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Determination of Important Quality Parameters of Cumin (Cuminum cyminum L.) Seeds Provided by Different Countries

Ünal KARIK[1*] **Orçun ÇINAR[2]** **Muharrem GÖLÜKÇÜ[3]**

[1]Aegean Agricultural Research Institute, Menemen-İzmir/TÜRKİYE
[2,3]West Mediterranean Agricultural Research Institute, Antalya/TÜRKİYE

[1]https://orcid.org/0000-0001-6707-191X *[2]https://orcid.org/0000-0002-8356-384X*
[3]https://orcid.org/0000-0003-1646-5876

**Corresponding author(Sorumlu yazar): unalkarik@gmail.com*

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ABSTRACT: *Cumin (**Cuminum cyminum** L.) is one of the most consumed spices worldwide. In this study, seeds obtained from India, Iran, Syria, Pakistan, Afghanistan and Türkiye (Denizli) were used as the materials. Different parameters including essential oil content of seeds (%), essential oil composition (%), fixed oil content (%), fatty acid composition (%), colour values (l, a, b), total phenolic substance (mg GAE/g dry herb) and total flavonoid substance (mg CE/g dry herb) were determined. Result showed that the content of essential oil in unground seeds varied between 1.08% and 4.68%, while, the values were 3.20%-5.02% in ground seeds. Gamma-terpinen-7-al, cuminal, gamma-terpinene and beta-pinene were the prominent main compounds in all cumin seed samples. The fixed oil content ranged from 2.38% to 17.50% in unground seeds and 2.25% to 17.47% in ground seeds. Six different fatty acids were found in fixed oil. Among these fatty acids, oleic acid was the main component. Oleic acid level varied between 56.63% and 65.12%. The CIE L^*, a^* and b^* colour values of the samples ranged between 40.12-45.29, 2.37-7.88, and 17.85-25.95, respectively. Total phenolic matter and flavonoid content of the cumin seed samples were founded between 7.00-11.06 mg GAE/g DW and 2.04-5.08 mg CE/g DW, respectively.*

Keywords: *Cumin, essential oil, fixed oil, colour, phenolic.*

Farklı Ülkelerden Sağlanan Kimyon (Cuminum cyminum L.) Tohumlarının Önemli Kalite Parametrelerinin Belirlenmesi

OZ: *Kimyon (**Cuminum cyminum** L.), dünya çapında en çok tüketilen baharatlardan biridir. Bu çalışmada materyal olarak Hindistan, İran, Suriye, Pakistan, Afganistan ve Türkiye'den (Denizli) elde edilen tohumlar kullanılmıştır. Tohumların uçucu yağ içeriği (%), uçucu yağ bileşimi (%), sabit yağ içeriği (%), sabit yağ bileşimi (%), renk değerleri (l, a, b), toplam fenolik madde (mg GAE/ g kuru ağırlık) ve toplam flavonoid madde (mg CE/g kuru ağırlık) belirlenmiştir. Sonuçlar, öğütülmemiş tohumlarda uçucu yağ oranının %1,08 ile %4,68 arasında değiştiğini, öğütülmüş tohumlarda ise %3,20 ile %5,02 arasında değiştiğini göstermiştir. Tüm kimyon tohumu örneklerinde gama-terpinen-7-al, cuminal, gama-terpinen ve beta-pinen öne çıkan ana bileşiklerdir. Sabit yağ oranı öğütülmemiş tohumlarda %2,38 ile %17,50 arasında, öğütülmüş tohumlarda %2,25 ile %17,47 arasında değişmektedir. Sabit yağın içeriği olarak 6 farklı yağ asidi belirlenmiştir. Bu yağ asitleri arasında oleik asit ana bileşendir. Oleik asit oranı %56,63 ile %65,12 arasında değişmektedir. Örneklerin CIE L*, a* ve b* renk değerleri 40,12-45,29, 2,37-7,88, 17,85-25,95 arasında yer almıştır. Kimyon tohumu örneklerinin toplam fenolik madde ve flavonoid içeriği sırasıyla 7,00-11,06 mg GAE/g DW, 2,04-5,08 mg CE/g DW arasında bulunmuştur.*

