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Full Length Research Paper

The effects of climatic conditions and geographical locations on the volatile flavor compounds of fig (*Ficus carica* L.) fruit from Iran

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The effects of climatic conditions and geographical locations on the volatile flavor compounds of *Ficus carica* fruit were investigated in this study. Fruit flavor compounds were extracted by using ultrasound (US) water bath apparatus and eluted by n-pentane, diethyl ether (1:2) solvent and then analyzed by gas chromatography-flame ionization detector (GC-FID) and gas chromatography-mass spectrometer (GC-MS). Fifty-one fruit compounds and fifty fruit compounds in the Garmsar and Karaj location, respectively including aldehydes, alcohols, esters, ketones, monoterpenes, sesquiterpenes and other compounds were indentified and quantified. The major flavor compounds of *F. carica* fruit obtained from Garmsar and Karaj location were *P*-cymene, decanol, carvacrol, tricosane, tetracosane, pentacosane, heptacosane, octacosane and nonacosane. Compared with Karaj location, Garmsar showed the highest content of aldehydes and alcohols. Since the aldehydes and alcohols content of *F. carica* fruit is considered as one of the more important indicators of high quality; climatic conditions and geographical locations apparently have a profound influence on *F. carica* volatile quality.

Key words: *Ficus carica L.*, fig fruit, flavor compounds, climatic conditions, geographical locations, ultrasound.

INTRODUCTION

The fig (*Ficus carica L.*) is an economically important crop cultivated extensively in Iran. The total annual of fig production of Iran was about 76,414 tons in 2010 (FAO, 2012). The fruit of *F. carica* are used commercially for jam, beverages, cake, chocolate, marmalade, dried fruit, fresh fruit, medicines etc (Sabet, 1998). Paeizeh cultivar is a common type (parthenocarpic or requires no pollination for fruit set). This cultivar produces a light breba crop (first crop) and a heavy main crop, which is used as a commercial crop. Paeizeh fruits are mainly used fresh in Iran and little quantities are used for jam production. The quality of a fig fruit may be calculated not only with concentration of total soluble solids and relative amounts of sugar but also with the amount of oxygenated compounds present in the fruit. The volatile compounds present in fresh and processed fruits affect significantly the flavor and quality of the aroma, which is formed by a complex mixture of aldehydes, alcohols, ketones, esters, lactones, terpenes and other compounds (Oliveira et al., 2010a).

The variability in aroma compounds has been reported to depend on climatological conditions, cultivar, maturity and technological factors like harvest, post-harvest treatments, processing and storage conditions (Oliveira et al., 2010b). Until now, numerous investigations performed aimed at identifying the volatiles in the fig fruit (Gibernau et al., 1997; Grison-Pige et al., 2002; Oliveira et al., 2010a, b). Branched aldehydes and alcohols are important flavor compounds in many food products (Salem, 2003). It had been previously recognized that oxygenated compounds are important factor in deceiving

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Abbreviations: US, Ultrasound; **GC-FID,** gas chromatography-flame ionization detector; **GC-MS,** gas chromatography-mass spectrometer.

and attracting the pollinators. These results may have consequences for yield in agriculture (Kite et al., 1991; Andrews et al., 2007). However, there are not any studies on "the effect of climatic conditions and geographical locations in fig volatile flavor compounds even though the effect of climatic conditions and geographical locations on the other plants volatile have been investigated in many areas throughout the world (Owuor et al., 1988; Ramachandra-Rao and Rout, 2003; Medini et al., 2009; Vidic et al., 2010).

In this study, we compared the volatile compounds isolated from two geographical locations with the aim of determining whether the quantity of oxygenated compounds was influenced by geographical locations. The aim of this study was to evaluate the influence of different environmental conditions on the volatile compounds of *F. carica*.

MATERIALS AND METHODS

In 1989, fig trees were planted at 8 × 4 m with three replication at an orchard in Garmsar (latitude 35° 13′ N, longitude 52° 19′ E; desert climate, average rainfall 120 mm per year and average temperature 19.1°C; soil was classified as loam-clay; pH range 6.9 to 7.0). Also, trees were planted at 8 × 4 m with three replication at an orchard in Karaj in 1989 (latitude 35° 48′ N, longitude 50° 57′ E; temperate climate, average rainfall 300 mm per year and average temperature 16.0°C; soil was classified as loam-clay; pH range 6.9 to 7.0). In this experiment, Paizeh cultivar was used as plant material.

