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Research Article

Comparison of quality properties of the Iranian Saffron (*Crocus sativus* L.) and Saffron grown in macro and micro locations in Turkey

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ABSTRACT

Volatile and bioactive compositions of saffron collected from different locations in Turkey and Iran were investigated using gas chromatography-mass spectrometry (GC-MS/FID and GC-MS/MS) for identification and quantification of volatile compounds. Ultrasound-assisted extraction method using methanol:ethyl acetate solvent mixture was used to isolate the volatile components of saffron. This study revealed that the amounts of the volatile and bioactive compounds of saffron varied between different geographical locations. The most important bioactive compounds of saffron, safranal, crocin and crocetin, were also quantitatively analyzed in all saffron samples. The highest amount of safranal and crocin were observed in Hatay Yayladağı saffron with 22532.97 mg kg^{-1} and 647.26 mg kg^{-1}, respectively. The highest amount of crocetin was obtained with 6.73 mg kg^{-1} in Ankara Ayaş saffron. While Hatay kırıkhan saffron contained the highest fraction of fatty acid content with 23.56%, the highest fraction of bioactive components was discovered in Karabük Safranbolu ovacuma saffron with 90.84%. According to the obtained outcomes, the highest qualities saffron were determined to be observed in Hatay Yayladağı and Karabük Safranbolu ovacuma saffron, respectively.

Keywords: *Crocus sativus* L., GC-MS analysis, Saffron, ultrasound-assisted extraction, volatile components.

İran safranı (*Crocus sativus* L.) ile Türkiye'nin makro ve mikro lokasyonlarında yetiştirilen safranın kalite özelliklerinin karşılaştırılması

ÖZ

İran ve Türkiye'nin farklı lokasyonlardan toplanan safranın uçucu ve biyoaktif bileşimleri, uçucu bileşiklerin tanımlanması ve miktar tayini için gaz kromatografisi-kütle spektrometrisi (GC-MS/FID ve GC-MS/MS) kullanılarak araştırılmıştır. Safranın uçucu bileşenlerini izole etmek için metanol:etil asetat çözücü karışımı kullanılarak ultrason destekli ekstraksiyon yöntemi kullanılmıştır. Bu çalışma, safranın uçucu ve biyoaktif bileşiklerinin miktarlarının farklı coğrafi konumlar arasında doğrulandığını ortaya koymak için yapılmıştır. Safran, safranal, krosin ve krosetin gibi en önemli biyoaktif bileşikler de tüm safran örneklerinde kantitatif olarak analiz edilmiştir. En yüksek safranal ve krosin sırasıyla 22532.97 mg kg^{-1} ve 647.26 mg kg^{-1} ile Hatay Yayladağı safranında gözlemlendi. En yüksek krosetin miktarı 6.73 mg kg^{-1} ile Ankara Ayaş safranında elde edilmiştir. Yağ asidi içeriği en yüksek fraksiyon %23.56 ile Hatay Kırıkhan safranı içerirken, biyoaktif bileşenlerin en yüksek fraksiyonu %90.84 ile Karabük Safranbolu ovacuma safranında bulunmuştur. Elde edilen sonuçlara göre en yüksek kalite safranın Hatay Yayladağı ve Karabük Safranbolu ovacuma safranında gözlendiği belirlenmiştir.

Anahtar Kelimeler: *Crocus sativus* L., GC-MS analizi, Safran, ultrason destekli ekstraksiyon, uçucu bileşenler.

1. INTRODUCTION

Saffron (*Crocus sativus* L.) is a highly valued herb because of its stigmas, which are widely used as spice, medicinal drugs and food additives. Saffron has an important pharmacological potential and is economically valuable spice. The saffron plant has a wide history of use in traditional medicinal treatment or prevention of different types of diseases, including cancer.[1-3] The dried saffron stigma contains crocin, safranal and picrocrocin,

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and these photochemical substances are responsible for the color, aroma and taste of the saffron.[4] Crocetin is an aglycone part of naturally occurring crocin and is produced in biological systems as a hydrolytically bioactive metabolite.[5,6] Studies on the pharmacological activities of crocetin have shown that this aglycone is a therapeutically useful bioactive metabolite.[6]

