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Antioxidant activity, volatile compounds and fatty acid compositions of *Cephalaria syriaca* seeds obtained from different regions in Turkey

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SUMMARY: Crude oil yield, fatty acid composition, volatile compounds, antioxidant activity and some characteristics of *Cephalaria syriaca* seeds collected from different locations in Turkey were studied. Antioxidant capacity was determined by DDPH and ABTS tests and the results were in the range of 18.8-67.3% and 0.0-41.8 mmol Trolox eq g^{-1} DW, respectively; while total phenolic contents were between 4339-11907 mg GAE kg^{-1}. The average α-tocopherol content was found to be in the range of 54-467 mg kg^{-1}. Oil yield was between 11.2-24.0%. Oleic and linoleic acids were the predominant fatty acids. A total of 30 different volatile compounds were identified in the samples, mostly consisting of alcohols and aldehydes. The results of this study showed that *Cephalaria syriaca* seeds can be considered as alternative raw material in the production of edible oil, and can be used as a source of natural antioxidants and food additives.

***KEYWORDS*:** *ABTS; Acetaldehyde;* Cephalaria syriaca*; DPPH; GC-MS; Hexanal; Phenolics*

RESUMEN: ***Actividad antioxidante, compuestos volátiles y composición en ácidos grasos de semillas de* Cephalaria syriaca *obtenidas de diferentes regiones de Turquía.*** Se estudió el rendimiento de aceite crudo, la composición en ácidos grasos, los compuestos volátiles, la actividad antioxidante y algunas características de las semillas de *Cephalaria syriaca* recolectadas en diferentes lugares de Turquía. La capacidad antioxidante se determinó mediante pruebas DDPH y ABTS y los resultados estuvieron en el rango de 18.8-67.3% y 0.0-41.8 mmol Trolox eq g^{-1} DW, respectivamente, mientras que el contenido fenólico total estuvo entre 4339-11907 mg GAE kg^{-1}. El contenido promedio de α-tocoferol se encontró en el rango de 54-467 mg kg^{-1}. El rendimiento del aceite estuvo entre 11,2-24,0%. Los ácidos oleico y linoleico fueron los ácidos grasos predominantes. Se identificaron un total de 30 compuestos volátiles diferentes en las muestras, principalmente alcoholes y aldehídos. Los resultados de este estudio mostraron que las semillas de *Cephalaria syriaca* pueden considerarse como materia prima alternativa en la producción de aceite comestible, y pueden usarse como fuente de antioxidantes naturales y aditivos alimentarios.

PALABRAS CLAVE: *ABTS; Acetaldehído;* Cephalaria syriaca*; DPPH; Fenólicos; GC-MS; Hexanal*

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1. INTRODUCTION

The interest in different edible oils, including plant seeds with high nutrition value, industrial and pharmaceutical significance, has recently increased. Since oils obtained from different sources generally have different fat compositions, no oil source alone is considered sufficient for all purposes. This has brought about the demand for new oil sources. In line with the increasing demand and scientific studies on the nutritional properties of these oils, determining their quality properties and composition from non-conventional seeds has gained importance (Nehdi, 2011).

Cephalaria Schrad. ex Roem. and Schult. originates from the Greek word for head (kephale). *Cephalaria* species have flowers which are densely arranged on the floral receptacle in the form of a head. There are 94 endemic plant species which are members of the *Cephalaria* (Dipsacaceae) family and it has a wide distribution in regions of the Mediterranean, Balkan, Middle East and North Africa (Davis, 1970; Gokturk *et al.*, 2003). Of these plant species which belong to the *Cephalaria* family, 29 show a wide distribution in Turkey (Gokturk and Sumbul, 2014). It has been reported that *Cephalaria* species have various biological properties including antibacterial, antifungal, antioxidant and cytotoxic activities (Kirmizigül *et al.*, 1996; Mustafaeva *et al.*, 2008; Pasi *et al.*, 2009; Sarıkahya and Kırmızıgül, 2010). Therefore, it is used in medicine, agriculture and veterinary medicine (Kayce and Kirmizigül, 2010). *Cephalaria syriaca* L. (CS), *pelemir* in Turkish, is predominantly found in the southeastern region of Turkey as a weed in cereal fields. The oil of this plant seed is sometimes extracted and used in the baking industry to enhance the quality of bakery products (Yazicioğlu *et al.*, 1978). There is no extensive study on the antioxidant activity, volatile compound or fatty acid composition of CS seeds, which are widely grown in Turkey.

The aim of this study was to determine and compare crude oil yield, fatty acid composition, volatile compounds, antioxidant activity and some characteristics of *Cephalaria syriaca* seeds collected from different altitudes and locations in Turkey.