Preparation of fruit sample

In the last week of September 2009, at least 10 mature fruits from each fig trees were collected from many parts of the same trees located in the orchards in Garmsar and Karaj cities, early in the morning (6 to 8 am) and only during dry weather.

Chemical compounds

Sugar content was measured using a methodology described by Saini et al. (2006). The total soluble solid content (TSS) was measured using a hand-held refractometer.

Fruit extraction technique

The methodology used in this study was described by Alissandrakis et al. (2003). In order to obtain the volatile compounds such as aldehydes, alcohols, esters and ketones from the fruits, about 50 g of fresh mature fruits (peel and pulp) were cut into small pieces and crushed, and then immediately placed in a 2000 ml spherical flask, along with 300 ml of n-pentane: diethyl ether (1:2). The flask was covered and then placed in an ultrasound (US) water bath apparatus for 20 min. Ultrasonic extractions were performed with an ultrasonic cleaning bath-Fisatom Scientific-FS14H (Frequency of 40 KHz, nominal power 90 W and 24 × 14 × 10 cm internal dimensions water bath). The temperature of the US water bath was held constant at 25°C. The extract was subsequently filtered through Magnesium sulfate ($MgSO_4$) monohydrate. The extract was finally concentrated with a gentle stream of nitrogen to 1 ml, placed in a vial and sealed. It was kept in the freezer at -4°C until the gas chromatography-mass spectrometry (GC-MS) analysis.

GC and GC-MS

An Agilent 6890N gas chromatograph equipped with a DB-5 (30 m × 0.25 mm i.d; film thickness = 0.25 µM) fused silica capillary column (J and W Scientific) and a flame ionization detector (FID) was used. The column temperature was programmed from 50°C (5 min) to 240°C (20 min) at a rate of 3°C/min. The injector and detector temperatures were 290°C and helium was used as the carrier gas at a flow rate of 1 ml/min and a linear velocity of 22 cm/s. The linear retention indices (LRIs) were calculated for all volatile compounds using a homologous series of n-alkanes (C8-C30) under the same GC conditions. The weight percent of each peak was calculated according to the response factor to the FID. Gas chromatography-mass spectrometry was used to identify the volatile compounds. The analysis was carried out with a Varian Saturn 2000R. 3800 GC linked with a Varian Saturn 2000R MS. The oven condition, injector and detector temperatures, and column (DB-5) were the same as those given above for the Agilent 6890 N GC. Helium was the carrier gas at a flow rate of 1 ml/min and a linear velocity of 38.7 cm/s. Injection volume was 1 µL.

Identification of compounds

Compounds were identified by comparing their linear retention indexes (LRIs) and matching their mass spectra with those of reference compounds in the data system of the Wiley library and NIST Mass Spectral Search program (Chem. SW. Inc; NIST 98 version database) connected to a Varian Saturn 2000R MS. Identifications were also determined by comparing the retention time of each compound with that of known compounds (McLafferty and Stauffer, 1991; Adams, 2001).

Data analysis

SPSS 18 was used for analysis of the data obtained from the experiments. Analysis of variations was based on the measurements of 8 compounds. Variations between two locations were analyzed using the one-way analysis of variance (ANOVA). Correlation between pairs of characters and altitude was evaluated using Pearson's correlation coefficient (Tables 2 and 3).

RESULTS

Flavor compounds of *F. carica* fruit obtained from Garmsar location

GC-MS analysis of the fruit obtained from Garmsar location allowed the identification of 51 volatile compounds (Table 1, Figure 1), which included: 16 oxygenated terpenes (5 aldehydes, 9 alcohols, 1 ester and 1 ketone), 15 non-oxygenated terpenes (9 monoterpenes and 6 sesquiterpenes), 15 other compounds and 5 acids.