Anahtar Kelimeler: *Kimyon, uçucu yağ, sabit yağ, renk, fenolik.*

INTRODUCTION

Cuminum cyminum L. is the most prevalent spice worldwide after pepper (Kanani *et al.,* 2019). This spice is among the oldest and most widely grown plants with various medicinal, nutritional, and healing properties. *C. cyminum* L. is broadly used in the beverage, food, distillery, pharmaceutical, and perfumery industries (Bhatt *et al.,* 2017). It is widely grown in dry and semi-arid areas, such as Egypt, China, Türkiye, Saudi Arabia, and the Mediterranean, particularly in India and Iran. India is also the largest consumer of cumin, while China is its largest exporter. *C. cyminum* L. is traditionally used as an astringent, anti-flatulence, coagulant, and stimulant and is effective against diarrhea, indigestion, epilepsy, toothache, pertussis, indigestion, and jaundice (Rebey *et al.,* 2017; Bhatt *et al.,* 2017; Thippeswamy *et al.,* 2005; Piri *et al.,* 2019).

Essential oils in cumin seeds vary between 2% to 4% depending on the area of cultivation and production materials used (Kanani *et al.,* 2019). In studies conducted in different countries, the main component of the essential oil has been determined as *C. cyminum* L. aldehyde, Y-terpinene, 7-alpha cymene and β-pinene. *C. cyminum* L. seeds also have fixed oils. The amount of fixed oils in the seeds varies from 10% to 20%, with 60% oleic acid and 30% linoleic acid as its main components (Kanani *et al.,* 2019; Moghaddam *et al.,* 2015).

C. cyminum L. is cultivated in late autumn and winter under temperate climates and in summer and early spring under tropical climates. About 5 to 6 months after planting, the seeds grow and bear fruit and are harvested. While in Türkiye in 2019, the total cultivation area was 32.188 ha and the total production was 20.245 tons, in 2020, the total cultivation area dropped to 21.213 ha and the total production decreased to 13.926 tons. The biggest issues for *C. cyminum* L. production areas worldwide and in our country are root diseases and low yields. Hence, the statistics of cultivation areas and yield values show great changes every year.

This study was carried out to determine important quality parameters of cumin seeds obtained from different sources. The comparison of essential oil, fixed oil, colour, total phenolic substance and total flavonoid substance content were also considered in seeds from different sources. The seeds were analyzed separately as unground and ground forms in terms of essential oil and fixed oil content and composition and the effect of two different applications on yield and quality were demonstrated. The aim of this study was to determine some quality parameters of cumin samples obtained from important cumin producer countries. The goal was to determine how important quality characteristics such as essential oil, fixed oil and colour of cumin, vary according to countries. Thus, products in the international cumin trade were evaluated in terms of quality.

MATERIALS and METHODS

Materials

Materials studied included *C. cyminum* L. seeds obtained from six different countries: 1-India, 2-Iran, 3-Syria, 4-Pakistan, 5-Afghanistan, and 6-Türkiye (Denizli). A commercial company imported the seed samples in 2021 and they all populations.

Methods

Different parameters including essential oil content (%), essential oil composition (%), fixed oil content (%), fatty acid composition (%), colour values (l, a, b), total phenolic substance (mg GAE/g dry weight) and the total flavonoid substance (mg CE/g dry weight) amount in seeds were determined. Also, the seeds were analyzed as unground and ground forms. The milling process was done with a hand grinder.

Essential oil content

The dried samples were weighed as 20 gr. The weighed sample was put into the Clevenger apparatus. Deionized water was added as 200 mL. The hydrodistillation was realized over 2 h. Essential oil content was calculated by using essential oil amount and the weight of the plant material (Anonymous, 2011).

Essential oil composition

The essential oil composition of samples was analyzed by gas chromatography (Agilent 7890A) coupled by flame ionization detector and mass spectrometry (Agilent 5975C) using capillary column (HP Innowax Capillary; 60.0 m×0.25

mm×0.25 µm). Essential oils were diluted in a 1:50 ratio with hexane. GC-MS/FID analysis was carried out at split mode of 40:1. Injection volume and temperature were adjusted as 1 µL and 250 °C, respectively. Helium was the carrier gas at a constant flow rate of 0.8 mL/min. The oven temperature was programmed as follows: 60 °C for 10 min, increased at 4 °C/min to 220 °C, and held at 220 °C for 10 min. MS spectra were monitored between 35 to 450 amu and the ionization mode used was electronic impact at 70 eV. The relative percentage of the components was calculated from GC-FID peak areas, and components were identified by Wiley 7 and Oil Adams Libraries (Uysal Bayar and Çınar, 2020).

