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Comparison and Correlation of the Compositions in Volatile Constituents from Different Parts of Summer Savory (*Satureja hortensis* L.)

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Abstract
In this study, the variability of essential oil composition in different parts of summer savory was investigated. Extraction of essential oils from air-dried leaves and healthy seeds was done using water-distillation in Clevenger-type apparatus for 4 h. In total, 23 and 24 components were identified in the leaves and seeds of summer savory, respectively. Carvacrol (46.023%), Estragole (Methyl Chavicol) (6.257%), Caryophyllene (4.753%), and *E*-Caryophyllene (4.753%) were the major constituents in the seeds and Carvacrol (56.537%), γ-Terpinene (21.377%), and *p*-Cymene (8.587%) were the major constituents in the leaves. Among all constituents, Carvacrol, Caryophyllene, *E*-Caryophyllene, *β*-Bisabolene, *cis*-*α*-Bisabolene, Caryophyllene oxide, *Z*-Citral, *E*-Citral, γ-Terpinene, and *δ*-3-Carene were present in both of leaves and seeds. Significant positive and negative correlations were detected between constituents for the investigated parts of summer savory. In addition, the correlation analysis of same volatile constituents in seeds and leaves indicated that some constituents in one part of summer savory have a significant correlation with another part. Also, γ-Terpinene in leaves has a negative significant correlation with γ-Terpinene in the seeds.

Keywords: Carvacrol, essential oil, estragole, *p*-Cymene, γ-Terpinene.

Introduction

In recent decades, numerous studies have been carried out to replace chemicals with natural substances, and several reports have confirmed that medicinal plants have antioxidant or anti-radical compounds. Essential oils with biological, pharmacological and antioxidant activities have many uses in different industries. Also, they have an extensive antimicrobial activity and eliminate fungi, bacteria, germs and free radicals (Van-Vuuren et al., 2009; Shibamoto et al., 2010). Derived essential oils from plants are also used as aroma or flavor in foods and beverages. Because of having different compounds in essential oils and beneficial medicinal properties, summer savory (*Satureja hortensis* L.) has attracted lots of attention worldwide. This herbaceous

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plant belongs to the *Lamiaceae* family, which is native to the Mediterranean region (Omidbaigi et al., 2007) and cultivated in many other countries. Essential oils of summer savory has various medicinal benefits including antioxidant (Güllüce et al., 2003), antimicrobial (Mihajilov-Krstev et al., 2009), antibacterial (Zeidán-Chuliá et al., 2013), antifungal (Dikbas et al., 2008), antispasmodic and anti-diarrhea (Hajhashemi et al., 2000), anti-ulcer and anti-inflammatory (Hajhashemi et al., 2002), antitumor (Ramezani et al., 2016) and antigelatinolytic (Zeidán-Chuliá et al., 2013) activities. It has been reported that the essential oil of summer savory is rich of different medicinal components such as: Carvacrol (Katar et al., 2017), γ-Terpinene (Kizil et al., 2009), Thymol (Mahboubi and Kazempour, 2011) and *p*-Cymene (Adiguzel et al., 2007). It must be taken into consideration that the presence of various compounds and different chemical structures of the essential oils can be due to the location of plant growth, soil type, weather, water content, harvesting times, plant growth stage, post-harvest physiology and etc. Even the season can also affect the chemical structure of the essential oil before or after flowering. Another important factor is the genetic structure of the plant. In general, all genetic or environmental factors can affect the biosynthesis of essential oils in a particular plant. Thus, in different environmental conditions a plant species can produce different essential oils containing various compounds with different effects. Therefore, a variety of chemical structures leads to variation in chemical compounds (Hassanzadeh et al., 2017; Etehadpour et al., 2019; Reaisi et al., 2019).

The main purpose of this study was to analyze and to compare essential oils' compounds in different parts of summer savory, their percentages and correlation between compounds. To the best of our knowledge, it is the first time that the correlation of the same volatile constituents in different parts of summer savory is investigated together, which can be useful in various industries. In addition, the results of this study can be useful for detecting and separating of special compound (s) from different parts of this plant in future studies.