The quality of saffron is chemically determined by the existence of three main secondary metabolites; crocin (water-soluble crocetin esters), picrocrocin (monoterpene glycoside and safranal precursor) and safranal (an important essential oil component) are responsible for colour and bitter taste of saffron. These metabolites are essential for the quality of saffron. The amounts of these metabolites in saffron vary according to the geography where saffron is grown, and therefore, geographical origin is very important for high quality saffron production.[7,8] To increase product profitability, many researchers are working on the evaluation of saffron by-products such as tepals, stamens, styles, leaves and corms.[9,10]

Saffron, which can be grown in tropical and subtropical climates in the northern hemisphere, is successfully grown in various ecologies up to 2000 m high altitude. One of the origins of saffron is Anatolian ecology. Although most of the parts of Turkey have suitable ecology for saffron cultivation, saffron is widely grown in safranbolu region.[11] There is no information about the first origin of saffron around the world, but Iran is reported to be the first origin for saffron production and then, it was spreaded out to Turkey and Greece. However, today saffron is successfully grown in Spain, Italy, France, Switzerland, Morocco, Egypt, Israel, Azerbaijan, Pakistan, India, New Zealand, Australia and Japan. Total saffron production around the world is about 205 tons; Iran 160 tons (~ 80%), India 8-10 tons (~ 5%), Greek 4-6 tons (~ 3%), Morocco 0.8-1 tons (~ 0.5%), Spain 0.3-0.5 tons (~ 0.25%) and the rest of it was produced by other countries.[12,13] According to the literature, location and saffron corms from different origins can have an impact on saffron productivity and quality.[14] Fatty acid components are analyzed by GC-MS and GC-MS FID. [15,16, 17]

Today, many researchers have focused on the identification of new volatile compounds in saffron and new analytical techniques. Sample characterization is generally neglected. Some researchers purchase saffron and analyze it without paying attention to its origin or originality.[18] The main objective of this study is to compare the qualities of saffron obtained from different locations. Specifically, it was aimed to compare the qualities of Iranian saffron, which is known to be the main production area of saffron around the World, and macro and micro-locations in Turkey. Saffron samples were collected from the different cities (macro) and their counties (micro) in Turkey. The amounts of safranal, crocin, crocetin, volatile compounds, fatty acids and bioactive components of the obtained samples were evaluated to discriminate the qualities of the collected saffron samples.

2. MATERIALS AND METHODS

Saffron samples were obtained from traditional production areas. The saffron stigmas were dried at room temperature for two days following harvest and placed in 1g glass jars with lids. samples were received from the production areas by cargo. Iranian saffron was obtained from the province of Rezevi Khorasani. Saffron stigma samples in Turkey were obtained from different locations including Hatay (Kırıkhan, Iskenderun, Hassa and Yayladağı counties), Karabük (Safranbolu county Yukarıbucak and Ovacuma villages), Ankara (Ayaş, Nallıhan and Polatlı counties), Çukurova region (Adana-Cukurova, Mersin-Tarsus and Osmaniye-Kadirli counties) and Antalya (Korkuteli county). The altitude and coordinate information of saffron production locations are given in Table 1. Safranal ≥90% stabilized, (W338907-Sample-K), crocetin dialdehyde (18804-10 MG) and crocin (17304-1G) standards were purchased from Sigma Aldrich and used as received.

2.2. Preparation of standard substances and extraction procedure

0.5 mg mL-1 safranal, crocin ve crocetin standard solutions were prepared in ethanol, diluted with 10 - 2.000 ng mL-1 concentrations and stored at 4 °C. The extractions of saffron stigma samples were accomplished using the ultrasonic-assisted solvent extraction method. 100 mg of stigma was grinded and put in a flask. 1.8–4.2 mL of methanol:ethyl acetate (30:70) mixture was then added to the flask. Obtained mixture was then sonicated in an ultrasonic bath for 15 min. After sonication, obtained extract was centrifuged for 3 min at 5000 rpm. This process was repeated three times and obtained supernatants were collected in a different flask. The solvent mixture was evaporated with a final volume of 1 mL and obtained extracts were stored at +4 ºC in the dark for GC-MS analyses. [4,19]

