Industrial Crops & Products 109 (2017) 74–78

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

Research paper

Change in some biochemical and bioactive properties and essential oil composition of coriander seed (*Coriandrum sativum* L.) varieties from Turkey

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ARTICLE INFO

Keywords:
Coriander
Fatty acid
Mineral
Phenolic content
Antiradical activity

ABSTRACT

Coriander (*Coriandrum sativum* L.), is a specific species for Mediterranean region and it is cultivated for several purposes such as medicinal, cooking and cosmetic. Coriander seed oil is widely used in the food, health, cosmetics, soft drinks and chocolate industries all around of the world. Coriander essential oil is also utilised by the humans in terms of its medicinal properties traditionally. The present study was aimed to investigate some biochemical and bioactive properties of the coriander samples. Besides, four different varieties from Turkey (Arslan, Gamze, Gürbüz, Erbaa) were compared in the study. The highest crude oil content (COC) was calculated for the Gamze cultivar. The highest amounts of calcium, magnesium, sulphur, copper and boron were determined in the Gamze cultivar while the lowest values were for the Arslan one. The significant variation was observed in mineral contents of seed and seed oil samples. Petroselinic acid was the major fatty acid for all coriander cultivars. The lowest antiradical activity was found in the Erbaa cultivar and the highest amount of total phenolic compounds was for the Arslan cultivar. This study is the first report about biochemical and bioactive properties of the four coriander varieties from Turkey.

1. Introduction

Coriander (*Coriandrum sativum* L.), from the Umbelliferae (Apiaceae) family, is a native species for the Mediterranean region and is also widely grown in Russia, Central Europe, North Africa and Asia (Sahib et al., 2013). Coriander has been used since ancient times in terms of cooking, medication and flavouring (Nadeem et al., 2013). Among the medication properties, coriander has been reported to exhibit such as antioxidant, anti-diabetic, anti-mutagenic, anthelmintic, sedative-hypnotic, anticonvulsant, diuretic, antifungal, anticancer, anxiolytic, hepatoprotective, anti-protozoal, anti-ulcer, post-coital, antifertility, cholesterol lowering, protective against lead toxicity and heavy metal detoxificier (Momin et al., 2012). Coriander seeds are composed of essential oils, triglycerides, sugars, proteins and vitamin C and utilized as a seasoning agent in liqueurs, teas, meat products and pickles (Illes et al., 2000). The oil contents of different coriander varieties can be affected by the fruit size. Small-fruit types contain higher oil compared with large-fruited types and oil composition of seeds can be affected by many factors, such as genetic structure, climatic conditions, plant and soil macro and micro nutrient contents and agronomical practices (Telci et al., 2006). It is also evaluated that coriander plant is rich in reservoir of micronutrients and nutritional elements (Bhat et al., 2014).

In medical plants, plant nutrients have a great importance in terms of yield and essential oil components. Phosphorus increases efficiency by improving parameters such as enzyme activity, root development, flower formation and seed development (Nyoki and Ndakidem, 2014). Potassium has great precaution for the activity of enzymes required in medicinal plants (Khalid, 2014). Besides, plant nutrients do not only increase the yield but also increase the amount of essential oil (Hornok, 1980; Khalid and Mahmoud, 2015).

In the present work, it was aimed to study crude oil content, fatty acid-mineral composition and bioactive properties of seed oil extracted from different coriander varieties (Arslan, Gürbüz, Gamze, Erbaa). Essential oil composition was also monitored in these varieties and compared.

2. Material and methods

2.1. Materials

The seeds used in the experiment (Arslan, Gürbüz, Gamze, Erbaa)

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http://dx.doi.org/10.1016/j.indcrop.2017.08.008
Received 13 April 2017; Received in revised form 5 August 2017; Accepted 7 August 2017
Available online 17 August 2017

Table 1
The climatic information of the study area.