Materials and methods

Plant growth condition and harvesting

Summer savory seeds were cultivated at the experimental farm of the University of Mohaghegh Ardabili (UMA) in Ardabil province, Iran. The average annual temperature in the experimental farm is 9 °C, with average annual minimum temperature of 3 °C and average annual maximum temperature of 15.1 °C, the average annual rainfall is 303.4 mm, the average annual relative humidity is 70% and the average number of frosty days is 127 days. Irrigation was carried out twice a week until flowering and seeds production. Seeds were harvested after seed production in the plants and the leaves were also harvested at the same time and transferred to the laboratory for further analysis.

Distillation procedure of essential oils

To determine the essential oils composition in leaves and seeds of summer savory, each one was analyzed separately. First, 50 g air-dried leaves with three replicates were grounded and extraction of essential oil was done using water-distillation in Clevenger-type apparatus for 4 h. The extracted essential oil was dried over anhydrous sodium sulfate and stored at 4 °C. For the extraction of essential oil from the seeds, 50 g of healthy seeds with three replicates were ground and the rest of the steps were done similar to the extraction of essential oils steps from the leaves.

Analysis of distilled essential oils

From 3 replicates related to each plant organ, 1 μL of extracted essential oils from each replicate were injected to the GC/MS to determine the type of the constituents. The Gas Chromatography with

Spectroscopy Detector, manufactured by Agilent Company, with the technical specifications of Agilent 7890B Series GC and Agilent 5977 Series MSD was applied with the capability of injecting liquid samples and the Split/Splitless Inlet dilution. The detector was equipped with an EL-type ionization system and the analyzer was Single Quadrupole. To achieve its high sensitivity, the detector was Triple-Axis Detector (EMP), which has very low Noise and Drift. Helium was used as the carrier gas. Type of capillary column was HP-5M5 (30 m× 0.25mm; film thickness 0.25 µm) and its temperature program was performed according to Table 1.

Table 1. GC-MS temperature ramp program (temperature limits: from -60 °C to 325 °C [350 °C]).

Initial		50 °C	Hold Time 1 min
Ramp 1	8 °C/min	100 °C	0
Ramp 2	2 °C/min	110 °C	2 min
Ramp 3	5 °C/min	185 °C	0
Ramp 4	30 °C/min	280 °C	3 min
Ramp 5	20 °C/min	300 °C	1 min

The compositions were identified based on the comparison of mass spectra and their relative retention times with those of standards, NIST05A, and Wiley7N libraries data of the GC-MS system.

Statistical analysis

Calculation of standard deviation and drawing of Figure 1 was done using Microsoft Excel 2010 and correlation of components was analyzed using Insightful S-Plus v8.0.4 software. The correlation analysis of volatile constituents in leaves, seeds, and similar constituents was studied separately. In this software, the correlation between constituents was done pairwise with 1000 bootstrapping. Among the four main options obtained by the software (Observed, Bias, Mean, and SE), by dividing Observed into SE, the obtained numbers 2 and above 2 (≥2) were considered as significant correlations. The significant correlation coefficients were determined with samples bootstrapping and obtained Standard Error (SE) values were used for performing the t-test and determining significant correlation coefficients. The main reason for using this software was high bootstrapping that shows the more accurate correlations.

Results

By analyzing essential oils in different organs of summer savory, 23 (Table 2) and 24 (Table 3) volatile constituents were identified in the seeds and the leaves of summer savory, respectively.

Among all components in seeds and leaves, only 10 components including: Carvacrol, Caryophyllene, *E*-Caryophyllene, *β*-Bisabolene, *cis*-*α*-Bisabolene, Caryophyllene oxide, *Z*-Citral, *E*-Citral, γ-Terpinene, and *δ*-*3*-Carene were identified in both seeds and leaves. The highest amounts of volatile components in seeds were Carvacrol (46.023 %), Estragole (6.257%), Caryophyllene (4.753%), and *E*-Caryophyllene (4.753%) and the highest amounts of volatile components in leaves were Carvacrol (56.537%), γ-Terpinene (21.377%) and *p*-Cymene (8.587%) (Fig. 1).

According to Table 4, based on the analysis of the volatile constituents correlation in summer savory seeds, components such as Caryophyllene with *E*-Caryophyllene, *β*-Bisabolene with *α*-Copaene, Decane with *α*-Cubebene, and *α*-Cubebene with *δ*-Cadinene have a completely positive significant correlation (r=1). Other components that have a positive correlation and numbers have been separated with bold font style in Table 4, which follow this rule. Because of their correlation coefficients were less than 1, the relationship is not perfectly positive.

Table 2. Composition of essential oil in the seeds of summer savory (*Satureja hortensis* L.).