2.3. Gas Chromatography- Tandem mass spectrometry (GC-MS/MS) analysis

Volatile components of saffron samples were identified by GC-MS/MS (Hewlett-Packard 6890) instrument equipped with HP-5MS fused silica column (5% phenyl methyl polysiloxane 30 m 0.25 mm i.d.. film thickness 0.25 µm) and Hewlett-Packard mass selective detector 6890. GC-MS/MS analyses were carried out under the same conditions reported in the literature. [4, 19, 20]

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Table 1. Altitude and coordinate information of safran production locations

Macro	Micro	Elevation	Longitude (E)	Latitude (N)
HATAY	Kırıkhan	122	36 36	31 22
	İskenderun	10	36 36	35 08
	Hassa	288	36 36	42 30
	Yayladağı	711	36 36	02 08
KARABÜK	Safranbolu Yukarıçiflik	829	41 32	17 43
	Safranbolu Ovacuma	376	41 32	27 45
ANKARA	Ayaş	902	40 32	01 18
	Nallıhan	596	40 31	09 20
	Polatlı	811	39 32	35 11
ÇUKUROVA	Adana Çukurova	95	37 35	06 09
	Tarsus	35	36 34	57 35
	Osmaniye Kadirli	94	37 36	23 04
ANTALYA	Korkuteli	871	37 30	03 19
IRAN	Rezaviye Horasani	955	36 59	16 36

2.4. Gas Chromatography-Mass spectrometry flame ionization detector (GC-MS/FID) analysis

The amounts of safranal, crocin and crocetin were detected by GC-MS/FID (Hewlett-Packard 6890) instrument equipped with HP-88 fused silica column (100 m 0.25 mm i.d.. film thickness 0.25 µm) and Hewlett-Packard mass selective detector 6890. The oven was heated to 60 ºC and waited for 1 min at that temperature. Then, the temperature was raised to 100 ºC by 5 ºC min^{-1} and waited for 4 min. The temperature was increased by 5 ºC min^{-1} to 135 ºC and waited for 20 min. Finally, it was increased by 10 ºC min^{-1} to 170 ºC and waited for 22 min. The gas mixture to the flame was made of 60 mL min^{-1} of H2 (UHP grade), 400 mL min^{-1} air (zero grade), 10 mL min^{-1} Helyum (99.9999%) as carrier gas. Injector temperature was kept at 200 ºC. [4, 19]

3. RESULTS AND DISCUSSION

In this study, the quality of saffron samples obtained from different locations was evaluated using two different aspects. First, evaluation involved in some quality comparisons of saffron samples obtained from 13 different micro-locations in five different macro locations in Turkey and Iranian saffron. In both studies, the volatile components in the stigma samples were determined by GC-MS/MS analysis. The amount of active ingredients indicating the quality of saffron such as safranal, crocin and crocetin in the stigma were determined by GC-MS/FID analysis. Both analysis methods are explained comparatively.

3.1. Comparisons of the qualities of saffron samples

Safranal fractions of Iranian saffron and saffron grown in different locations in Turkey and the amounts of safranal, crocin and crocetin in these saffron samples were summarized in Table 2. According to the Table 1, the highest fractions of safranal were obtained with the order by 86.88% Safranbolu Ovacuma saffron in Karabük, 75.48% Yayladağı saffron in Hatay, 70.23% Polatlı saffron in Ankara, 68.58% Osmaniye Kadirli in Çukurova. Safranal fraction in Iranian saffron was found to be 64.66%. When safranal fractions were compared, the highest amount of safranal was observed in Safranbolu Ovacuma saffron in Karabük with 86.88%. Safranal, which is the most abundant volatile component in saffron, was reported to constitute 60-70% of the volatile components in saffron in the literature.[21] In another report, it was reported that 93% of safranal was found in the saffron sample according to the olfactometric.[22]

In another study, the fractions of safranal in Spanish saffron collected from different locations were found to be 77.7% (SF-SP4), 73.2% (SF-SP3), 64.5% (SF-SP2), SF-SP6 (50.7%), 32.1% (SF-SP1) and 29.8% (SF-SP5). Significant differences on the safranal fractions were observed among the different locations. Such differences were reported to be due to different agricultural practices or drying methods of saffron.[23]

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Table 2. Comparison of the safranal fractions and the amounts of safranal, crocin and crocetin compounds obtained from Iranian saffron and saffron from micro and macro locations in Turkey.

