorded in Bam and Cukurcak populations, respectively. The amounts of oxygenated monoterpenes in *C. cyminum* (36.11-46.16 %) were richer than *B. persicum* (27.24-31.81 %). Sesquiterpenes levels were lower than monoterpenes. Biosynthesis of sesquiterpene hydrocarbon components in *C. cyminum* species was more than twice that of *B. persicum*. Even oxygenated sesquiterpenes components were not observed in *B. persicum* populations. Except for Cukurcak population in *C. cyminum*, other populations of this species had considerably high content of alcohol components than *B. persicum*. Esters and ethers were obtained in very minor amounts (Table 3). The results of chemical analysis (GC-MS/FID) of populations showed that *C. cyminum* species had a relatively higher compositional diversity. Bam and Zirkuh populations of *B. persicum* contained 31 and 30 components, respectively. Rayen and Cukurcak populations of *C. cyminum* had 38 constituents. Taskopru (43) and Asagialicomak (44) contained a higher number of components (Table 2). From the oil constituents, 21 components were exclusive of *C. cyminum* populations. In contrast, nine components were specific to *B. persicum* populations.

γ-terpinene (39.62 %), cuminal (17.95 %), o-cymene (11.12 %), benzenemethanol, α-methyl- (7.49 %), 1-phenyl-1-butanol (6.41 %), limonene (6.41 %), β-pinene (2.29 %), α-pinene (1.90 %), isopulegone (1.09 %) and sabinene (1.01 %) were identified as the major constituents of Bam population. The major components of Zirkuh were γ-terpinene (33.62 %), cuminal (19.34 %), benzenemethanol, α-methyl- (9.52 %), limonene (8.66 %), 1-phenyl-1-butanol (8.41 %), o-cymene (5.37 %), α-pinene (2.12 %), terpinolene (1.38 %), isopulegone (1.27 %) and cuminol (1.05 %) (Table 2). Previous studies on *B. persicum*, support our findings on the major constituents of volatile oil (Foroumadi et al., 2002; Ehsani et al., 2016; Rustaie et al., 2016; Sanei Dehkordi et al., 2016; Khaledi and Hassani, 2018). Talebi et al. (2018), in their study with seven populations of wild *B. persicum* Boiss. from Northeast of Iran noted that γ-terpinene (29.2-40.1 %), cumin alcohol (16.4-28.4 %), cumin aldehyde (9-18.9 %), ρ-cymene (9.4-15.6 %), safranal (3.4-7.9%), limonene (3.7-6.4 %), β-pinene (0.8-2.3 %), α-pinene (0.3-1.7 %),

and sabinene (0.8-1.2 %) were the main constituents of the volatile oils; very similar to the findings of our study.

The results demonstrated that cuminal (22.80 %), benzenemethanol, α-methyl- (22.65 %), γ-terpinene (19.41 %), β-pinene (11.22 %), 1-phenyl-1-butanol (10.32 %), o-cymene (4.90 %) and isopulegone (1.49 %) were the dominant constituents in Rayen population of *C. cyminum*. The main constituents of essential oils from Cukurcak were cuminal (37.64 %), γ-terpinene (16.79 %), o-cymene (12.67 %), β-pinene (11.92 %), 1-phenyl-1-butanol (5.45 %), benzenemethanol, α-methyl- (5.3 %), isopulegone (1.36 %), α-phellandrene (1.02 %) and α-pinene (1.01 %). The predominant components of Taskopru sample volatile oil were cuminal (26.75 %), γ-terpinene (16.76 %), benzenemethanol, α-methyl- (15.25 %), 1-phenyl-1-butanol (12.59 %), β-pinene (11.64 %), o-cymene (6.5 %) and isopulegone (1.54 %). Furthermore, in Asagialicomak population essential oil cuminal (24.18 %), γ-terpinene (18.26 %), benzenemethanol, α-methyl- (17.48 %), β-pinene (11.35 %), 1-phenyl-1-butanol (9.76 %), o-cymene (6.41 %), α-phellandrene (2.36 %), isopulegone (1.23 %) and α-pinene (1.02 %) were found as the main components (Table 2). Moghaddama and Ghasemi Pirbalouti, (2017), compared 20 *C. cyminum* accessions and determined γ-terpinene (26.53-37.81 %), ρ-cymene (12.84-21.22 %), cumin aldehyde (9.45-20.66 %), cumin alcohol (1.63-15.22 %), β-pinene (8.32-13.84 %) and safranal (2.3-6.37 %) as the major constituents. in another study, propanal (26.19 %), benzenemethanol (25.4 %), 1-phenyl-1-butanol (16.49 %), γ-terpinene (13.04 %), β-pinene (7.28 %), cymene (4.24 %) and pulegone (2.58 %) were identified as the main components of this plant (Haghiroalsadat et al., 2011). In another study, the oil constituents of fruit samples from Emirdag (Turkey) were cumin aldehyde (19.25-24.80 %), p-mentha-l,3-dien-7-al (7.54-9.30 %), p-mentha-l,4-dien-7-al (36.51-44.91 %), γ-terpinene (8.61-9.72 %), ρ-cymene (5.94-6.45 %) and β-pinene (4.99-5.60 %) (Baser et al., 1992). The results of our study are in line with the findings of various studies on the chemical components of cumin (Rihawy et al., 2014; Esmaeili, 2015; Moghaddama et al., 2015; Tahir et al., 2016). Among the major components identified in all populations, γ-terpinene (39.62 %) was the highest in Zirkuh and cuminal (37.64 %) in Cukurcak.