Row	Compounds	Abb.	MF	MW	RI	Per
1	Octane	O	C_8H_{18}	114.232	800	0.907±0.195
2	Decane	De	$C_{10}H_{22}$	142.2817	1000	0.260±0.030
3	δ-3-Carene	Dc	$C_{10}H_{16}$	136.2340	1008	0.430±0.545
4	*O*-Cymene	Oc	$C_{10}H_{14}$	134.2182	1022	0.670±0.070
5	γ-Terpinene	Gte	$C_{10}H_{16}$	136.2340	1054	0.817±0.095
6	Estragole	Es	$C_{10}H_{12}O$	148.2017	1195	6.257±0.179
7	Carvacrol	C	$C_{10}H_{14}O$	150.221	1298	46.023±1.14
8	*Z*-Citral	Z	$C_{10}H_{16}O$	152.237	1316	1.653±0.300
9	*E*-Citral	E	$C_{10}H_{16}O$	152.2334	1338	0.623±0.110
10	α-Cubebene	Cu	$C_{15}H_{24}$	204.3511	1345	0.130±0.010
11	α-Copaene	Co	$C_{15}H_{24}$	204.3511	1374	0.377±0.023
12	(+)-Sativen	Sa	$C_{15}H_{24}$	204.3511	1390	0.127±0.030
13	α-Bergamotene	Be	$C_{15}H_{24}$	204.3511	1411	1.080±0.062
14	*E*-Caryophyllene	Tr	$C_{15}H_{24}$	204.357	1417	4.753±0.150
15	α-Humulene	Hu	$C_{15}H_{24}$	204.3511	1452	1.107±0.041
16	Caryophyllene	Ca	$C_{15}H_{24}$	204.357	1464	4.753±0.150
17	Germacrene-D	Ge	$C_{15}H_{24}$	204.3511	1484	1.027±1.457
18	β-Bisabolene	Bi	$C_{15}H_{24}$	204.357	1505	0.387±0.023
19	*cis*-α-Bisabolene	Bis	$C_{15}H_{24}$	204.3511	1506	3.246±0.175
20	δ-Cadinene	Cad	$C_{15}H_{24}$	204.3511	1522	0.410±0.010
21	Caryophyllene oxide	Car	$C_{15}H_{24}O$	220.3505	1582	2.367±0.056
22	Dill apiole	Dil	$C_{12}H_{14}O_4$	222.24	1620	0.107±0.005
23	Hexadecanoic acid	Pal	$C_{16}H_{32}O_2$	256.43	1959	0.130±0.030

Note: Abb.=Abbreviation, MF=Molecular Formula, MW=Molecular Weight (g/mol), RI=Retention Index, Per=Percentage (%).

Table 3. Composition of essential oil in the leaves of summer savory (*Satureja hortensis* L.).

Row	Compounds	Abb.	MF	MW	RI	Per
1	α-Thujene	Th	$C_{10}H_{16}$	136.238	924	1.273±0.064
2	Camphene	Cam	$C_{10}H_{16}$	136.238	946	0.067±0.005
3	Sabinene	Sa	$C_{10}H_{16}$	136.238	969	0.057±0.005
4	β-Pinene	Pi	$C_{10}H_{16}$	136.2340	974	0.547±0.025
5	β-Myrcene	My	$C_{10}H_{16}$	136.238	988	1.163±0.047
6	α-Phellandrene	Ph	$C_{10}H_{16}$	136.238	1002	0.920±0.591
7	δ-3-Carene	Dc	$C_{10}H_{16}$	136.238	1008	0.063±0.005
8	α-Terpinene	Te	$C_{10}H_{16}$	136.238	1014	2.323±0.070
9	*p*-Cymene	Cym	$C_{10}H_{14}$	132.2023	1020	8.587±0.070
10	(R)-(+)-Limonene	Li	$C_{10}H_{16}$	136.238	1024	0.393±0.011
11	β-Ocimene	Oci	$C_{10}H_{16}$	136.2340	1032	0.077±0.005
12	γ-Terpinene	Gte	$C_{10}H_{16}$	136.2340	1054	21.377±1.744
13	Thujanol	Thu	$C_{10}H_{18}O$	154.2493	1164	0.177±0.005
14	Myrtenal	My	$C_{10}H_{14}O$	150.221	1195	1.037±0.049
15	Carvacrol methyl ether	Cme	$C_{11}H_{16}O$	164.248	1241	0.227±0.005
16	Carvacrol	C	$C_{10}H_{14}O$	150.221	1298	56.537±0.380
17	*Z*-Citral	Z	$C_{10}H_{16}O$	152.237	1316	0.193±0.011
18	*E*-Citral	E	$C_{10}H_{16}O$	152.2334	1338	0.436±0.005
19	*E*-Caryophyllene	Tr	$C_{15}H_{24}$	204.357	1417	0.817±0.049
20	Caryophyllene	Ca	$C_{15}H_{24}$	204.357	1464	0.817±0.049
21	β-Bisabolene	Bi	$C_{15}H_{24}$	204.357	1505	1.020±0.103
22	*cis*-α-Bisabolene	Bis	$C_{15}H_{24}$	204.3511	1506	0.157±0.005
23	Spathulenol	Sp	$C_{15}H_{24}O$	220.356	1577	0.337±0.005
24	Caryophyllene oxide	Car	$C_{15}H_{24}O$	220.3505	1582	0.317±0.037