Location		GC-MS/MS	GC-MS/FID		
Macro	**Micro**	**Safranal (%)**	**Safranal (mg/kg)**	**Crocin (mg/kg)**	**Crocetin (mg/kg)**
HATAY	Kırıkhan	24.47	5422.74	379.84	1.30
	İskenderun	29.31	7828.07	91.80	5.98
	Hassa	28.56	3253.14	284.66	0.70
	Yayladağı	75.48	22532.97	647.26	3.40
KARABÜK	Safranbolu Yukarıçiflik	64.10	12095.55	77.56	0.20
	Safranbolu Ovacuma	86.88	21776.36	157.04	2.20
ANKARA	Ayaş	68.88	20609.74	526.04	6.73
	Nallıhan	66.97	14439.36	241.93	3.52
	Polatlı	70.23	16764.30	488.86	5.10
ÇUKUROVA	Adana Çukurova	65.53	14681.35	223.46	3.26
	Tarsus	57.48	15717.08	534.35	0.02
	Osmaniye Kadirli	68.58	14942.37	225.76	1.97
ANTALYA	Korkuteli	34.67	4450.01	221.23	2.20
IRAN	Rezevi Horasani	64.66	14678.80	358.38	5.80

The amounts of safranal significantly differed among the different locations. The highest amount of safranal was observed in the order by Yayladağı saffron with 22532.97 mg kg^{-1}, Safranbolu Ovacuma saffron with 21776.36 mg kg^{-1}, Ayaş saffron with 20609.74 mg kg^{-1}, Tarsus saffron with 15717.08 mg kg^{-1} and Korkuteli saffron with 4450.01 mg kg^{-1}. The amount of safranal in Iranian saffron was 14648.80 mg kg^{-1}. In the literature, the average amount of safranal in different locations was examined and results showed that safranal was obtained with 335.9 g kg^{-1} in Spanish saffron and 488.6 g kg^{-1} in Greek saffron. The geography plays an important role for the amounts of safranal found in saffron among different farming locations, especially in the regions of Greece, Iran, Italy and Spain, but no significant difference was observed between Iranian and Spanish saffron.[24] The amounts of safranal from 76 commercially available saffron samples in different countries varied between 1.35 and 10.56 g kg^{-1} by the GC-MS/FID analysis. [25]

According to GC-MS/FID analysis results, the highest amounts of crocin in the macro locations was obtained in the order of Yayladağı saffron in Hatay with 647.26 mg kg^{-1}, Tarsus saffron in Çukurova with 534.35 mg kg^{-1}, Ayaş saffron in Ankara with 526.04 mg kg^{-1}, Korkuteli saffron in Antalya with 221.23 mg kg^{-1} and Safranbolu Ovacuma saffron in Karabük with 157.04 mg kg^{-1} (Table 2). The amount of crocin in Iranian saffron was found to be 358.38 mg kg^{-1}. As seen in the Table 2, the highest amount of crocin was observed in Hatay Yayladağı saffron with 647.26 mg kg^{-1}. Crocin amounts in some locations in Turkey, especially Yayladağı and Kırıkhan in Hatay, Ayaş and Polatlı in Ankara and Tarsus in Çukurova locations, are found to be higher compared to the Iranian saffron. In the literature, the amounts of crocin under different locations, drying conditions and 20 months storage period were reported to be 333.33 mg kg^{-1} in Tehran and 293.33 mg kg^{-1}in Alborz in Iran.[26] This study shows that the amounts of crocin obtained from Iranian saffron are very close to our findings. When the crocetin amounts were evaluated according to GC-MS/FID analysis results, the highest crocetin amounts were obtained in the order of Ayaş saffron in Ankara with 6.73 mg kg^{-1}, Iskenderun saffron in Hatay with 5.98 mg kg^{-1}, Adana Çukurova saffron in Çukurova with 3.26 mg kg^{-1}, Safranbolu Ovacuma saffron in Karabük with 2.20 mg kg^{-1} and Korkuteli saffron in Antalya with 2.20 mg kg^{-1}. The amount of crocetin in Iranian saffron was 5.80 mg kg-1. The highest amount of crocetin was observed in Ayaş saffron in Ankara with 6.73 mg kg^{-1}.