Flavor compounds of *F. carica* fruit obtained from Karaj location

GC-MS analysis of the fruit obtained from Karaj location

Table 1. Volatile compounds of *Ficus carica* fruit (peel and pulp).

S/N	Compound	Garmsar	Karaj	KI	KI standard	S/N	Compound	Garmsar	Karaj	KI	KI standard
1	Nonane	*	*	900	900	31	(Z)- β -Caryophyllene	*	*	1418	1409
2	(1-Methylethyl)-benzene	*	*	919	926	32	α - Humulene	*	*	1459	1455
3	α - Pinene	*	*	928	939	33	Germacrene D	*	*	1480	1485
4	Benzaldehyde	*	*	953	960	34	α -Muurolene		*	1502	1500
5	β -Myrcene	*	*	988	991	35	E,E- α- Farnesene	*	*	1506	1506
6	Decane	*	*	998	999	36	δ-Cadinene		*	1526	1523
7	Octanal	*		999	999	37	Unknown	*	*	1543	_
8	α - Phellandrene	*	*	1000	1003	38	Caryophyllene oxide	*	*	1582	1583
9	P-Cymene	*	*	1020	1026	39	Hexadecane	*	*	1597	1600
10	Limonene	*	*	1025	1029	40	Unknown	*	*	1630	_
11	1,8-cineol	*	*	1027	1031	41	Unknown	*	*	1764	_
12	Benzyl alcohol	*	*	1031	1032	42	Octadecane	*	*	1798	1800
13	(E)-β-Ocimene	*	*	1036	1050	43	Pentadecanoic acid	*	*	1850	1850
14	γ-Terpinene	*	*	1055	1060	44	Nonadecane	*	*	1898	1900
15	(Z)- Linalool oxide	*	*	1070	1073	45	Hexadecanoic acid	*	*	1979	1984
16	(E)- Linalool oxide	*	*	1085	1087	46	Eicosan	*	*	1997	2000
17	Linalool	*	*	1098	1097	47	(Z,Z)-9,12,15-Octadecatrienoic acid	*	*	2166	2173
18	Nonanal	*	*	1101	1101	48	Docosane	*	*	2198	2200
19	Phenyl ethyl alcohol	*		1107	1107	49	Unknown	*	*	2222	_
20	Borneol	*	*	1163	1169	50	Tricosane	*	*	2297	2300
21	Epoxy linalool	*	*	1172	1172	51	Tetracosane	*	*	2397	2400
22	Estragole	*	*	1195	1195	52	Pentacosane	*	*	2498	2500
23	Decanal	*	*	1202	1202	53	Docosanoic acid	*	*	2531	2526
24	Decanol	*	*	1271	1270	54	Heptacosane	*	*	2716	2700
25	Bornyl acetate	*	*	1283	1289	55	Tetracosanoic acid	*	*	2741	2730
26	Tymol	*	*	1295	1290	56	octacosane	*	*	2797	2800
27	Carvocarol	*	*	1304	1298	57	Nonacosane	*	*	2903	2900
28	Undecanal	*		1309	1307	58	Unknown	*	*	2924	_
29	α -Copaene	*	*	1378	1377	59	Unknown	*	*	2951	_
30	β -Damascenone	*	*	1382	1380						

*Present in fruit.

allowed the identification of 50 volatile compounds (Table 1): 13 oxygenated terpenes [3 aldehydes, 8 alcohols, 1 ester and 1 ketone], 17 non-oxygenated terpenes (9 monoterpenes and 8 sesquiterpenes), 15 other. compounds and 5 acids.