Note: Abb.=Abbreviation, MF=Molecular Formula, MW=Molecular Weight (g/mol), RI= Retention Index, Per=Percentage (%).

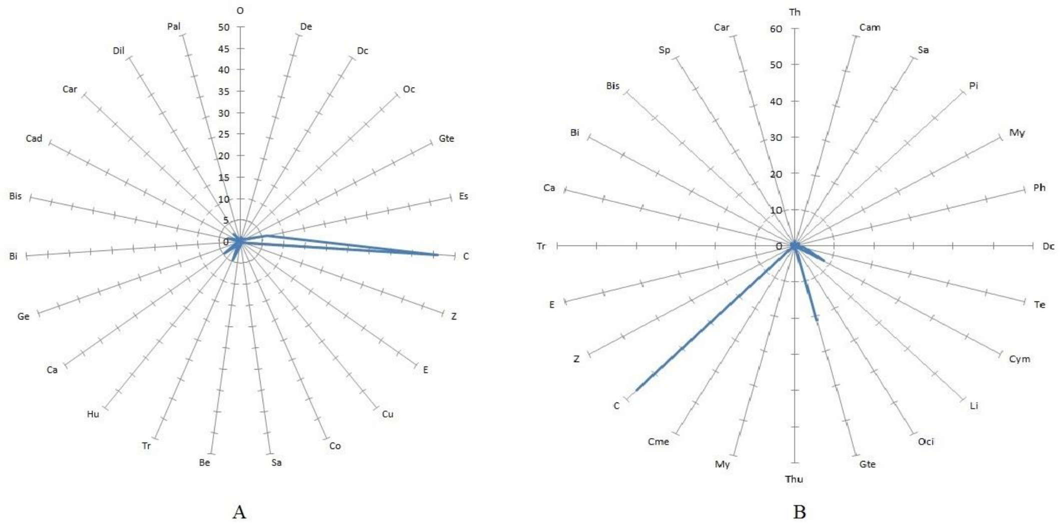

Fig. 1. Highest volatile constituents in the seeds (A) and leaves (B) of summer savory (*Satureja hortensis* L.).

Table 4. Correlation coefficient of essential oils compositions in seeds of summer savory (*Satureja hortensis* L.).