3.2. Evaluation of major components in saffron samples

Major components of saffron samples grown in Iran and different locations in Turkey are presented in Table 3. Six most abundant volatile components found in saffron samples identified by GC-MS/MS analysis are shown in Table 3.

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Table 3. Major volatile components of saffron samples obtained in Iran and macro and micro locations in Turkey.

The fractions (%) of major components observed in saffron grown in Hatay macro climate						
	Rt	**Volatile components**	**Kırıkhan**	**İskenderun**	**Hassa**	**Yayladağı**
1	12.706	Safranal	24.47	29.51	28.56	75.48
2	38.696	Glyceryl Arachidate	20.71	20.16	15.48	5.32
3	33.429	Linoleic Acid	9.53	2.65	0.38	0.34
4	31.481	Palmitic Acid	5.47	3.52	4.95	1.89
5	33.302	Stearolic Acid	4.04	4.59	8.40	3.07
6	39.466	Oleoamide	2.79	7.13	2.65	0.90
			67.01	**67.56**	**60.42**	**87.00**
The fractions (%) of major components observed in saffron grown in Karabük macro climate						
				Safranbolu Yukarıçiftlik		**Safranbolu Ovacuma**
1	12.706	Safranal		64.10		86.90
2	38.696	Glyceryl Arachidate		7.45		3.46
3	18.905	2,6,6-Trimethyl-4-Hydroxy-1-Cyclohexene-1-Carboxaldehyde		1.43		1.75
4	33.302	Stearolic Acid		3.06		1.23
5	31.481	Palmitic Acid		2.60		0.92
6	11.182	2,3-Dihydro-3,5-Dihydroxy-6-Methyl-4H-Pyran-4-One		0.73		0.69
				79.37		**94.95**
The fractions (%) of major components observed in saffron grown in Ankara macro climate						
				Ayaş	**Nallıhan**	**Polatlı**
1	12.706	Safranal		68.90	66.97	70.20
2	38.696	Glyceryl Arachidate		8.62	6.68	5.55
3	39.466	Oleoamide		3.56	1.10	1.18
4	33.302	Stearolic Acid		2.47	6.36	2.90
5	31.481	Palmitic Acid		1.65	2.67	0.00
6	33.465	Linolenic Acid Methyl Ester		1.44	2.05	0.18
				86.64	**85.83**	**80.01**
The fractions (%) of major components observed in saffron grown in Çukurova macro climate						
				Adana Çukurova	**Mersin Tarsus**	**Osmaniye Kadirli**
1	12.706	Safranal		65.5	57.5	68.6
2	38.696	Glyceryl Arachidate		6.98	7.48	6.94
3	33.302	Stearolic Acid		4.22	6.20	2.23
4	31.481	Palmitic Acid		2.40	0.00	1.94
5	5.098	Butenolide		2.36	0.63	0.33
6	11.182	2,3-Dihydro-3,5-Dihydroxy-6-Methyl-4H-Pyran-4-One		1.26	1.70	1.38
				82.72	**73.51**	**81.42**
The fractions (%) of major components observed in saffron grown in Antalya macro climate						
						Korkuteli
1	12.706	Safranal				68.6
2	38.696	Glyceryl Arachidate				6.94
3	33.302	Stearolic Acid				2.23
4	31.481	Palmitic Acid				1.94
5	17.661	Isopropylidenecyclopropyl Methyl Ketone				1.63
6	11.182	2,3-Dihydro-3,5-Dihydroxy-6-Methyl-4H-Pyran-4-One				1.38
						82.72
The fractions (%) of major components observed in saffron grown in Iran macro climate						
						Rezevi Horasanı
1	12.706	Safranal				64.7
2	38.696	Glyceryl Arachidate				7.10
3	33.429	Linoleic Acid				3.84
4	31.481	Palmitic Acid				2.46
5	33.302	Stearolic Acid				2.10
6	17.661	Isopropylidenecyclopropyl Methyl Ketone				1.81
						82.01