Fixed oil content and composition

The dried seeds were milled with a laboratory type miller (Retch GM200), then oil of seeds was extracted successively with petroleum ether using a soxhlet extractor (Büchi, Fat Extractor E-500) for 3 h. Oil content was calculated as % on dry matter bases.

The fatty acid composition of the samples was analyzed by gas chromatography (Agilent 7890A) coupled to flame ionization detector and mass spectrometry (Agilent 5975C) (GC-MS-FID). Firstly, fatty acid methyl esters (FAMEs) were prepared (Garces and Mancha, 1993) and then injected to the GC-MS/FID. Separations were performed using an HP innowax capillary column (60 m, 0.25-mm i.d., 0.25 µm film thickness). Helium was used as carrier gas at a flow rate of 0.8 mL min^{-1}. Injector temperature was 250 °C. The temperature programming for the column was applied as follow; started from 150 °C and raised to 200 °C with an increment of 10 °C/min, hold at 200 °C for 5 min, then increased to 250 °C with 5 °C/min increments and hold 250 °C at 10 min (30 min total). Each sample of 1 µL was injected by auto sampler with a split mode (1:40). The content (percentage by weight) of fatty acids was calculated from their corresponding integration data. MS spectra were monitored between 35-450 amu and the ionization mode used was electronic impact at 70 eV. The relative percentage of the components was calculated from GC-FID peak areas. FAMEs were further identified by using WILEY and OIL ADAMS libraries of the GC-MS system (Gölükcü *et.al.,* 2016).

Colour values

The measurement of the colour values used a Minolta CR-400 device. The measurement was made using mean values of colour values. The measurements were made using D65 light source as three different spots. The device was calibrated using a white ceramic calibration plate (CR-A43) before the measurements and all measurements were realized using a liquid measurement plate (CR-A502) (Özdemir, 2001).

Extraction

For extraction, 9.5 mL methanol with 80% purity was added to the 0.5 g sample and extraction was made in the orbital shaker for 1 h. The tube was centrifuged in 5000 rpm for 5 min. Later, the liquid phase in the tube was collected. Then 9.5 mL methanol with 80% purity was added to the residual in the tube and the same procedures were repeated 3 times. After this procedure, the extracts were taken to a 50 mL volumetric flask and diluted to the volume of the volumetric flask (Cemeroglu, 2010).

Total phenolic content

The total phenolic contents of the samples were determined spectrophotometrically according to to the method of Spanos and Wrolstad (1990). For this purpose, 100 µL was taken from the extracted sample and 900 µL deionized water, 4 mL Na_2CO_4 solution (75 g/L), 5 mL 0.2 N Folin Ciocalteau reactive was added. The mixture was stored in the dark for 2 h. The absorbance of the mixture was read at 765 nm wavelength in spectrophotometer device (Shimadzu UV-Vis 160A, Japan). The results were calculated as gallic acid equivalent.

Total flavanoid content

The total flavanoid contents of the samples were determined spectrophotometrically according to the method of Zhishen *et al.* (1999). For this purpose, 1 mL was taken from the extracted sample and 4 mL deionized water and 0.3 mL $NaNO_2$ solution (5%) were added. After 5 min, 0.60 mL AlCl3 solution (10%) was added. Later, 2 mL NaOH (4%) was added after 5 min. Total volume was completed with deionized water to 10 mL. The absorbance of the mixture was read at 510 nm wavelength in spectrophotometer device

(Shimadzu UV-Vis 160A, Japan). The results were calculated as catechin equivalent.

RESULTS and DISCUSSION

Essential oil content and oil composition (%)

The essential oil content of unground and ground seeds as well as its chemical composition are shown in Tables 1 and 2. There was a significant difference in essential oil content in unground and ground seeds. The essential oil content was found to be lower in unground seeds compared to ground seeds. The essential oil content of unground and ground seeds varied between 4.25%-2.01%, 4.97%-2.49%, 4.16%-2.14%, 5.02%-4.68%, 4.34%-1.08% and 3.20%-1.55%, depending on seed origin. Shukla *et al*. (2018) found that the essential oil contents of whole and ground cumin seeds were 1.99% and 3.99%, respectively. Also, Zheljazkov and Shiwakoti (2015) found values between 1.32% and 4.74% in their study in Canada. These results showed great similarity with our results. Karik *et al.* (2021), in their study, determined that the essential oil content in 10 different cumin seeds from seven different countries ranged between 1.16% and 1.98%, which are similar to our results (1.08-5.02%).