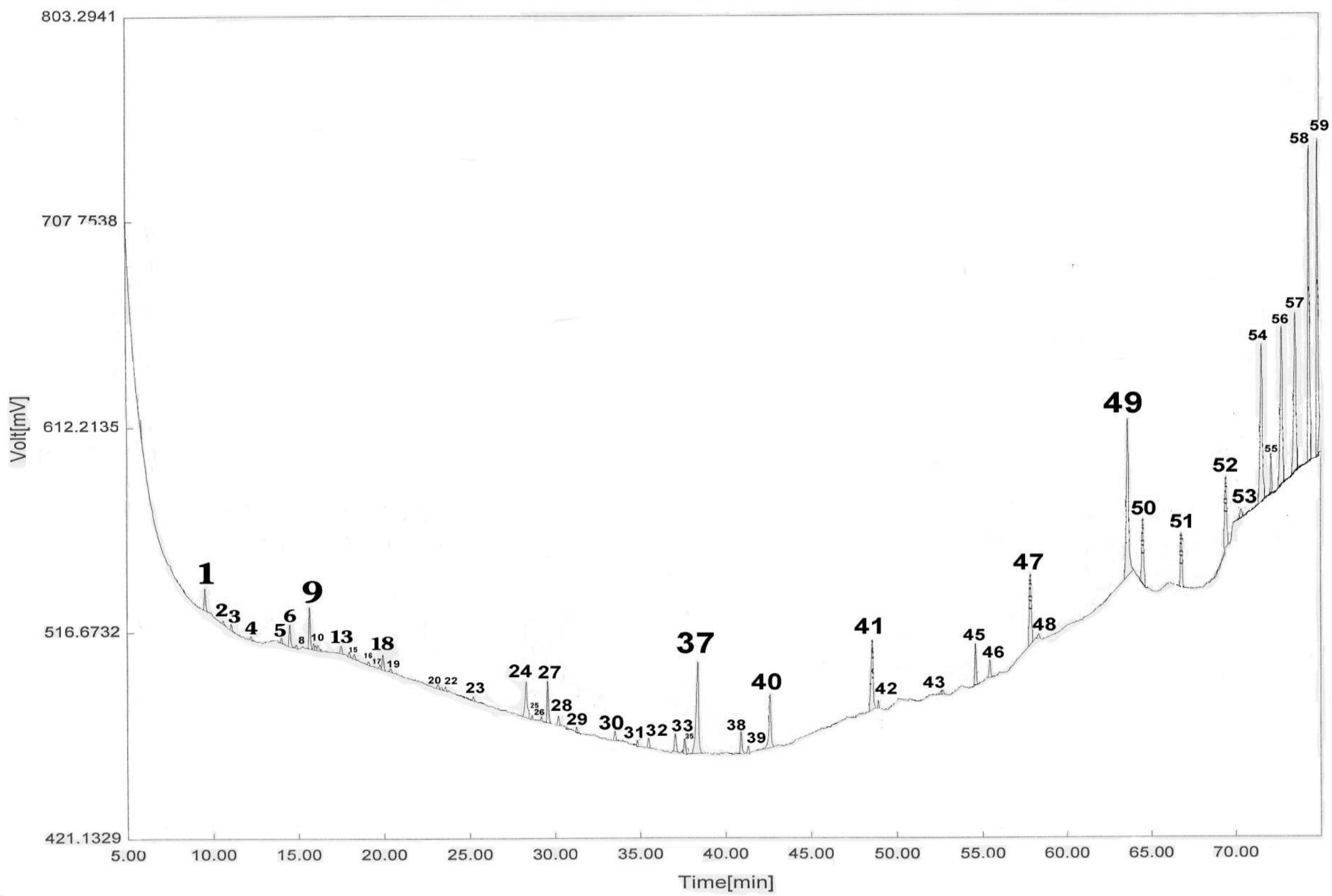

Figure 1. HRGC chromatogram of *Ficus carica* fruit volatile compounds.

Aldehydes

Five aldehyde compounds identified in this analysis were benzaldehyde, octanal, nonanal, decanal and undecanal (Table 2). In addition, they were quantified (from 0.36 to 1.25%) that it was determined and reported as relative amount of those compounds in this study. Fig volatile has nonanal, benzaldehyde and octanal (Oliveira et al., 2010 b). In addition, it also contained undecanal and decanal (Grison-Pige et al., 2002). Nonanal has a sweet, citrusy aroma (Sawamura et al., 2004), and is considered as one of the major contributors to fig flavor. Also it is the main aldehyde in this study.