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These six components have been detected as major volatile components of the saffron stigmas. The second most abundant component of the saffron samples for all locations was found to be glyceryl arachidate. The highest amount of volatile components in saffron samples were observed in the order of Safranbolu Ovacuma saffron in Karabük with 94.95%, Hatay Yayladağı saffron with 87.00%, Ankara Ayaş Saffron with 86.64%, Adana Çukurova saffron with 82.72% and Antalya Korkuteli Saffron with 82.72%. The amount of major volatile components in the Iranian saffron was found to be 82.01%.

3.3. Evaluation of essential fatty acid components

According to the obtained results, saffron samples contained significant amounts of fatty acids as major components. It was observed that saffron samples contain very rich essential fatty acid compositions including palmitic acid, pentadecanoic acid, stearolic acid, linoleic acid, linolenic acid methyl ester, stearic acid and oleoamide. These fatty acids found in saffron samples are shown in Table 4. The highest amounts of fatty acids found in saffron samples are observed with 23.56% from Kırıkhan saffron in Hatay, 13.79% from Antalya saffron, 13.40% from Nallıhan saffron in Ankara, 11.31% from Mersin Tarsus saffron and 9.76% from Safranbolu Yukarıçiftlik saffron in Karabük. The fatty acid fraction in the Iranian saffron is detected to be 10.36%. Table 4 shows that fractions of the volatile fatty acids in saffron stigmas are quite high, such amounts of fatty acids is considered to be very important for both human health and saffron quality. Tables 4 also shows that stearolic acid seems to be the most abundant fatty acid found in saffron stigmas for all locations. In the literature, differences between the amounts of saturated and unsaturated fatty acids in saffron pollens were found to be quite high. Omega acids (3,6,7,9) including linolenic acid have been reported to be found among the unsaturated fatty acids.[9]

Table 4. Volatile fatty acids obtained from Iranian saffron and saffron samples from micro and macro locations in Turkey.

		Fatty acid fractions (%)							
Macro Locations	Micro Locations	Palmitic (%)	Pentadecanoic (%)	Stearolic (%)	Linoleic (%)	Linolenic Methyl Ester (%)	Stearic (%)	Oleoamide (%)	**Total (%)**
HATAY	Kırıkhan	5.47	0.54	4.04	9.53	0.00	1.19	2.79	**23.56**
	İskenderun	3.52	0.54	4.59	2.65	0.00	1.13	7.13	**19.56**
	Hassa	4.95	0.00	8.40	0.38	0.00	1.39	2.65	**17.77**
	Yayladağı	1.89	0.00	3.07	0.34	1.12	0.52	0.90	**7.84**
KARABÜK	Safranbolu Yukarıçiflik	2.60	0.41	3.06	0.31	1.98	0.00	1.40	**9.76**
	Safranbolu Ovacuma	0.92	0.19	1.23	0.00	0.00	0.31	0.49	**3.14**
ANKARA	Ayaş	1.65	0.00	2.47	0.23	1.44	0.00	3.56	**9.35**
	Nallıhan	2.67	0.23	6.36	0.22	2.05	0.77	1.10	**13.40**
	Polatlı	0.00	0.27	2.90	0.28	0.18	2.66	1.18	**7.47**
ÇUKUROVA	Adana Çukurova	2.40	0.00	4.22	0.29	0.00	1.23	0.99	**9.13**
	Tarsus	0.00	0.44	6.20	0.41	0.00	3.21	1.05	**11.31**
	Osmaniye Kadirli	1.94	0.39	2.23	0.36	0.00	0.74	0.91	**6.57**
ANTALYA	Korkuteli	0.00	0.63	0.00	0.56	4.25	7.14	1.21	**13.79**
IRAN	Rezevi Horasanı	2.46	0.33	2.10	3.84	0.00	0.94	0.69	**10.36**