3.2 FATTY ACID COMPONENTS

In total, 15 fatty acids were identified from the fatty oil of *B. persicum* populations of Iranian origin (Table 4). Based on the results, palmitic acid, petroselinic acid, linoleic acid, linolenic acid and behenic acid were the major components of Bam and Zirkuh populations of *B. persicum*. Lauric acid (37.08 %) and linoleic acid (33.60 %) were determined as the major fatty oil components of Bam and Zirkuh populations of *B. persicum*, respectively. Besides, capric acid and gadoleic acid from Bam and stearic acid from Zirkuh were the other major constituents.

Except for lignoceric acid, which was not present in *C. cyminum* population oils, the other components were common in both species. Petroselinic acid (47.53-55.51 %), linoleic acid (22.58-26.32 %), lauric acid (13.46 %) and palmitic acid (2.68-3.03 %) were identified as the major components of *C. cyminum* populations. Petroselinic acid content in *C. cyminum* was significantly higher than in *B. persicum*. Comparisons between *B. persicum* populations from two different countries showed no dominant differences in terms of fatty acid components.

The monounsaturated fatty acids especially petroselinic acid have great importance because of their high nutritional value and the contribution to the oxidative stability of oils (Bettaib et al., 2012; Rebey et al., 2012; Rebey et al., 2013). The oils from *C. cyminum* populations fruits were characterized by the presence of a high proportion of monounsaturated and polyunsaturated fatty acids. Our findings are similar to the previous studies (Bettaib et al., 2012; Rebey et al., 2012; Rebey et al., 2013; Keskin and Baydar, 2016; Milica et al., 2016; Hajib et al., 2018). Oil samples from two species were rich in petroselenic acid (29-55 %). This fatty acid is the iconic characteristic of the seeds oil from Apiaceae species. These oils have potential industrial significance, especially in the paint industry (Bettaib et al., 2012; Rebey et al., 2013).

Linoleic acid as a predominant polyunsaturated fatty acid was also present in both species at appreciable levels. Considering linoleic acid and other polyunsaturated fatty acids profiles, our finding is similar to Milica et al. (2016) and Hajib et al. (2018). Nevertheless, some other studies reported lower values than our research (Bettaib et al., 2012; Rebey et al., 2012; Rebey et al., 2013). The saturated fatty acids (lauric and palmitic acids acids) exhibited a vast variability (15.13-37.08 %).

The minimum recommended value for PUFA : SFA ratio is 0.5 g (HMSO, 1994), which is significantly lower than our findings (0.79-1.41) except for Bam population of *B. persicum* (0.39). There is no scientific information for the PUFA : SFA ratio in previous studies on *C. cyminum* and *B. persicum* (Table 4).