The essential oil compositions of unground and ground cumin seeds are indicated in Tables 1 and 2. The chemical composition of the entire essential oil (100%) was determined in all samples and a total of 23 different chemical components were defined. The number of components ranged between 10 and 17. In all samples, gamma-terpinen-7-al, cuminal, gamma-terpinene and beta-pinene were the prominent and main components. Also, it was found that the precentages of the main components in the essential oil changed remarkably in the unground and ground seeds. Gamma-terpinen-7-al, which constituted the most important part of the essential oil in all samples, increased from 32.37% to 46.98%, 35.05% to 59.53%, 35.05% to 60.21%, 22.58% to 29.09%, 31.70% to 42.81% and 34.69% to 50.39% in the essential oil of ground and unground seeds in samples 1, 2, 3, 4, 5 and 6, respectively. The yield of cuminal, which was the second most important component of essential oil, in the ground and unground seeds ranged from 32.13% to 37.79%, 14.01% to 22.27%, 18.88% to 21.05%, 10.64% to 16.41%, 18.70% to 24.54% and 22.63% to 23.56%, in the seeds from different countries. Another important component in the essential oil is gamma-terpinene. Amounts of this essential oil decreased from 9.70% to 3.17%, 23.30% to 8.77%, 20.24% to 9.07%, 39.27% to 29.42%, 20.89% to 12.99% and 16.09% to 9.43% in the essential oil of ground and unground seeds in samples 1, 2, 3, 4, 5 and 6 respectively. The amount of beta-pinene in essential oils decreased from 17.03% to 0.28%, 16.60% to 4.09%, 15.94% to 4.47%, 3.74% to 2.21%, 17.84 to 9.46 and 14.56% to 6.82% in the essential oil of ground and unground seeds in samples 1, 2, 3, 4, 5 and 6, respectively When the results obtained are evaluated, it is seen that gamma-terpinen-7-al and cumin contents are higher in the essential oil of the unground seeds, while the amounts of gamma-terpinene and beta-pinene are higher in the ground seeds (Table 1 and Table 2). Celik and Ayran (2020) determined cuminal (42.90%), gamma-terpinen-7-al (22.64%) and gamma-terpinene (5.30%) as the main components of essential oil in cumin seeds originating from Türkiye. Karik *et al.* (2021), in their study, determined cumin as the main component of essential oil and its count varied between 21.37% and 46.52% in 10 different cumin seeds from seven different countries, and these values were similar to our results (16.41 - 37.79%).

In contrast, Singh *et al.* (2017) reported that the main components in cumin essential oil are β-pinene, p-cymene, g-terpinene and cuminaldehyde. Allaq *et al.* (2020) determined in their study that the main components are cumin aldehyde, gamma-terpinene, alpha and beta-pinene. Al-Snafi (2016) identified cuminaldehyde (19.25-27.02%), p-mentha-1,3-dien-7-al % (4.29-12.26), p-mentha-1,4-diene-7-al (24.48-44.91%), γ-terpinene (7.06-14.10%), p-cymene (4.61-12.01%), β-pinene (2.98-8.90%), cuminaldehyde, and γ-terpinene as the main components in cumin essential oil of Syrian origin, o-cymene, limonene and β-pinene in cumin essential oil of Indian origin transdihydrocarvone (31.11%), γ-terpinene (23.22%), p-cymene (15.8%), α-phellandrene (12.01%) and p-menth -2-en-7-ol (3.48%). Boughendjioua (2019) in his study in Algeria determined the main components and their contents as cuminal (36.31%), cuminic alcohol (16.92%), γ-terpinene (11.14%), safranal (10.87%) and p-cymene (9.85%). In some studies, the main components are similar, while in others they are different from each other. Thus, studies have shown that there are quite different chemotypes in cumin essential oil (Singh *et al*. 2017).

Table 1. Essential oil content and composition of unground and ground cumin (*Cuminum cyminum* L.) seeds.
Çizelge 1. Öğütülmüş ve öğütülmemiş kimyon (*Cuminum cyminum* L.) tohumlarının uçucu yağ oranı ve bileşenleri.