3.4. Evaluation of the bioactive components

Comparison of the bioactive components (drug, food, pharmacological) of the Iranian saffron and saffron grown in different locations in Turkey are given in Table 5. Bioactive components were identified with literature searches (PubChem and Sigma Aldrich Research Databases). Volatile fatty acids found in saffron samples are already shown in Table 4 and therefore, they are not included in Table 4. Safranbolu Ovacuma saffron in Karabük had the highest amount of volatile compounds (90.84%) with bioactive properties, followed in the order by 82.31% in Yayladağı saffron in Hatay, 79.31% in Ayaş saffron in Ankara, 77.03% in Osmaniye Kadirli saffron in Çukurova region and 55.28% in Korkuteli saffron in Antalya. The fraction of the bioactive volatile components found in the Iranian saffron was 74.41%. It has been reported in the literature that bioactive compounds may differ between dissimilar genotypes or genotypes collected from different geographic regions.[27,28] Therefore, none of the bioactive components were found at the same amount for all locations.[24] In a

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study carried out with olfactometric technique, it was reported that 2,3-butanedione was found as a main flavor compound of Spanish saffron. In the same study, many bioactive components including safranal, isophorone, and 4-ketoisophorone were found in the saffron samples.[29] Isophorones are known to be bioactive and have chemopreventive, antimicrobial and antioxidant activity properties.

Table 5. Bioactive components of saffron samples obtained in Iran and macro and micro locations in Turkey.

Macro Locations	Micro Locations	Butenolide (%)	Cyclopentanone (%)	Isophorone (%)	Ketoisophorone (%)	Safranal (%)	1-Phenylethanol (%)	Glycerol Palmitate (%)	Glyceryl Arachidate (%)	Total (%)
HATAY	Kırıkhan	1.24	2.48	0.00	0.63	24.47	1.81	1.38	20.71	**52.72**
	İskenderun	1.74	1.20	1.44	0.64	29.51	0.46	1.37	20.16	**56.52**
	Hassa	1.49	1.46	1.68	0.40	28.56	0.00	1.34	15.48	**50.41**
	Yayladağı	0.85	0.19	0.00	0.00	75.48	0.00	0.47	5.32	**82.31**
KARABÜK	Safranbolu Yukarıçiflik	1.33	0.25	0.86	0.83	64.1	0.89	0.00	7.45	**75.71**
	Safranbolu Ovacuma	0.00	0.00	0.00	0.23	86.88	0.00	0.27	3.46	**90.84**
ANKARA	Ayaş	0.59	0.00	0.00	0.55	68.88	0.00	0.67	8.62	**79.31**
	Nallıhan	1.24	0.18	0.00	0.25	66.97	0.00	0.65	6.68	**75.97**
	Polatlı	0.20	0.00	0.00	0.27	70.23	0.00	0.53	5.55	**76.78**
ÇUKUROVA	Adana Çukurova	2.36	0.00	0.00	0.66	65.53	0.00	0.61	6.98	**76.14**
	Mersin Tarsus	0.63	0.00	1.29	0.7	57.48	0.00	0.83	7.48	**68.41**
	Osmaniye Kadirli	0.33	0.00	0.00	0.61	68.58	0.00	0.57	6.94	**77.03**
ANTALYA	Korkuteli	2.30	0.00	2.61	0.83	34.67	0.00	1.24	13.63	**55.28**
IRAN	Rezevi Horasanı	1.24	0.00	0.00	0.63	64.66	0.00	0.78	7.10	**74.41**

4. CONCLUSION

In this work, we studied the effects of different geographical locations on the kind and amounts of volatile and fatty acid components of saffron. The results showed a significant effect of the location on the volatile compounds of saffron. On the basis of the obtained results, saffron is an adaptable plant and can be efficiently produced in different geographical and climate conditions. Geographic origin, drying process and different agricultural processes play an important effect on the qualities of saffron and may result in significant differences in the amounts of volatile and bioactive components in saffron samples. According to the obtained outcomes, the highest qualities saffron were determined to be observed in Hatay yayladağı and Karabük safranbolu ovacuma saffron, respectively. Even though Hatay yayladağı and Karabük safranbolu stations located in different geographic regions, their altitudes are very close. Therefore, they probably have similar climate effects on the qualities of saffron.

Conflict of interest

Authors declare that there is no a conflict of interest with any person, institute, company, etc.

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