The changes for petroselinic acid : linoleic acid ratio, which is important for the estimation of oxidative stability, were 0.78-1.59 for *B. persicum* populations and 2-2.18 for *C. cyminum* samples. Overall, it can be pointed out that the oxidative stability of *C. cyminum* populations appears to be relatively higher than *B. persicum* populations. The present results are in agreement with Bettaieb et al. (2013). The above-mentioned components have in-

Table 2: Volatile oil components of *B. persicum* and *C. cyminum* populations from Iran and Turkey

RT[a]	RI[b]	Components (%)	*B. persicum*		*C. cyminum*				ID
			Bam	Zirkuh	Rayen	Cukurcak	Taskopru	Asagialicomak	
8.813	1032	α-pinene	1.903	2.12	0.855	1.01	0.962	1.029	1
9.838	1079	camphene	-	0.338	-	-	-	-	1
10.936	1120	β-pinene	2.292	2.61	11.225	11.928	11.649	11.352	1
11.256	1131	sabinene	1.015	0.981	0.688	0.695	0.684	0.724	1
12.103	1158	δ-3-carene	0.074	-	0.04	0.043	0.043	0.04	1
12.418	1168	β-myrcene	0.789	0.759	0.704	0.617	0.691	0.746	1
12.635	1175	α-phellandrene	-	-	0.603	1.024	0.985	2.362	1
13.121	1190	α-terpinene	0.318	0.429	0.172	0.118	0.153	0.166	1
13.791	1210	limonene	6.415	8.665	0.333	0.39	0.318	0.39	1
14.146	1219	1,8-cineole	-	0.343	-	-	-	-	1
14.163	1220	β-phellandrene	0.462	0.355	0.396	0.466	0.458	0.569	1
14.919	1240	*cis*-ocimene	-	0.18	-	-	-	-	1
15.547	1256	γ-terpinene	39.627	33.62	19.418	16.795	16.762	18.264	1
16.503	1281	o-cymene	11.122	5.377	4.904	12.676	6.505	6.413	1
16.932	1293	terpinolene	0.357	1.386	0.044	0.055	0.05	0.056	1
24.125	1469	*trans*-sabinene hydrate	0.046	-	0.036	0.041	-	0.046	1
25.418	1501	α-copaene	-	-	0.252	0.318	0.326	0.334	2
27.186	1546	β-gurjunene	-	-	0.046	0.039	0.07	0.08	1
27.369	1550	linalool	-	-	0.03	-	0.03	-	1
27.506	1554	*cis*-sabinene hydrate	-	-	0.092	-	0.067	0.058	1
28.119	1569	*trans*-2-menthenol	-	-	-	0.084	0.047	0.081	1
28.582	1581	isopulegone	1.096	1.272	1.49	1.363	1.547	1.233	1
28.948	1590	bornyl acetate	0.053	0.554	0.035	0.041	0.035	0.071	1
29.046	1592	*trans*-α-bergamotene	-	-	0.063	0.089	0.09	0.106	1
29.67	1608	caryophyllene	-	0.261	0.135	0.334	0.255	0.433	1
29.721	1610	terpinene-4-ol	0.471	0.528	-	-	-	-	1
30.625	1633	*cis*-2-menthenol	-	-	-	0.061	0.036	0.058	1
31.781	1664	*trans* -pinocarveol	-	-	0.055	0.059	0.073	0.067	1
32.05	1671	*trans*-β-farnesene	-	-	0.264	0.285	0.358	0.395	1
32.181	1674	(-)-isoledene	-	-	-	-	0.043	0.048	3
32.433	1681	α-humulene	-	-	-	-	0.033	0.07	1
32.908	1693	β-farnesene	0.046	-	0.034	-	-	-	1
33.177	1701	(-)-β-acoradiene	-	-	0.156	0.325	0.185	0.335	1
33.251	1702	γ-muurolene	0.114	0.146	0.188	-	-	-	1
33.303	1704	γ-curcumene	-	-	-	-	0.231	0.239	1
33.898	1720	germacrene D	0.15	0.172	-	-	-	-	1
34.167	1727	zingiberene	0.137	-	-	-	0.028	-	1
34.396	1733	phellandral	0.18	0.215	-	0.182	0.207	0.167	1
34.745	1742	β-selinene	-	-	0.042	0.071	0.07	0.073	1
34.831	1745	(-)-carvone	0.215	0.201	0.138	-	-	-	1