Months		Temperature (°C)	Precipitation (mm)	Relative humidity (%)
2013	2014	average		
September	–	17.0	10.3	44.1
October	–	9.2	52.5	58.9
November	–	6.3	16.9	68.7
December	–	−3.6	25.4	72.1
–	January	2.0	31.6	72.8
–	February	4.7	17.6	57.3
–	March	8.1	88.9	57.1
–	April	14.1	2.9	44.3
–	May	16.7	39.7	50.4
–	June	19.7	52.9	46.8
–	July	25.2	np	33.7

np: no precipitation.

were harvested (in July 2014) from the kind plots established (in September 2013) in trial area of Erciyes University Agricultural Research and Application Center. The seeds were kept in room temperature until they were analyzed. In the region where the experiment was established, summers are hot and arid, winters are cold and snowy. The climatic information of the land where the experiment was established is given in Table 1.

2.2. Essential oil extraction

Essential oils were extracted by a water vapor distillation apparatus (Clavenger aparatus). A 100 g of fresh coriander fruits were weighed and extracted for 4 h by the distillation system. The yields are given in Table 2 as%.

2.2.1. Essential oil composition analysis

Essential oil composition (EOC) analysis for each variety was repeated three times and mean values were given for EOC. GC–MS analyses of volatile components of the essential oils were run on an Agilent 5975C gas chromatography system (Agilent Technologies, Avondale, PA, USA) equipped with a mass selective detector (Agilent Technologies) and HP-5 MS column (30 m × 0.25 μm) under 90 kPa pressure, 1:25 split and 1 μl injection volume. The oven temperature was held at 50 °C for 5 min, and increased from 50 to 150 °C at 3 °C/min, finally increased to 230 °C/min and held for 10 min. Diluted samples (1/100 in hexane, v/v) as 1 μl was injected automatically in a continuous mode. The carrier gas was helium with a flow rate of 1.6 ml/min. Qualitative analysis was based on the comparison of retention times and the computer mass spectra libraries using Wiley7n.l, Flavor2.L and HPCH1607.L.

2.3. Crude oil content

Crude oil content (COC) was determined according to the method (method 920.39) reported by AOAC (1990). Crude oil was extracted with an automatic oil-analyzer (Velp SER 148/6, Italy). Analysis was performed in triplicates and crude oil contents were given as percentage of total sample weight.

2.3.1. Fatty acid composition

Fatty acid methyl esters (FAME) in samples were prepared using 1-step extraction-transesterification process (Sukhija and Palmquist, 1988). The FAME profile for a 0.6-μL sample at a split ratio of 1:50 was generated using a gas chromatography (Schimadzu, GC 2010 plus) equipped with a flame ionization detector (Schimadzu, Kyoto, Japan), a 100-m fused silica capillary column (i.d. 0.25 mm) and H_2 as the carrier gas. The FAMEs were separated using a temperature gradient program (Chilliard et al., 2013) and the peaks were identified based on comparison of retention times with authentic standard (Supelco #37, Supelco Inc., Bellefonte, PA, USA; L8404 and O5632, Sigma).

2.4. Bioactivity tests

2.4.1. Sample preparation

Coriander seeds were ground using an electric grinder into a fine powder. Thirty grams of a powdered seeds were extracted using *n*-hexane (300 ml) with laboratory type shaker for overnight. After extraction process, the hexane-oil mixture was passed through a filter paper and then *n*-hexane was evaporated in a rotary evaporator to obtain the oil of coriander samples. A sample of oil (0.25 ml) was dissolved with 1.25 ml of *n*-hexane and then 1.25 ml of methanol was added. The mixture was vigorously stirred by vortex and centrifuged at 4100 rpm for 5 min (Hettich, Germany). The methanolic phase was separated from the lipid phase using pipette and the residue was extracted twice with a new portion of methanol (2 × 1.25 ml) and the methanolic phases were combined (Kozłowska et al., 2016).

2.4.2. Total phenolic content analysis

Total phenolic content of the methanolic extracts of seed oils was determined using the Folin-Ciocalteu's reagent (Singleton and Rossi, 1965) according to the method described by Kozłowska et al. (2016) with some modifications. The methanolic extract (0.25 ml) was diluted with water (1 ml) and then the Folin Ciocalteu's reagent (0.5 ml) was added. After 3 min, 1 ml of a sodium carbonate solution (1.9 M) was added and filled up to 5 ml with distilled water. The samples were left to stand in darkness for 60 min and then the absorbance was measured

Table 2
Essentail oil composition of coriander varieties.