Sample Örnek			1-India G	1-India UG	2-Iran G	2-Iran UG	3-Syria G	3-Syria UG
Essential oil yield (%) Uçucu yağ oranı (%)			4.25	2.01	4.97	2.49	4.16	2.14
RT	RI	Compound / Madde	(%)					
10.29	1015	alpha-pinene	0.48	5.01	0.74	-	0.45	-
10.41	1018	alpha-thujene	-	-	0.35	-	-	-
13.36	1099	beta-pinene	17.03	0.28	16.60	4.09	15.94	4.47
13.91	1112	sabinene	0.76	0.33	0.96	0.29	0.88	0.32
15.65	1152	beta-myrcene	0.68	4.39	0.85	0.28	0.77	0.31
17.31	1190	limonene	-	-	0.31	-	-	-
17.72	1200	beta-phellandrene	-	-	0.37	-	0.37	-
19.21	1234	gamma-terpinene	9.70	3.17	23.30	8.77	20.24	9.07
20.25	1258	cymene	5.39	0.71	6.40	3.04	6.24	3.07
31.35	1560	isopulegone	0.76	0.35	0.52	0.90	0.60	0.79
37.76	1779	cuminal	32.13	37.79	14.01	22.27	18.88	21.05
38.22	1796	gamma-terpinen-7-al	32.37	46.98	35.05	59.53	35.05	60.21
44.27	2034	p-mentha-1.4-dien-7-ol	0.26	0.38	0.31	0.51	0.24	0.43
45.37	2080	p-cymen-7-ol	0.44	0.60	0.23	0.32	0.34	9.07
Total (%)/Toplam (%)			100	100	100	100	100	100

G=Ground/Öğütülmüş UG=Unground/Öğütülmemiş.

Table 2. Essential oil content and composition of unground and ground cumin (*Cuminum cyminum* L.) seeds.
Çizelge 2. Öğütülmüş ve öğütülmemiş kimyon (*Cuminum cyminum* L.) tohumlarının uçucu yağ oranı ve bileşenleri.

Sample Örnek			4-Pakistan G	4-Pakistan UG	5-Afghanistan G	5-Afghanistan UG	6-Türkiye G	6-Türkiye UG
Essential oil yield (%) Uçucu yağ oranı (%)			5.02	4.68	4.34	1.08	3.20	1.55
RT	RI	Compound/Madde	(%)					
10.29	1015	alpha-pinene	2.82	1.19	0.78	0.23	0.42	-
10.41	1018	alpha-thujene	-	0.30	0.35	-	-	-
13.36	1099	beta-pinene	3.74	2.21	17.84	9.46	14.56	6.82
13.91	1112	sabinene	0.99	0.80	0.99	0.65	0.65	0.42
15.65	1152	beta-myrcene	1.03	0.77	0.75	0.62	0.80	0.57
15.83	1156	alpha-phellandrene	-	-	-	0.45	1.22	2.02
17.31	1190	limonene	7.85	7.42	-	-	0.46	-
17.72	1200	beta-phellandrene	0.56	0.80	0.43	0.47	0.52	0.45
18.70	1222	beta-ocimene	1.76	1.59	-	-	-	-
19.21	1234	gamma-terpinene	39.27	29.42	20.89	12.99	16.09	9.43
20.25	1258	cymene	6.16	6.16	5.89	5.39	5.65	4.29
20.75	1270	alpha-terpinolene	0.99	1.15	-	-	-	-
30.24	1526	linalool	-	0.17	-	-	-	-
31.35	1560	isopulegone	0.65	1.07	1.20	2.02	0.59	0.59
32.29	1590	terpinen-4-ol	0.48	0.61	-	0.37	0.07	0.21
37.26	1761	ar-curcumene	-	-	-	-	-	0.48
34.13	1652	trans-beta-farnesene	-	-	-	-	0.29	-
35.06	1683	alpha-terpineol	-	0.18	-	-	-	-
37.76	1779	cuminal	10.64	16.41	18.70	24.54	22.63	23.56
38.22	1796	gamma-terpinen-7-al	22.58	29.09	31.70	42.81	34.69	50.39
43.88	2017	carotol	-	-	-	-	0.55	-
44.27	2034	p-mentha-1.4-dien-7-ol	0.25	0.33	0.29	-	0.41	0.42
45.37	2080	p-cymen-7-ol	0.22	0.32	0.21	-	0.41	0.36
Total (%)/Toplam (%)			100	100	100	100	100	100

G=Ground/Öğütülmüş UG=Unground/Öğütülmemiş.

According to the essential oil analysis results, seed from Pakistan had the highest value with 5.02% in terms of essential oil content in the ground seeds. In the samples of other countries such as India, Iran, Syria and Afghanistan, the essential oil rate was above 4%. The Turkish population had the lowest value in terms of essential oil content. Since essential oil determines the odor in cumin seeds, it is known that samples with more essential oil stand out in terms of quality.