Since the aldehyde content of fig fruit is considered as one of the most important indicators of high quality, climatic conditions and geographical locations apparently have a profound influence on fig volatile quality. Between the two geographical locations examined, Garmsar showed the highest content of aldehydes (Table 2). Aldehydes were also compared between the two locations in this study. Octanal and undecanal were identified in Garmsar location, while they were not detected in Karaj. Compared with Karaj, Garmsar had improved and increased aldehyde compounds about 3.5 times for *F. carica* fruit (Table 2; Figure 2).

Alcohols

Nine alcohol compounds identified in this analysis were 1,8-cineol, benzyl alcohol, linalool, phenyl ethyl alcohol, borneol, epoxy linalool, decanol, tymol and carvacrol (Table 2). The total amount of alcohols ranging from 2.64 to 4.24% was determined and reported as the relative amount of those compounds in *F. carica* fruit. Decanol and carvacrol were the main compounds in this study and they were the most abundant. Decanol has a green aroma (Kohara et al., 2006) and its level is important to flavor character in fig fruit. Between the two geographical locations examined, Garmsar showed the highest content

Table 2. Statistical analysis of variation in volatile compounds of Paizeh figs located in two different regions.

Compound	Garmsar location (%)		Karaj location (%)		F value
	Mean	Standard error	Mean	Standard error	
Oxygenated compounds					
a) Aldehydes					
1) Benzaldehyde	0.07	0.008	0.04	0.006	
2) Octanal	0.15	0.01	0.00	0.00	
3) Nonanal	0.57	0.04	0.26	0.07	F**
4) Decanal	0.15	0.01	0.06	0.008	
5) Undecanal	0.31	0.03	0.00	0.00	F**
Total	1.25	0.09	0.36	0.08	
b) Alcohols					
1) 1,8-cineol	0.24	0.01	0.18	0.01	F**
2) Benzyl alcohol	0.05	0.009	0.03	0.001	
3) linalool	0.17	0.007	0.10	0.01	
4) phenyl ethyl alcohol	0.15	0.02	0.00	0.00	
5) Borneol	0.17	0.01	0.09	0.01	F**
6) Epoxy linalool	0.10	0.007	0.04	0.01	
7) Decanol	1.98	0.002	1.22	0.02	F**
8) Tymol	0.16	0.004	0.10	0.006	
9) Carvacrol	1.22	0.02	0.88	0.11	F**
Total	4.24	0.08	2.64	0.17	
c) Esters					
1) Bornyl acetate	0.18	0.004	0.11	0.009	F**
d) ketone					
1) β-Damascenone	0.28	0.008	0.17	0.02	F**
Total oxygenated compounds	5.95	0.19	3.28	0.29	
Monoterpenes					
1) α-Pinene	0.23	0.02	0.33	0.008	
2) β-Myrcene	0.22	0.01	0.24	0.01	
3) α -Phellandrene	0.15	0.01	0.17	0.003	
4) P-Cymene	1.27	0.01	1.35	0.03	
5) Limonene	0.16	0.008	0.17	0.01	
6) (E)- β - Ocimene	0.42	0.06	0.47	0.01	
7) γ -terpinene	0.29	0.02	0.34	0.03	
8) (z)-linalool oxide	0.23	0.01	0.29	0.02	
9) (E)-linalool oxide	0.16	0.008	0.17	0.02	
Total	3.13	0.15	3.53	0.14	
Sesquiterpenes					
1) α-Copaene	0.15	0.004	0.11	0.003	
2) (Z)- β -Caryophyllene	0.14	0.008	0.10	0.009	
3) α-Humulene	0.28	0.04	0.21	0.009	
4) Germacrene D	0.72	0.08	0.54	0.03	
5) α-Muurolene	0.00	0.00	0.15	0.007	
6) E,E-α-Farnesene	0.49	0.04	0.41	0.02	
7) δ-cadinene	0.00	0.00	0.14	0.008	
8) Caryophyllene oxide	0.88	0.03	0.87	0.03	
Total	2.66	0.20	2.53	0.11	