Compound	RT[c]	*Arslan* (%)	*Gürbüz*	*Erbaa*	*Gamze*
alpha-pinene	9.63	0.47	0.12	0.18	0.09
p-cymene	13.61	0.35	0.27	nd[a]	0.17
limonene	13.79	0.27	0.27	0.12	0.22
gamma-terpinene	15.22	1.99	1.68	0.70	0.95
linalool	17.30	89.46	89.44	91.77	89.77
camphor	19.21	2.79	2.70	2.01	2.83
terpinene-4-ol	20.78	0.20	0.18	nd	0.14
alpha-terpineol	21.41	0.28	0.34	nd	0.37
geraniol	24.36	1.84	2.37	2.29	2.02
geranyl acetate	30.03	1.88	1.90	1.89	2.47
EOC[b] (%)		0.30 ± 0.07	0.33 ± 0.06	0.38 ± 0.02	0.35 ± 0.03

[a] nd: not determine.
[b] EOC: essential oil content.
[c] RT: retention time.

Table 3
Crude oil content and fatty acid composition of coriander varieties.

Fatty acids (%)	Varieties			
	Arslan	*Gürbüz*	*Erbaa*	*Gamze*
C16:0	3.72 ± 0.04	3.16 ± 0.08	3.21 ± 0.11	3.11 ± 0.18
C18:0	1.08 ± 0.01	0.70 ± 0.52	0.95 ± 0.07	1.66 ± 0.54
C18:1 *n12*	79.78 ± 0.47	81.45 ± 0.42	81.96 ± 0.06	80.90 ± 0.29
C18:2 *n6c*	14.72 ± 0.2	13.97 ± 0.09	13.51 ± 0.11	13.88 ± 0.20
C20:0	0.70 ± 0.67	0.31 ± 0.09	0.19 ± 0.03	0.11 ± 0.02
C18:3 *n3*	nd[a]	0.20 ± 0.02	nd	0.27 ± 0.11
COC[b] (%)	4.79 ± 0.67	6.17 ± 0.34	5.96 ± 0.67	6.25 ± 0.47

[a] nd: not determined.
[b] COC: crude oil content.

at 760 nm using a UV/Vis spectrophotometer (Lambda 25, Perkin Elmer, USA). Total phenolic content in each sample was determined using a standard curve prepared by gallic acid. The results were expressed as milligrams of gallic acid per ml of oil (mg GAE/ml oil).

2.4.3. Antiradical activity

The antiradical activity of the methanolic extracts of the seed oils was determined against DPPH radical. Each methanolic extract (0.5 ml) of seed oils was diluted with 3.25 ml of methanol and then 0.25 ml of 1 mM methanolic solution of DPPH was added. The mixture was vigorously mixed by a vortex and left in darkness for 10 min. The absorbance was measured at 515 nm against pure methanol using a UV/Vis spectrophotometer (Lambda 25, Perkin Elmer, USA). The antiradical activity of the samples was calculated as% inhibition using the following equation:

$$\% \text{ Inhibition} = [(Abs_c - Abs_s)/Abs_c] \times 100$$

where Abs_c is the absorbance of control (DPPH solution) and Abs_s is the absorbance of sample (Kozłowska et al., 2016).

2.5. Mineral composition

Mineral composition analysis was carried out both on seed and crude oil. Approximately 0.5 g of seeds was taken and 10 ml of nitric + perchloric acid mixture was added to the sample to determine some minerals in the seed. Then the samples were subjected to wet ashing until 1 ml of sample remained. After the ashing procedure was completed, the samples were diluted with distilled water and analyzed by ICP-OES spectrometer (Perkin-Elmer, Optima 4300 DV, ICP/OES, Shelton, CT 06484-4794, USA). For oil samples, approximately 0.1 ml of ashed sample was taken and diluted with distilled water to make the final volume as 10 ml. These samples were then analyzed by ICP OES spectrometer (Perkin-Elmer, Optima 4300 DV, ICP/OES, Shelton, CT 06484-4794, USA). The contents of Ca, Mg, Na, K, P, S, Fe, Mn, Zn, Cu, B, Cd, Cr, Pb and Ni were determined (Mertens, 2005).