	C	Ca	Tr	Bi	Bis	Car	Z	E	Gte	O	De	Oc	Dc	Es
C	1													
Ca	-0.9515	1												
Tr	-0.9515	**1**	1											
Bi	**-0.9698**	**0.9978**	**0.9978**	1										
Bis	-0.7294	**0.9045**	**0.9045**	**0.8742**	1									
Car	-0.01046	0.3176	0.3176	0.2538	0.6916	1								
Z	**0.9956**	-0.9186	-0.9186	**-0.9428**	-0.6623	0.08303	1							
E	**0.9851**	-0.8844	-0.8844	**-0.9135**	-0.6009	0.1617	**0.9969**	1						
Gte	-0.7389	**0.9103**	**0.9103**	**0.8808**	**0.9999**	0.6815	-0.6727	-0.612	1					
O	-0.7482	**0.916**	**0.916**	**0.8874**	**0.9996**	0.6712	-0.683	-0.623	**0.9999**	1				
De	**-0.9618**	0.8309	0.8309	**0.866**	0.5142	-0.2638	**-0.9832**	**-0.9945**	0.5261	0.5379	1			
Oc	-0.7181	**0.8973**	**0.8973**	**0.866**	**0.9999**	0.7035	-0.6499	-0.5877	**0.9995**	**0.999**	0.5	1		
Dc	-0.6894	0.4331	0.4331	0.492	0.00733	**-0.7172**	-0.754	-0.8037	0.02121	0.03521	0.8614	-0.009164	1	
Es	-0.4561	**0.7078**	**0.7078**	**0.6592**	**0.9415**	0.8946	-0.3709	-0.2963	**0.9367**	**0.9317**	0.1949	**0.9469**	-0.3302	1
Cu	**-0.9618**	0.8309	0.8309	**0.866**	0.5142	-0.2638	**-0.9832**	**-0.9945**	0.5261	0.5379	**1**	0.5	0.8614	0.1949
Co	**-0.9698**	**0.9978**	**0.9978**	**1**	**0.8742**	0.2538	**-0.9428**	**-0.9135**	**0.8808**	**0.8874**	**0.866**	**0.866**	0.492	**0.6592**
Ge	-0.2772	**0.5593**	**0.5593**	**0.503**	**0.8594**	0.9637	-0.1862	-0.1078	**0.8522**	**0.8448**	0.00343	**0.8677**	-0.505	**0.9815**
Be	-0.8829	**0.9845**	**0.9845**	**0.9707**	**0.9652**	0.4787	-0.8352	-0.789	**0.9687**	**0.9721**	0.7206	**0.9608**	0.2685	**0.8205**
Hu	-1	0.9526	0.9526	**0.9707**	0.7319	0.01408	**-0.9953**	**-0.9845**	0.7413	0.7506	**0.9608**	0.7206	0.6867	0.4593
Cad	**-0.9618**	0.8309	0.8309	**0.866**	0.5142	-0.2638	**-0.9832**	**-0.9945**	0.5261	0.5379	**1**	0.5	0.8614	0.1949
Dil	**0.696**	-0.4413	-0.4413	**-0.5**	-0.01649	**0.7107**	**0.76**	**0.8091**	-0.03037	-0.04437	**-0.866**	0.00	**-1**	0.3216
Sa	0.8367	**-0.9646**	**-0.9646**	**-0.9449**	**-0.985**	-0.5565	0.7818	0.73	**-0.9873**	**-0.9894**	-0.6547	**-0.982**	-0.18	**-0.869**
Pal	-0.2437	-0.06647	-0.06647	0.00	-0.4856	**-0.9672**	-0.3333	-0.4069	-0.4735	-0.4611	0.5	-0.5	**0.8706**	-0.7519

Note: The bold numbers have significant correlation which determined with 1000 samples bootstrapping, obtained Standard Error (SE) values were used for performing t-test and determining significant correlation coefficients.

Table 4 (Continued). Correlation coefficient of essential oil compositions in the seeds of summer savory (*Satureja hortensis* L.).

	Cu	Co	Ge	Be	Hu	Cad	Dil	Sa	Pal
Cu	1								
Co	**0.866**	1							
Ge	0.00343	**0.503**	1						
Be	0.7206	**0.9707**	**0.6958**	1					
Hu	0.9608	**0.9707**	0.2806	0.8846	1				
Cad	**1**	**0.866**	0.00343	0.7206	**0.9608**	1			
Dil	**-0.866**	-0.5	0.497	-0.2774	**-0.6934**	**-0.866**	1		
Sa	-0.6547	**-0.9449**	**-0.7582**	**-0.9959**	-0.8386	-0.6547	0.189	1	
Pal	0.5	0.00	-0.8643	-0.2402	0.2402	0.5	**-0.866**	0.3273	1

Note: The bold numbers have significant correlation which determined with 1000 samples bootstrapping, obtained Standard Error (SE) values were used for performing t-test and determining significant correlation coefficients.