Table 2. Contd

Other compounds				
1) Nonane	0.74	0.08	0.95	0.16
2) (1-methylethyl)-benzene	0.14	0.02	0.15	0.02
3) Decane	0.80	0.07	1.02	0.04
4) Estragole	0.15	0.007	0.16	0.01
5) Hexadecane	0.28	0.04	0.36	0.02
6) Octadecane	0.24	0.03	0.30	0.01
7) Nonadecane	0.08	0.008	0.10	0.005
8) Eicosan	0.61	0.01	0.73	0.01
9) Docosane	0.22	0.006	0.31	0.02
10) Tricosane	3.08	0.08	3.73	0.12
11) Tetracosane	1.86	0.03	2.17	0.08
12) Pentacosane	3.14	0.08	3.44	0.18
13) Heptacosane	8.99	0.49	7.94	0.46
14) Octacosane	8.42	0.56	8.40	0.10
15) Nonacosane	8.99	1.10	8.63	0.49
Total	37.74	2.61	38.39	1.72
Acids				
1) Pentadecanoic acid	0.18	0.007	0.21	0.002
2) Hexadecanoic acid	1.43	0.01	1.57	0.01
3) (Z,Z)-9,12,15-Octadecatrienoic acid	3.23	0.07	3.24	0.10
4) Docosanoic acid	0.39	0.01	0.46	0.02
5) Tetracosanoic acid	0.96	0.06	1.04	0.01
Total	6.19	0.15	6.52	0.14
Unknowns	42.37	1.75	43.78	0.88
Total	98.04	5.05	98.03	3.28

Mean is average composition (%) in two different regions used with three replicates. St. err. = Standard error. F value is accompanied by its significance, indicated by: NS = not significant, * = significant at P = 0.05, ** = significant at P = 0.01 .

of alcohols (Table 2). Alcohols were also compared between the two locations in this study. Phenyl ethyl alcohol was identified in Garmsar location, while it was not detected in Karaj. Compared with Garmsar, Karaj had improved and increased alcohol compounds about 1.6 times for *F. carica* fruit (Table 2; Figure 2).

Esters

The only ester compounds identified in this analysis was bornyl acetate. The total amount of esters ranged from 0.11 to 0.18%. Bornyl acetate has a grassy aroma (Sawamura et al., 2004). Between the two geographical locations examined, Garmsar showed the highest content of esters (Table 2; Figure 2).

Ketones

The only ketone compound identified in this analysis was β-damascenone. Between the two geographical locations examined, Garmsar showed the highest content of ketones (Table 2; Figure 2).

Monoterpene hydrocarbons

The total amount of monoterpene hydrocarbons ranged from 3.13 to 3.53%. P-cymene was the major compound among the monoterpene hydrocarbons of *F. carica* fruit in this study. *P*-Cymene has a green, fresh aroma (Sawamura et al., 2004) and is considered as one of the major contributors to fig flavor. Between the two geographical locations examined, Karaj showed the highest content of monoterpene hydrocarbons (Table 2).