3. Results and discussion

3.1. Essential oil content and composition

The essential oil contents (EOC) and composition results are given in Table 2. The essential oil content ranged from 0.30 to 0.38%. The highest EOC was found in the Erbaa variety while the lowest one was in the Arslan variety. In some studies, related to essential oil ratio of coriander; Wierdak (2013) reported that EOC of coriander was in the range of 0.17–0.29 ml/100 g while Inan et al. (2014) reported as to be 0.21-0.69% and Zheljazkov et al. (2014) informed as to be 0.117–0.358 ml/100 g. Additionally, Tuncturk (2011) determined EOC of coriander as to be 0.32% in 2006 harvesting year and 0.31% in 2007 and Tuncturk (2006) stated that it was in the range of 0.38–0.44% in 2007. It can be said that variations in the EOC among the varieties are due to some factors such as the genotypic nature of the varieties (Tuncturk, 2011), climate and breeding conditions (Inan et al., 2014).

A total of 10 essential oil components of coriander varieties were determined as a result of the study. Linalool was identified as the main component, followed by camphor and geraniol according to the levels, respectively. Linalool ratios ranged from 89.44% to 91.77% and it was the highest in Erbaa variety and the lowest was in Gurbuz variety. Bandoni et al. (1998) reported that the essential oil of coriander was composed by linalool (68.9–83.7%), γ-terpinene (2.2–5.1%), camphor (3.2–4.8%), α-pinene (1.0–6.5%), geraniol (1.4–3.2%) and geranyl acetate (0.83.8%). Zheljazkov et al. (2014) reported that linalool content was in the range of 50.7–67.9% and Sourmaghi et al. (2015) determined it as in the range of 66.29–63.27% while Ozel et al. (2010) stated as in the range of 76.12–82.74% for the coriander samples. The results of the current study indicate that the higher linaool content was determined compared with the reported results in these studies. The linalool ratios obtained from coriander plant may vary depending on the cultivars, environmental conditions and field of cultivation. Linalool is widely used as a bioactive substance of coriander seeds, because it has many uses of the field, such as liquor and perfumery industries (Inan et al., 2014).

3.2. Crude oil content and fatty acid composition

The results of crude oil content and fatty acid composition are given in Table 3. When the varieties were taken into consideration, crude oil content (COC) ranged from 4.79 to 6.25%. The highest COC was found in Gamze variety while the lowest was in Arslan variety. A total of six different fatty acids were detected in the present study. Petroselinic acid (C18:1, n12) was identified as the major fatty acid component, followed by linoleic acid (C18:2, n6c) and palmitic acid (C16:0), respectively. Petroselinic acid rates varied between 79.78% and 81.96% and it was the highest in the Erbaa variety and the lowest in the Arslan variety. This range was determined as to be higher than previous studies (Sriti et al., 2011; Kiralan et al., 2009; Kozłowska et al., 2016; Griffiths et al., 1992) because petroselinic acid was not seperated from oleic acid peak due to they are positional isomers. Uitterhaegen et al. (2016) informed that the presence of petroselinic acid with its anti-aging and anti-inflammatory activities gives the coriander seed oil application opportunities in the cosmetic and functional food industry.

3.3. Bioactivity tests

Total phenolic content and antiradical activities of coriander cultivars were given in Table 4. Among the cultivars, the highest total phenolic content was determined in Arslan cultivar while the lowest value was for Gamze cultivar. Wangensteen et al. (2004) investigated

Table 4
Total phenolic content and antiradical activity of seed oil samples.