Analysis correlation among volatile constituents in summer savory leaves indicated a completely positive significant correlation (r=1) between some components such as Caryophyllene with *E*-Caryophyllene, *β*-Bisabolene with *cis*-*α*-Bisabolene, *Z*-Citral, Carvacrol methyl ether, Camphene, Sabinene, (R)-(+)-Limonene and *β*-Ocimene, *cis*-*α*-Bisabolene with *Z*-Citral, Carvacrol methyl ether, Camphene, Sabinene, (R)-(+)-Limonene and *β*-Ocimene, *Z*-Citral with Carvacrol methyl ether, Camphene, Sabinene, (R)-(+)-Limonene and *β*-Ocimene, *E*-Citral with Thujanol, Carvacrol methyl ether with Camphene, Sabinene, (R)-(+)-Limonene and *β*-Ocimene, Camphene with Sabinene, (R)-(+)-Limonene and *β*-Ocimene, Sabinene with (R)-(+)-Limonene and *β*-Ocimene, and (R)-(+)-Limonene with *β*-Ocimene. Meanwhile, completely negative significant correlation (r=-1) was detected between components such as *δ*-3-Carene with *β*-Bisabolene, *cis*-*α*-Bisabolene, *Z*-Citral, Carvacrol methyl ether, Camphene, Sabinene, (R)-(+)-Limonene and *β*-Ocimene (Table 5). The correlation analysis of 10 volatile constituents were the same in both seeds and leaves (Table 6), demonstrated that the Carvacrol in seeds has a negative significant correlation with Caryophyllene, *E*-Caryophyllene, *β*-Bisabolene, *cis*-*α*-Bisabolene, and *Z*-Citral in leaves.

Table 5. Correlation coefficient of essential oils compositions in the leaves of summer savory (*Satureja hortensis* L.).

	C	Ca	Tr	Bi	Bis	Car	Z	E	Gte	Th	My	Pi
C	1											
Ca	0.8019	1										
Tr	0.8019	**1**	1									
Bi	**0.8583**	**0.9948**	**0.9948**	1								
Bis	**0.8583**	**0.9948**	**0.9948**	**1**	1							
Car	**0.9302**	0.5265	0.5265	**0.61**	**0.61**	1						
Z	**0.8583**	**0.9948**	**0.9948**	**1**	**1**	**0.61**	1					
E	0.01519	**-0.5852**	**-0.5852**	-0.5	**-0.5**	0.3812	-0.5	1				
Gte	**-0.8755**	-0.9908	-0.9908	**-0.9994**	**-0.9994**	**-0.6369**	**-0.9994**	0.4699	1			
Th	**0.9277**	0.967	0.967	**0.9878**	**0.9878**	**0.7258**	**0.9878**	-0.3592	**-0.9926**	1		
My	**0.9059**	0.9795	0.9795	**0.9948**	**0.9948**	**0.6872**	**0.9948**	-0.4096	**-0.9977**	**0.9985**	1	
Pi	**0.9915**	0.8727	0.8727	**0.9177**	**0.9177**	**0.8746**	**0.9177**	-0.1147	**-0.9308**	**0.9683**	**0.9532**	1
My	**0.9475**	0.9509	0.9509	**0.9774**	**0.9774**	**0.7639**	**0.9774**	-0.3054	**-0.9841**	**0.9984**	**0.9938**	**0.981**
Ph	0.1165	-0.5	-0.5	-0.4096	-0.4096	0.473	-0.4096	**0.9948**	0.378	-0.2628	-0.3151	-0.01343
Te	**0.9953**	0.8562	0.8562	**0.9042**	**0.9042**	**0.89**	**0.9042**	-0.0822	**-0.9183**	**0.9596**	**0.9428**	**0.9995**
Thu	0.01519	**-0.5852**	**-0.5852**	-0.5	**-0.5**	0.3812	-0.5	**1**	0.4699	-0.3592	-0.4096	-0.1147
Cme	**0.8583**	**0.9948**	**0.9948**	**1**	**1**	**0.61**	**1**	-0.5	**-0.9994**	**0.9878**	**0.9948**	**0.9177**
Cam	**0.8583**	**0.9948**	**0.9984**	**1**	**1**	**0.61**	**1**	-0.5	**-0.9994**	**0.9878**	**0.9948**	**0.9177**
Sa	**0.8583**	**0.9948**	**0.9948**	**1**	**1**	**0.61**	**1**	**-0.5**	**-0.9994**	**0.9878**	**0.9948**	**0.9177**
Dc	**-0.8583**	**-0.9948**	**-0.9948**	**-1**	**-1**	**-0.61**	**-1**	**0.5**	**0.9994**	**-0.9878**	**-0.9948**	**-0.9177**
Cym	**0.3666**	-0.2619	-0.2619	-0.1628	-0.1628	0.6826	-0.1628	**0.9359**	0.1287	-0.00730	-0.0619	0.2427
Li	**0.8583**	**0.9948**	**0.9948**	**1**	**1**	**0.61**	**1**	-0.5	**-0.9994**	**0.9878**	**0.9948**	**0.9177**
Oci	**0.8583**	**0.9948**	**0.9948**	**1**	**1**	**0.61**	**1**	**-0.5**	**-0.9994**	**0.9878**	**0.9948**	**0.9177**
Sp	**-0.8735**	-0.4096	-0.4096	-0.5	**-0.5**	**-0.9912**	-0.5	**-0.5**	**0.5295**	**-0.6286**	**-0.5852**	**-0.803**