Sesquiterpene hydrocarbons

The total amount of sesquiterpene hydrocarbons ranged

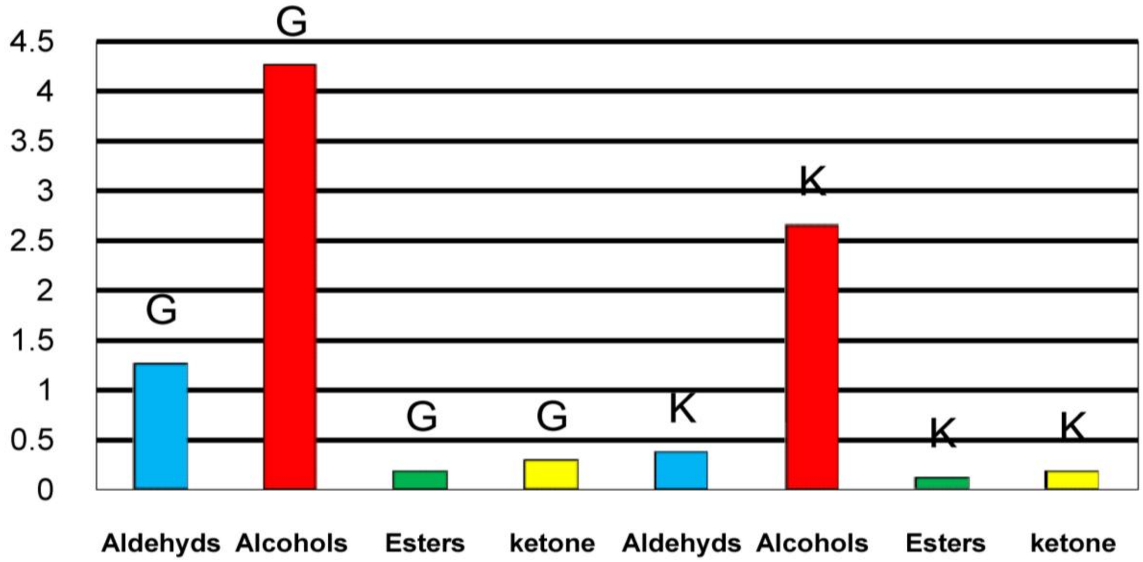

Figure 2. Comparison of oxygenated compounds (%) - aldehydes, alcohols, esters and ketones of Paizeh figs located in two different regions, Garmsar (G) and Karaj (K).

Table 3. Correlation matrix (numbers in this table correspond with main oxygenated compounds mentioned in Table 2).

Compound	Nonanal	Undecanal	1,8-Cineol	Borneol	Decanol	Carvacrol	β -Damascenone
Undecanal	0.96**						
1,8-cineol	0.97**	0.97**					
Borneol	0.96**	0.98**	0.99**				
Decanol	0.96**	0.99**	0.97**	0.96**			
Carvacrol	0.92**	0.93**	0.85*	0.86*	0.92**		
β -Damascenone	0.96**	0.95**	0.93**	0.92**	0.97**	0.92**	
Bornyl acetate	0.94**	0.97**	0.93**	0.93**	0.99**	0.94**	0.98**

*Significant at 0.05; **significant at 0.01.

from 2.53 to 2.66%. Germacrene D, caryophyllene oxide and E, E-α-farnesene were the major compounds among the sesquiterpene hydrocarbons of F. *carica* fruit in this study. Between the two geographical locations examined, Garmsar showed the highest content of sesquiterpenes (Table 2).

Results of correlation

Simple inter-correlations between 8 compounds are presented in a correlation matrix (Table 3). The highest positive values or r (correlation coefficient) were between borneol and 1,8-cineol (99%), decanol and undecanal (99%), bornyl acetate and decanol (99%), borneol and undecanal (98%), and bornyl acetate and β - damascenone (98%). When the 8 compounds were cluster-analyzed, there was clustering of only 6 compounds into 3 two-compound factors above the 98% level of function. These 3 factors resulted from the clustering of highly positively interrelated compounds such as borneol and 1,8-cineol (99%), decanol and undecanal (99%], bornyl acetate and decanol (99%] (Table 3).

Results of statistical analyses

The Duncan’s multiple range test was used to separate the significant geographical locations. Of the 8 individual compounds analyzed, all showed statistically significant differences due to the influence of climatic conditions and geographical locations. These differences on the 1% level occurred in nonanal, undecanal, 1,8-cineol, borneol, decanol, carvacrol, bornyl acetate, β-damascenone (Table 2). Sugar (%) and TSS (%) also showed statistically significant differences due to the influence of climatic conditions and geographical locations (Table 3 and 4).

Table 4. Statistical analysis of variation in chemical compounds of Paizeh figs located in two different regions. Mean is average compounds (%) in two different regions used with three replicates.

Trait	Garmsar location (%)		Karaj location (%)		F-value
	Mean	Standard error	Mean	Standard error	
Sugar (%)	9.8	0.40	7.1	0.30	F**
Total soluble solid (%)	13.27	0.52	9.1	0.41	F**

F value is accompanied by its significance, indicated by ns = not significant, * = significant at P = 0.05 and ** = significant at P = 0.01.