Bioactive properties	*Gürbüz*	*Arslan*	*Erbaa*	*Gamze*
Total phenolic content (mg[a] GAE/ml oil)	0.35 ± 0.05	0.51 ± 0.01	0.33 ± 0.03	0.32 ± 0.01
Antiradical activity (% inhibition)	76.31 ± 0.02	76.77 ± 0.015	66.76 ± 0.03	74.53 ± 0.025

[a] GAE: Gallic acid equivalent.

the antioxidant activities of coriander seeds and leaves extracted with different solvents and stated that the total phenolic content of coriander oil was 0.14 ± 0.01 mg GAE/ml oil. Kozłowska et al. (2016) found that total phenolic content of coriander seed oil extracted with hexane was 0.17 ± 0.15 mg GAE/ml oil. It could be said that the studied cultivars have higher total phenolic content compared with the literature results.

Except Erbaa cultivar, the other cultivars demonstrated similar antiradical activities and the highest activity was monitored in Arslan cultivar. Ramadan et al. (2003) determined the antiradical activities of ten different seed oils including coriander seed oil and stated that 35% of DPPH radicals was quenched. Additionally, Ramadan and Moersel (2006) compared the antiradical performance of some common and unusual vegetable oils and determined that coriander seed oil had the highest effectiveness among the oils in inhibiting of free radicals. They also stated that after 60 min incubation, 26.7% of DPPH radicals was quenched by coriander seed oil. The studied cultivars showed higher scavenging ability.

3.4. Mineral composition

When the content of minerals in the seed and crude oil of coriander were examined, it has been determined that the varietal differences significantly effected the mineral composition. In addition, the crude oil was extracted by both hexane and petroleum ether and it was observed that the mineral contents changed according to extraction solvent type. The amount of Ca varied between 19894–27720 ppm and the highest value was detected in the Gamze cultivar, while the lowest was in the Erbaa cultivar. The amount of K and P varied between 18790–26110 ppm and 3770–6570 ppm, respectively, and the highest value was determined in the Erbaa cultivar and the lowest was in Arslan cultivar. The content of Mg and Na ranged between 2438–3074 ppm and 72.10–88.80 ppm, respectively, and the highest value was determined in Gamze cultivar and the lowest was in Arslan cultivar (Table 5).

In terms of microelement contents, the amounts of Fe and Mn changed between 121–253 ppm and 45.85–82.89 ppm, respectively, and Erbaa cultivar had the highest content and Arslan cultivar had the lowest value. The Cu and B contents varied between 17.30–20.40 ppm and 7.85–20.60 ppm, respectively, and were found as the highest for Gamze cultivar, and the lowest for Erbaa cultivar.

It could be seen that there were differences among the heavy metal contents of varieties. The highest amount of Cr was determined in the Erbaa cultivar, the highest amount of Cd was in the Gamze cultivar while the highest amount of Ni and Pb in the Arslan cultivar (Table 5). The WHO and FAO have determined the maximum allowable limit of Cd in cereals and legumes as 0.5 ppm and the results were found as to be lower than this limit.

It has been determined that the mineral contents of crude oil were not affected by different extraction methods generally. The highest amount of Ca, S and Na in crude oil was determined in Erbaa cultivar and the lowest was in Gürbüz cultivar (Table 5). The amounts of K and P ranged from 8100 to 11220 ppm and 12060–15360 ppm, respectively, and the highest values were obtained from Gürbüz cultivar while the lowest values were in the Erbaa cultivar. The highest amounts of Cu, Fe and Mn in crude oil were obtained from Erbaa, Gamze and Gürbüz varieties, respectively. However, the lowest values of Cu, Fe and Mn were obtained from Arslan cultivar. The amount of Zn reached the highest level in the Arslan cultivar and the lowest was in the Erbaa cultivar. The highest values of Cd and Pb elements were determined in Gamze cultivar while the lowest values were found in Arslan cultivar and the highest Ni value was observed in Erbaa cultivar. In the study of Bhat et al. (2014), the mineral composition of coriander seed was determined as to be Ca (7090 ppm), K (12670 ppm), P (4090 ppm), Mg (3030 ppm), Na (350 ppm), Fe (163 ppm), Zn (47 ppm) for fresh weight. When it was compared with the present study results, the amounts of Ca, K and P were monitored as to be lower and the amount of Mg was determined as to be similar. Additionally, the amounts of Fe and Zn were found to be higher in the Erbaa and Gamze cultivars and lower in the Arslan and Gurbuz cultivars when compared with the aforementioned results. Özcan, 2004 determined the mineral contents of thirty-two plants used as condiments in Turkey and Ca and K amounts of coriander were detected as lower than those of the studied cultivars while B, Cr and Fe contents were higher than those of studied cultivars. In a different study, Zengin et al. (2008) determined the mineral content of coriander samples and measured as 5.8 ± 0.4 mg P, 267 ± 0.2 mg K, 10.8 ± 0.5 mg Ca and 2.9 ± 0.0 mg Mg in 1 g sample. Mg results were in accordance with the present research results but the other elements were different from the reported results in the current study. These differences could be the result of variation in the region, climate and soil conditions in which the plants were grown.