Fixed oil content and fatty acid composition (%)

The fixed oil content and its composition in ground and unground seeds are shown in Table 3. There were remarkable results across populations in terms of fixed oil content. In sample 1 the highest oil amount was observed, which, ranged from 17.47% in ground seeds to 17.50% in unground seeds. The lowest fixed oil content was 2.52% in ground seeds and 2.38% in unground seeds in sample 4. In other populations, the fixed oil content ranged between 8.64% and 11.15%. Çelik and Ayran (2020) determined the fixed oil rate in cumin seeds originating from Türkiye as 11.26%, and the results obtained in our study largely coincide with values between 10.89-11.15% in the population of Turkish origin. In studies conducted in other countries, Hajib *et al.* (2018) determined values of 16.30-25.70% in seeds collected from six different regions in Morocco. Al-Snafi (2016) found a content of 10.00% in Iraq, Bettaieb *et al.* (2011) found 17.77% in Tunisian origin material and 15.40% in an Indian population, while Shahnaz *et al.* (2004) measured 18.70% in seeds originating from Pakistan. Therefore, there is large variation in fixed oil content in studies conducted in different countries. Singh *et al.* (2017) showed that fixed oil content in cumin seeds varied between 2% and 37% in populations which is similar to our obtained values (2.38 and 17.50%).

The chemical composition of the fixed oil in cumin seeds is indicated in Table 3. There was no significant difference between the values obtained in the same population in ground and unground seeds. Therefore, the grinding pricess does not cause any changes in the chemical structure of the fixed oil in the seed. Six different fatty acids were identified in fixed oil. Among them, oleic acid was the main component. Oleic acid content ranged between 65.12% and 56.63% followed by linoleic acid which ranged between 32.47% and 29.79% among the samples. The other fatty acids as well as their highest and lowest amounts were palmitic acid (6.91%-3.27%), linolenic acid (2.15%-0.15%), stearic acid (1.68%-0.63%) and palmitoleic acid (0.28%-0.25%). The amount of oleic acid in sample 4 was lower (57.80-56.83%) but the palmitic acid value was higher (6.91-6.82%) than other samples. In the other five samples, oleic acid varied between 63.62%-64.76% and palmitic acid ranged between 3.27%-3.65% (Table 3). In the studies conducted on the chemical composition of the fixed oil in cumin seeds, Çelik and Ayran (2020) determined the oleic acid content was 66.59%, the linoleic acid content was 26.46% and the palmitic acid content was 4.33% in the materials originating from Türkiye, which are very similar to the our results. Keskin (2015) identified petroselinic acid (55.44%-60.18%), linoleic acid (27.8%-29.16%), oleic acid (4.84%-9.69%) and palmitic acid (3.39%-4.01%) in his study with two cumin varieties originating in Türkiye and one population. Shahnaz *et al.* (2004) measured petroselinic acid (51%), linolenic acid (18%), oleic acid (14%) and palmitic acid (11%) in the fixed oil obtained from cumin seeds in their study in Pakistan, which were quite different from the values we obtained in our study. Hajib *et al.* (2018) detected 54.9%-60.9% petroselinic acid, 30.1%-31.3.3% linoleic acid, 2.9%-3.4% palmitic acid and 1.3%-2.3% oleic acid in cumin seeds collected from six different regions in Morocco which are different from the values obtained in our study. Singh *et al.* (2017) showed that the fatty acids in fixed oil of cumin seeds and their amounts are different in studies conducted in different countries, which may be due to the material used and environmental factors.

When the fixed oil content in cumin seeds was evaluated, it was seen that the highest value was obtained from the Indian sample with 17.50%. The lowest fixed oil content was determined in Pakistani seed with 2.38%. Samples from other countries were around 10%. The fixed oil content in cumin is important for spice quality, and it is known that samples with higher quality are preferred for marketing.

CIE Colour values

Colour is one of the basic organoleptic quality attributes for many food products includes spices and condiments. Many pre-harvest factors, especially the variety or origin, can affect the colour of cumin seeds. Along with other quality characteristics, colour values can also affect the amount of cumin used as spice in many food products. Mean colour values of ground cumin seeds evaluated within the scope of the research are given in Table 4.