Note: The bold numbers have significant correlation which determined with 1000 samples bootstrapping, obtained Standard Error (SE) values were used for performing t-test and determining significant correlation coefficients.

Table 5 (Continued). Correlation coefficient of essential oils compositions in leaves of summer savory (*Satureja hortensis* L.).

	Myr	Ph	Te	Thu	Cme	Cam	Sa	Dc	Cym	Li	Oci	Sp
Myr	1											
Ph	-0.2073	1										
Te	**0.9741**	0.01924	1									
Thu	-0.3054	**0.9948**	-0.0822	1								
Cme	**0.9774**	-0.4096	**0.9042**	**-0.5**	1							
Cam	**0.9774**	-0.4096	**0.9042**	-0.5	**1**	1						
Sa	**0.9774**	-0.4096	**0.9042**	-0.5	**1**	**1**	1					
Dc	**-0.9774**	0.4096	**-0.9042**	0.5	**-1**	**-1**	**-1**	1				
Cym	0.04971	**0.9668**	0.2743	**0.9359**	-0.1628	-0.1628	-0.1628	0.1628	1			
Li	**0.9774**	-0.4096	**0.9042**	-0.5	**1**	**1**	**1**	**-1**	-0.1628	1		
Oci	**0.9774**	-0.4096	**0.9042**	**-0.5**	**1**	**1**	**1**	**-1**	-0.1628	1	1	
Sp	**-0.6719**	**-0.5852**	**-0.822**	-0.5	**-0.5**	-0.5	-0.5	0.5	**-0.7731**	**-0.5**	**-0.5**	1

Note: The bold numbers have significant correlation which determined with 1000 samples bootstrapping, obtained Standard Error (SE) values were used for performing t-test and determining significant correlation coefficients.

Table 6. Correlation coefficient of similar essential oils compositions in seeds and leaves of summer savory (*Satureja hortensis* L.).

Seeds \ Leaves	C	Ca	Tr	Bi	Bis	Car	DC	Z	E	Gte
C	-0.7074	**-0.9896**	**-0.9896**	**-0.9698**	**-0.9698**	-0.3985	0.9213	**-0.9698**	**0.696**	0.9609
Ca	**0.8905**	0.9859	0.9859	**0.9978**	**0.9978**	**0.6613**	**-1**	**0.9978**	-0.4413	**-0.9995**
Tr	**0.8905**	0.9859	0.9859	**0.9978**	**0.9978**	**0.6613**	**-1**	**0.9978**	-0.4413	**-0.9995**
Bi	**0.8583**	**0.9948**	**0.9948**	**1**	**1**	**0.61**	**-1**	**1**	-0.5	**-0.9994**
Bis	**0.9995**	0.8204	0.8204	**0.8742**	**0.8742**	**0.9181**	**1**	**0.8742**	-0.01649	**-0.8903**
Car	0.7142	0.1545	0.1545	0.2538	0.2538	0.9213	**-1**	0.2538	**0.7107**	-0.287
Z	-0.6383	**-0.9718**	**-0.9718**	**-0.9428**	**-0.9428**	-0.311	**1**	**-0.9428**	**0.76**	0.9308
E	-0.5753	**-0.95**	**-0.95**	**-0.9135**	**-0.9135**	-0.2348	**0.866**	**-0.9135**	**0.8091**	0.899
Gte	**0.999**	0.8283	0.8283	**0.8808**	**0.8808**	**0.9125**	**0.866**	**0.8808**	-0.03037	**-0.8966**

Note: The bold numbers have significant correlation which determined with 1000 samples bootstrapping, obtained Standard Error (SE) values were used for performing t-test and determining significant correlation coefficients.