RT[a]	RI[b]	Components (%)	*B. persicum*		*C. cyminum*				ID
			Bam	Zirkuh	Rayen	Cukurcak	Taskopru	Asagialicomak	
35.025	1750	*cis*-piperitol	-	-	-	0.045	-	0.052	1
36.038	1777	β-sesquiphellandrene	0.085	-	-	-	-	0.145	1
36.974	1802	cuminal (cumin aldehyde)	17.95	19.345	22.809	37.642	26.758	24.181	1
37.125	1805	1-phenyl-1-butanol	6.417	8.412	10.32	5.45	12.59	9.765	1
37.480	1813	benzenemethano, α-methyl-	7.493	9.525	22.654	5.3	15.25	17.487	1
38.447	1835	anethole	-	-	-	0.134	0.04	0.073	1
40.289	1877	isoterpinolene	0.157	0.355	0.119	0.05	0.118	0.121	3
44.072	1977	cuminyl acetate	0.045	0.185	-	-	-	-	1
45.138	2008	caryophyllene oxide	-	-	0.058	0.133	0.097	0.081	1
45.743	2029	carotol	-	-	0.282	0.949	0.702	0.758	1
46.435	2054	α,α'-dihydroxy-m-diisopropylbenzene	-	-	0.032	0.082	0.07	0.074	3
46.982	2073	p-mentha-1,4-dien-7-ol	0.172	0.37	0.403	0.279	0.365	0.368	1
47.551	2093	viridiflorol	-	-	-	-	0.103	0.05	1
47.922	2107	cuminol (cumin alcohol)	0.644	1.051	0.686	0.638	0.832	0.75	1
49.874	2190	thymol	0.054	0.077	-	-	-	-	1
50.52	2220	carvacrol	-	-	0.051	0.188	0.084	0.087	1
53.644	2384	dill apiole	0.101	0.092	-	-	-	-	1
Volatile oil content (%)			3.9	4.73	2.65	2.2	2.0	2.5	

RT: Retention time; RI: Retention indices calculated against n-alkanes (C7-C30) on HP-Innowax column; ID: Identification method 1: RI-MS; 2: RI-Rf; 3: MS

Table 3: Grouped chemical components of *B. persicum* and *C. cyminum* populations essential oil from Iran and Turkey

Grouped chemical components(%)	*B. persicum*		*C. cyminum*			
	Bam	Zirkuh	Rayen	Cukurcak	Taskopru	Asagialicomak
Monoterpene hydrocarbons	64.531	57.175	39.501	45.867	39.378	42.232
Oxygenated monoterpenes	27.245	31.814	36.11	46.166	42.676	36.986
Sesquiterpene hydrocarbons	0.532	0.579	1.18	1.461	1.689	2.258
Oxygenated sesquiterpenes	-	-	0.34	1.082	0.902	0.889
Alcohols	7.493	9.525	22.654	5.3	15.25	17.487
Esters	0.098	0.739	0.035	0.041	0.035	0.071
Ethers	0.101	0.092	-	-	-	-
Others	-	-	0.032	0.082	0.07	0.074
Total (%)	100	99.924	99.852	99.999	100	99.997

dustrial applications especially in the manufacturing of oil based paints (Bettaib et al., 2012; Rebey et al., 2013).

The ratio of linoleic acid : linolenic acid is a prominent indicator for comparing the relative nutritional value of oils from different plant sources (Rebey et al., 2013). This value varied widely among the populations of both species tested. *C. cyminum* had significantly higher values than *B. persicum* (Table 4).

The iodine values were calculated according to the fatty acid components. The saturated fatty acids, mono-

unsaturated fatty acids and polyunsaturated fatty acids levels of samples influenced the iodine values (Maestri et al., 1998). Oxidative susceptibility was estimated based on the fatty acids profile. According to Table 4, no significant variation was observed in the oxidative susceptibility of *C. cyminum* populations. However, this value for Zirkuh population was twice more than that of *B. persicum* (Bam population).

The variations for Iodine values, oxidative susceptibility and theoretical oxidative stability index for all the samples were almost similar due to the homogenous unsaturated fatty acids profiles. All these values represent the theoretical stability of the oil (Chu and Kung, 1998).

Generally, the oxidative susceptibility and theoretical oxidative stability index values of samples were correspondingly increased with high linoleic acid content more than monounsaturated fatty acids (especially petroselinic acid). Linoleic acid is much more susceptible to oxidation than monounsaturated fatty acids (Chu and Kung, 1998). However, there is no available data on iodine values, oxidative susceptibility and theoretical oxidative stability index on *C. cyminum* and *B. persicum*.