Table 5
Mineral composition of seed and crude seed oil of coriander varieties.

Minerals	*Arslan*			*Gürbüz*			*Erbaa*			*Gamze*		
	Seed (ppm)	Crude oil (ppm)		Seed (ppm)	Crude oil (ppm)		Seed (ppm)	Crude oil (ppm)		Seed (ppm)	Crude oil (ppm)	
		HE[b]	PEE[c]		HE	PEE		HE	PEE		HE	PEE
Ca	20930	4980	5160	23210	4260	4560	19894	6192	2861	27720	5220	5400
K	18790	9.42	11.58	20500	11.22	10.02	26110	8.10	8.58	23190	10.32	11.28
Mg	2438	93.96	98.70	2921	73.92	79.20	2944	83.34	84.60	3074	88.62	85.80
P	3770	12.66	13.38	5073	15.36	11.94	6570	12.06	14.58	5080	12.78	13.86
S	1675	66.60	59.58	1641	61.26	61.80	1870	66.60	65.58	1905	63.24	63.60
Na	72.1	1603	1874	84.45	1274	1807	77.80	2007	1374	88.8	1528	1528
Cu	19.50	1.26	1.02	19.90	1.44	1.26	17.30	1.56	1.86	20.40	1.26	1.62
Fe	121	0.2	0.36	126	0.36	0.30	253	0.30	0.48	196	0.42	0.54
Mn	45.85	0.12	0.36	57.50	0.54	0.30	82.89	0.48	0.24	64.35	0.42	0.42
B	12.25	1.56	2.10	14.40	1.20	1.32	7.85	1.38	1.98	20.60	2.04	1.50
Zn	27.30	11.40	11.88	34.33	10.02	9.90	66.15	6.24	6.72	78.00	10.32	9.36
Cd	0.30	0.24	0.24	0.40	0.24	0.12	0.24	0.24	0.18	0.43	0.30	0.24
Cr	0.95	0.12	nd	0.70	nd[a]	0.12	1.20	nd	nd	0.80	0.06	0.18
Ni	3.40	1.50	1.26	2.35	1.20	1.44	2.45	1.68	1.14	2.90	1.26	0.90
Pb	2.70	0.12	0.12	2.50	0.06	0.06	2.15	nd	0.06	2.45	0.24	0.18

[a] nd: not determined.
[b] HE: hexane extraction.
[c] PEE: petroleum ether extraction.

4. Conclusion

In this study, essential oil composition, crude oil content and fatty acid profile, bioactive properties and mineral composition of seed oil of four different coriander varieties were evaluated. Differences were observed in varieties in terms of crude oil, fatty acid, essential oil levels and mineral composition. As a major essential oil component, linalool was observed as the highest in Erbaa cultivar. On the other hand, the total amount of phenolic substances in the Arslan variety was found to be higher than those of the other varieties, and the antiradical activity was also high in this direction. Mineral contents of Gamze cultivar were higher compared with the others. Turkish coriander cultivars showed significant differences in terms of studied parameters.

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