Discussion

Results indicated that both seeds and leaves of summer savory are rich of Carvacrol. γ-Terpinene and *p*-Cymene which are in the biosynthesis pathway of Carvacrol (Mohtashami et al., 2018), both are components of leaves essential oils.

Since only γ-Terpinene was produced and *p*-Cymene was not produced in the seeds, it could be concluded that γ-Terpinene is probably involved in the Carvacrol biosynthesis pathway or it is produced in leaves and then transferred to the seeds. Carvacrol has antimicrobial (Cresols and Cresols, 2006), antibacterial (Ultee et al., 1999; Burt et al., 2005; Zhou et al., 2007; Xu et al., 2008; Uchida et al., 2014), antifungal activities (Ramos et al., 2013), controlling of root-knot nematodes *Meloidogyne* spp. (Nasiou and Giannakou, 2017), and priming effects on reactive oxygen species (ROS) production (Huang et al., 2010). Therefore, high amount of Carvacrol production both in leaves and seeds can be of interest to researchers in various industries. On the other hand, it may be that a special component with both beneficial and harmful effects. For example, Estragole is produced as the second most volatile component in terms of quantity in summer savory seeds, it has been reported that it is metabolized to compounds such as 1'–hydroxyestragole, 4-allylphenol, estragole-2', 3'-oxide, and 3'-hydroxyanethole. 1'–hydroxyestragole conjugate with sulfate and form a special compound called sulfuric acid ester that binds to DNA and causes hepatocellular carcinogenicity in mice (Drinkwater et al., 1976; Anthony et al., 1987; Alhusainy et al., 2012). Although, we couldn't find any reports of previous researchers until now on the harmfull effects of such compunds on human beings, safety instructions should be regarded before consuming.

Correlation analysis demonstrated that components such as Carvacrol with *α*-Humulene, and *δ*-3-Carene with Dill apiole have completely negative significant correlations (r=-1). It means that the amount and production of these components in the seeds are inversely related to each others, in a way that by increasing the production of one of them the production of another one reduced and vice versa. Also in correlation analysis of same volatile constituents in both seeds and leaves, it can be concluded that by increasing the Carvacrol in seeds, the production of mentioned volatile constituents in the leaves decreases and vice versa. Because of Carvacrol in seeds has positive significant correlation with *E*-Citral in leaves, by increasing or decreasing the Carvacrol in seeds, the *E*-Citral in the leaves will be increased or decreased accordingly. With analysis of Carvacrol in leaves, it is observed that it has a positive significant correlation with Caryophyllene, *E*-Caryophyllene, *β*-Bisabolene, *cis*-*α*-Bisabolene, and γ-Terpinene in the seeds. This indicates that by increasing or decreasing the Carvacrol in the leaves, the quantities of mentioned components increase or decrease accordingly in the seeds. For example, γ-Terpinene which is involved in the biosynthetic pathway of

Carvacrol in the seeds, has a positive significant correlation with Carvacrol in leaves (r=0.999). The results indicated that the Carvacrol in the leaves probability associates with γ-Terpinene production in the seeds. Another important result of the current research is negative significant correlation of γ-Terpinene in leaves with γ-Terpinene in the seeds (r=-0.8966). This means that the production of this component in different parts has a non-directional correlation. Also, *β*-Bisabolene, *cis-α*-Bisabolene,and *Z*-Citral in leaves have a completely positive significant correlation (r=1) with *β*-Bisabolene in the seeds.

Conclusion

In the present study the volatile constituents of the seeds and leaves of summer savory plants cultivated in Ardabil province of Iran were investigated. Different parts of *Satureja hortensis* L. are promising sources of essential oils. Considerable variations were observed in the compositions of essential oils. 23 and 24 constituents (GC/MS) were identified in the seeds and leaves of summer savory, respectively. The main constituents were Carvacrol, Estragole, Caryophyllene and *E*-Caryophyllene in the seeds and Carvacrol, γ-Terpinene, and *p*-Cymene in the leaves. Among all components, 10 constituents were similar in both seeds and leaves. Correlation analysis of essential oils compositions in different parts of summer savory showed significant positive and negative correlations among variables. Also, correlation coefficients of the same essential oil compositions in both seeds and leaves showed some constituents in one part have significant positive or negative correlation with other constituents in the other part. The results of this study can be useful for food scientists, pharmacists, botanical physiologists and etc.

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Conflict of interest

The authors indicate no conflict of interest for this work.

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