The differences in fatty acids profiles of *C. cyminum* and *B. persicum* populations from various localities of Iran and Turkey are seemingly dependent on the genetic factors (Bettaib et al., 2012; Rebey et al., 2013), environmental and edaphic characteristics and agricultural practices (Bettaib et al., 2012; Rebey et al., 2013; Keskin and Baydar, 2016) as well as they depend upon the large geographical variations (Keskin and Baydar, 2016; Hajib et al., 2018).

Table 4: Fatty acid components and some parameters related with fatty oil quality of *B. persicum* and *C. cyminum* populations from Iran and Turkey

Fatty Acid (%)	*B. persicum*		*C. cyminum*			
	Bam	Zirkuh	Rayen	Asagialicomak	Cukurcak	Taskopru
Capric acid C 10 : 0	3.09	0.71	0.24	0.82	0.65	0.68
Lauric acid C 12 : 0	37.08	22.92	16.21	15.13	24.22	13.46
Myristic acid C 14 : 0	0.86	0.34	0.1	0.23	0.75	0.21
Palmitic acid C 16 : 0	4.53	6.24	3.03	2.89	2.68	2.99
Palmitoleic acid C 16 : 1	0.43	0.25	0.35	0.39	0.34	0.35
Margaric acid C 17 : 0	0.21	0.51	0.03	0.02	0.03	0
Margoleic acid C 17 : 1	0.59	0.26	0.04	0.03	0.06	0.07
Stearic acid C 18 : 0	0.97	1.99	0.60	0.67	0.56	0.72
Petroselinic acid C 18 : 1 (n-6)	29.12	26.36	52.64	53.51	47.53	55.51
Linoleic acid C 18 : 2 (n-6)	18.34	33.60	26.32	25.76	22.58	25.49
Linolenic acid C 18 : 3 (n-3)	1.01	4.82	0.24	0.27	0.30	0.17
Arachidic acid C 20 : 0	0.12	0.14	0.05	0.04	0.06	0.04
Gadoleic acid C 20 : 1	1.18	0.55	0.13	0.20	0.14	0.27
Behenic acid C 22 : 0	2.05	1.04	0.03	0.61	0.10	0.06
Lignoceric acid C 24 : 0	0.33	0.28	ND	ND	ND	ND
Saturated fatty acids (SFA %)	49.24	34.17	20.05	20.41	29.05	18.16
Monounsaturated fatty acids (MUFA %)	31.32	27.42	53.16	54.13	48.07	56.20
Polyunsaturated fatty acids (PUFA %)	19.35	38.42	26.56	26.03	22.88	25.66
PUFA : SFA	0.39	1.12	1.32	1.28	0.79	1.41
MUFA : PUFA	1.62	0.71	2	2.08	2.1	2.19
Petroselinic acid : Linoleic acid	1.59	0.78	2	2.08	2.1	2.18
Linoleic acid : Linolenic acid	18.16	6.97	109.67	95.41	75.15	149.94
Iodine value	62.64	98.09	96.08	95.96	84.85	96.96
Oxidative susceptibility	957.62	2021.42	1261.56	1240.33	1094.17	1220.25
Theoretical oxidative stability index (TOSI) hours	6.79	4.04	6.12	6.15	6.34	6.29

4 CONCLUSIONS

Our findings showed significant differences in the volatile oil content, volatile oil and fatty oil constituents' profile of *B. persicum* and *C. cyminum* populations from Iran and Turkey. It can be inferred that genetic characteristics, location (region) and climatic conditions have sensible effects on the oil contents and its ingredients. As known, the production of primary and secondary metabolites in plants is directly and continuously associated with multiple biotic and abiotic factors. The identification and characterization of secondary metabolites profile in medicinal plants and especially in native plants are crucial to assign a specific characteristic for those precious species and, to make them new candidates for the multidisciplinary use with several industries. Besides, the identification of compositional profile of native neglected plant species labels the plants a recognizable criterion for the commercial cultivation and exploitation. Moreover, by the characterized secondary metabolites profile; natural habitats will be safer and intact since, the agricultural systems try to concentrate on a defined species production and, the miss and over-harvesting of the related species will be limited in favor of natural habitats diversity.

Inline, identifying the major components and the possible chemotypes and the characterization of bioactive substances with the potential pharmaceutical application from medicinal and aromatic plants provide a broaden way and horizon in front of the producers, entrepreneurs and policy makers for the efficient utilization of natural habitats and cultivated plants.

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