The CIE L^*, a^* and b^* colour values of the samples ranged between 40.12-45.29, 2.37-7.88, 17.85-25.95, respectively. While the L^* value of the first five samples were similar to each other, the colour value of the Turkish origin cumin seed was higher than the others. This means that this sample is lighter (whiter) in colour brightness. When the a^* colour values, which is an indicator of redness (positive values), are taken into consideration, it is seen that the first sample (Indian cumin seed) is significantly different (higher) from the others. This means that the sample is redder than the others. The lowest a^* colour value was determined for the seed originated from Afghanistan. CIE b colour value of the cumin seed originated from Pakistan is quite different from the others (lower b colour value). The highest b^* colour value was determined for the sample obtained from Türkiye, as in the L^* colour value. It is thought that the values expressing the red and yellow colour tones are due to the carotenoid compounds in the samples. As a matter of fact, in a study conducted in India by Aruna and Baskaran (2010), they found that carotenoids such as lutein, β-carotene, α-carotene, neoxanthin, violaxanthin are present in cumin seeds. In addition, it is reported that luteolin and apigenin, which have a yellow colour flavonoid structure, are found in the composition of cumin seeds (Tayade and Adivarekar 2013, Singh *et al.,* 2017). Chroma (C^*) colour values, which can be calculated using a^* and b^* colour values and can also be expressed as intensity or saturation, ranged from 18.14 to 26.23 for these samples. The highest chroma colour value was determined as 26.23 for the ground seed originated from Türkiye, followed by India and Afghanistan. Another colour component that can be calculated using a^* and b^* values, h° value, also known as "hue angle", ranged from 71.42 to 84.43. The Indian sample had the lowest h° colour value due to the difference in a^* colour value. On the other hand, the h° value of the sample originated from Afghanistan, which had the lowest a^* colour value, also had the highest h° value. As an overall assessment, the colour values of cumin showed significant differences according to seed origin. There are limited studies on colour values of cumin seed. Kirkin *et al.* (2014) determined the CIE L^*, a^* and b^* colour values of cumin seed as about 50, 6 and 20, respectively.

Table 3. Fixed oil content and composition of unground and ground cumin (*Cuminum cyminum* L.) seeds.
Çizelge 3. Öğütülmüş ve öğütülmemiş kimyon (*Cuminum cyminum* L.) tohumlarının sabit yağ oranı ve bileşenleri.

Sample Örnek	1-India G	1-India UG	2-Iran G	2-Iran UG	3-Syria G	3-Syria UG	4-Pak. G	4-Pak. UG	5-Afg. G	5-Afg. UG	6-Tur. G	6-Tur. UG
Fixed Oil Yield (%) Sabit Yağ Oranı (%)	17.47	17.50	9.61	10.17	10.50	10.82	2.52	2.38	8.64	8.79	10.89	11.15
Fatty acids						(%)						
Palmitic acid	3.28	3.27	3.65	3.60	3.62	3.62	6.91	6.82	3.60	3.60	3.57	3.52
Palmitoleic acid	0.26	0.26	0.25	0.25	0.25	0.25	0.28	0.27	0.25	0.25	0.25	0.25
Stearic acid	0.66	0.63	0.87	0.85	0.88	0.87	1.68	1.65	0.85	0.84	0.98	0.96
Oleic acid	64.48	64.40	65.12	64.68	64.76	64.69	57.80	56.63	63.83	63.62	64.12	63.99
Linoleic acid	31.16	31.28	29.79	30.29	30.17	30.25	31.35	32.47	30.94	31.18	30.78	31.00
Linolenic acid	0.15	0.15	0.32	0.32	0.31	0.32	1.98	2.15	0.53	0.51	0.29	0.28

G=Ground/Öğütülmüş UG=Unground/Öğütülmemiş.

Table 4. Colour values of cumim (*Cuminum cyminum* L.) seeds.
Çizelge 4. Kimyon (*Cuminum cyminum* L.) tohumlarının renk değerleri.

Sample/Örnek	L^*	a^*	b^*	C^*	h°
1-India	40.12	7.88	23.42	24.72	71.42
2-Iran	41.02	3.27	22.82	23.05	81.85
3-Syria	41.19	3.13	23.15	23.36	82.34
4-Pakistan	40.87	3.29	17.85	18.14	79.53
5-Afghanistan	41.13	2.37	24.33	24.44	84.43
6-Türkiye	45.29	3.67	25.95	26.23	82.13

In the evaluation made in terms of colour values, it was seen that the Turkish population was above the other samples. Colour is a very important parameter in spice quality. Particularly in plants such as cumin, anise, fennel and black cumin, which are granular spices, the seeds should exhibit their own unique colour. Harvest and post-harvest processes in these seeds adversely affect the seed colour. The most common problem in cumin is discoloration. In this respect, the Turkish population is preferred because it was lighter in colour than other samples.