DISCUSSION

Our observations that different climatic conditions and geographical locations have an effect on some of the compositions are in accordance with other studies (Owuor et al., 1988; Ramachandra-Rao and Rout, 2003; Medini et al., 2009; Vidic et al., 2010). The compositions of *F. carica* fruit obtained from the different climatic conditions and geographical locations were very similar. However, relative concentration of compounds differed according to climatic conditions and geographical locations. The major pathway of oxygenated compounds biosynthesis in higher plants is as below:

Mevalonic acid → Isopentenyl Pyrophosphate → 3.3-dimethylallylpyrophosphate→ geranyl pyrophosphate→ Alcohols and Aldehyds

The steps in the pathway are catalyzed by isopentenyl pyrophosphate isomerase and geranyl pyrophosphate synthase, respectively (Hay and Waterman, 1995),, the amount of alcohol and aldehyd compounds obtained from Karaj location were low, and this may be because of decrease in endogenous enzymes activity [isopentenyl pyrophosphate isomerase (IPI) and geranyl pyrophosphate synthase (GPS) thus resulting in decreased labile compounds. Also, the lower proportion of the detected alcohol and aldehyd compounds in Karaj location was probably due to temperature (Sekiya et al., 1984), which is the most important environmental factor in the control of endogenous enzymes.

A comparison of our data with those in the literatures revealed that some of our results in this study are different from other literatures (Gibernau et al., 1997; Grison-Pige et al., 2002; Oliveira et al., 2010 a). This indicated that some of the compositions identified in our study are not compatible with the published one. It may be related to cultivar that can influence compositions of fig fruit. However, it should be kept in mind that the isolation method also has an effect on some of the compounds (Porto and Decort, 2009. Furthermore, a high positive correlations between two compounds such as borneol and 1,8-cineol (99%), decanol and undecanal (99%), bornyl acetate and decanol (99%), borneol and undecanal (98%), and bornyl acetate and β -damascenone (98%] suggest a genetic control (Scora et al., 1976). Whether such dependence between two compounds is due to their derivation of one from another is not known. However, without a thorough knowledge of the biosynthetic pathway leading to each terpenoid compound, the true significance of these observed correlations is not clear.

Result show that the change of environmental conditions such as geographic and climatic conditions had very strong influence on a volatile compounds profile. The origin of these changes should be sought mainly in the differences in altitude, insolation (solar radiation), average temperature, humidity, chemical composition of soil, etc (Vidic et al., 2010). In addition, air pollution can also affect volatile compounds (Stevovic et al., 2011). Soil compositions are also cofactor for various enzymes and different metabolic processes (Abu-Darwish and Abu-Dieyeh, 2009), and can be involved in activation or inactivation of certain enzymatic groups, leading to the predominance of a particular biosynthetic pathway. Solar radiations can also do this work as good as soil compositions (Khadhri et al., 2011).

The effect of altitude is also very important on the percentage of chemical compositions and it can be explained by the difference in the geographic locations. Karaj is located at the southern foot of the Elburz Mountains and is situated at 3,800 m above sea level, while Garmsar is located on a plain and 1,138 m above sea level. It is well-known that the average temperature away from the mountain is a few degrees lower than that in plain region, and this may explain the differences in volatile compounds. It can be assumed that a remarkable change in environmental conditions caused the shift in biosynthesis of particular terpenoids. Finally, the observed differences in the two locations may be related to contamination degree and air pollution. There is a lot of pollution in Karaj and this can be attributed to contamination from traffic and industrial activities.

Conclusion

The remarkable variability in the chemical composition of the volatile compounds of *F. carica* that was found in this study could be attributed to the environmental conditions.

We found that the climate and location together are the main factors that influence the pathway and percentage of compositions. The volatile compounds obtained from Garmsar location contained more oxygenated compounds and fewer monoterpene compounds than those isolated from Karaj. It is easy to observe the significant variations among Garmsar and Karaj location, mainly in terms of the quantities of oxygenated compounds. The aromatic compounds, sugar and TSS are very important in the fresh consumption group, food industries and other areas. Therefore, many studies such as this are very crucial in order to identify the best of climatic conditions and geographical locations for fig trees that can produce the most of sugar, TSS and oxygenated compounds. Also, this study can serve as an indicator for adaptability of these trees to special environmental conditions, as well as their evolution. Further research on the relationship between geographical location and aroma compounds (oxygenated terpenes) is necessary.

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