Total phenolic and flavonoid content

Phenolic substances have a significant effect on the quality of the products considered as spices. Phenolic components are also important with their positive effects on human health, their effects on taste and flavour, colour formation, antimicrobial and antioxidant properties. The average values of the total phenolic and flavonoid content of ground and unground cumin seeds evaluated within the scope of the study are given in Table 5.

Phenolic substances can be found as phenolic acid or flavonoid structures in plant materials. Total phenolic matter and flavonoid content of the cumin seed samples ranged between 7.00-11.06 mg GAE/g DW and 2.04-5.08 mg CE/g DW, respectively. While the highest phenolic and flavonoid contents were determined in Syrian seed, the lowest values were found in Indian seed. Phenolic and flavonoid content of cumin can vary depending on cultivar, climate factors, cultural practices, phenological stage of plant, and also postharvest factors. Nadeem and Riaz (2012) reported values of 4.1 to 53.6 mg GAE/g DW total phenolic content for cumin cultivars. Total phenolic contents of four cumin accessions were determined as 11.96-14.40 mg GAE/g DW by Alinian *et al.* (2016). Bettaieb *et al.* (2011) reported that phenolic content (18.32-26.34 mg GAE/g DW) of cumin was affected by irrigation regime. They found that the highest phenolic content (26.34 mg GAE/g) was obtained by moderate water deficit (50% of field capacity), followed by severe water deficit (25%) and control (100%). Total phenolic content of cumin seed ranged from 1.09 to 18.60 mg GAE/g DW depending on the solvent used for extraction (Rebey *et al.,* 2012). Goodarzi *et al.* (2018) reported that cumin seed contains significant amounts of luteolin, apigenin, luteolin-7-*O*-glucosede and apigenin-7-*O*-glucosede as flavonoid compounds. While, the phenolic content of the materials in the present study coincided with reported values by Nadeem and Riaz (2012), they are generally lower than other literature values. This could be the result of cultivar differences. Additionally, cultural practices, and climate factors have effects on these findings.

CONCLUSIONS

In this study, some quality parameters of cumin seeds obtained from different countries were investigated. Materials obtained from six different countries: India, Iran, Syria, Pakistan, Afghanistan, and Türkiye (Denizli) were examined. The essential oil content (%), essential oil composition (%),fixed oil content (%), fatty acid composition (%), colour values (l, a, b), total phenolic substance (mg GAE/g dry weight) and total flavonoid substance (mg CE/g dry weight) were determined. The essential oil and fixed oil contents were determined in unground and ground seeds. According to the results obtained, the essential oil content in unground seeds varied between 1.08% and 4.68%, and between 3.20-5.02% in ground seeds. Gamma-terpinen-7-al, cuminal, gamma-terpinene and beta-pinene were the main components in all samples. The fixed oil content varied between 2.38%-17.50% in unground seeds and 2.25%-17.47% in ground seeds. Six different fatty acids were determined as the components of fixed oil. Among these fatty acids, oleic acid was the main component. Oleic acid content varied between 56.63% and 65.12%.The CIE L^*, a^* and b^* colour values of the samples ranged between 40.12-45.29, 2.37-7.88, 17.85-25.95. Total phenolic and flavonoid analysis are generally carried out to reveal the overall status of any plant for this purpose. Total phenolic matter and flavonoid content of the cumin seed samples ranged between 7.00-11.06 mg GAE/g DW and 2.04-5.08 mg CE/g DW, respectively.

Table 5. Phenolic and flavonoid content of cumin (*Cuminum cyminum* L.) seeds.
Çizelge 5. Kimyon (*Cuminum cyminum* L.) tohumlarının fenolik ve flavonoid madde miktarları.

Sample Örnek	Total phenolic content (mg GAE/g DW)/ Toplam fenolik miktarı (mg GAE/g DW)	Total flavonoid content (mg CE/g DW)/ Toplam flavonoid miktarı (mg CE/g DW)
1-India	7.00	2.04
2-Iran	10.24	4.23
3-Syria	11.06	5.08
4-Pakistan	10.35	4.26
5-Afghanistan	8.67	4.20
6-Türkiye (Denizli)	9.23	3.98

Based on the results, it was observed that the cumin populations obtained from different countries have different results in quality parameters. Results showed that not only morphological and yield characteristics but also quality characteristics should be considered for evaluating populations, especially for breeding studies.

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