2. MATERIALS AND METHODS

2.1. Plant materials and chemicals

The CS seeds used in the study were collected from different locations, at different altitudes, longitudes and latitudes, as determined by a Global Positioning System (GPS), at their maturation stage from June to August, 2017, according to their maturation levels. Samples were collected from the provinces of Mardin, Van, Gaziantep, Bitlis, Erzincan, Diyarbakır, Ağrı, Şanlıurfa, Siirt, Muş and Batman,

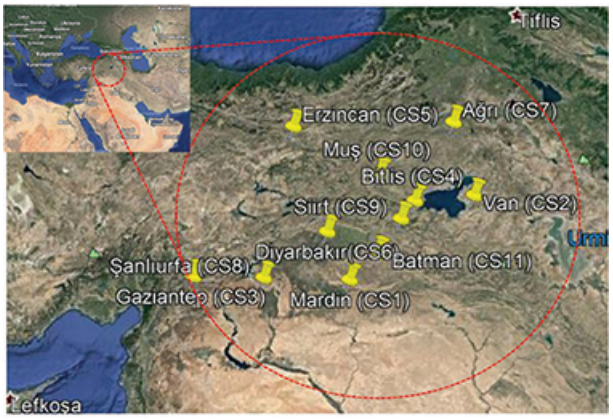

FIGURE 1. Map of locations where the samples of CS (*Cephalaria syriaca*) seeds collected.

all located in Turkey (Figure 1). Three groups of samples, each consisting of fifteen plants, were collected per location. Seed samples were coded as CS_1, CS_2…, and CS_{11}, according to the locations from where they were collected, as given in Table 1. Folin-Ciocalteu's reagent, methanol, n-hexane, isooctane, potassium persulfate methanol, isooctane, potassium persulfate, α-, β-, γ- and δ-tocopherol standards were obtained from Merck (Darmstadt, Germany). 2,2-diphenyl-1picrylhydrazyl (DPPH), 2,2+-azinobis-3-ethylbenzothiazoline-6-sulfonic acid, 5-methyl 2 hexanone, trolox and standards of fatty acid methyl esters (37 FAME mix) were obtained from Sigma Chemical Co. (Sigma–Aldrich GmbH, Sternheim, Germany).

2.2. Preparation of methanolic extract

9.5 mL methanol were added to 5 g hexane-defatted ground C*ephalaria* seed, and the contents were homogenized with a homogenizer (Heidolph, SilentCrusher M, Schwabach, Germany) at 10.000 rpm for 15 s. The homogenized sample was agitated at room temperature for 2 h at 200 rpm in a circular shaker (Heidolph, unimax 1010, Kelheim, Germany). Then, the contents were centrifuged at 8000 × *g* for 10 min at 4 °C. Following centrifugation, the supernatant was separated from the residue, and the residue was subjected to the same treatment in duplicate. The supernatants obtained at the end of extraction were combined and completed to 25 mL with methanol.

2.3. Seed analyses

2.3.1. Proximate analysis of seeds

The recommended methods of the Association of Official Analytical Chemists AOAC, (2005) were adopted to determine the levels of moisture, ash, crude protein and crude oil. The moisture content

TABLE 1. Geographical information on location of *Cephalaria syriaca* samples collected

***Cephalariasyriaca* (location)**	**Code**	**Altitude, m**	**Latitude**	**Longitude**
Mardin	CS_1	596	37°15′07.51″	40°43′36.76″
Van	CS_2	1668	38°34′52.93″	43°17′56.65″
Gaziantep	CS_3	980	37°02′41.84″	37°17′08.84″
Bitlis	CS_4	1703	38°25′50.31″	42°07′47.02″
Erzincan	CS_5	1376	39°42′26.63″	39°29′10.32″
Diyarbakır	CS_6	718	37°53′31.99″	40°09′20.50″
Ağrı	CS_7	1687	39°42′04.42″	43°02′14.46″
Şanlıurfa	CS_8	457	37°06′27.54″	38°54′38.55″
Siirt	CS_9	711	37°56′07.09″	41°53′58.22″
Muş	CS_{10}	1584	38°48′12.61″	41°33′27.65″
Batman	CS_{11}	748	37°53′06.18″	41°14′52.27″

was determined by drying the samples at 105 °C to constant weight. The ash content was determined in a laboratory furnace at 600 °C, and the temperature was increased gradually. Nitrogen content was determined by using the Kjeldhal method. Crude oil was obtained by the Soxhlet extraction method by exhaustively extracting 10 g of each sample in a Soxhlet apparatus using hexane as the extractant. Each measurement was performed in triplicate and the results were averaged.

2.3.2. Determination of total phenolic content

The phenolic content (TPC) of CS seed extracts was determined using the Folin-Ciocalteu reagent (Singleton and Rossi, 1965). Samples (0.4 mL, two replicates) were placed in test tubes; 2 mL of Folin-Ciocalteu's reagent and 1.6 mL of sodium carbonate (7.5%) were added. The tubes were agitated and allowed to stand for 60 min. Absorption was measured at 765 nm in a UV-spectrophotometer (Agilent 8453, Agilent technologies, CA, USA). Gallic acid was used as a standard for the calibration curve (y = 0.0063x + 0.049). The total phenolic content was expressed as gallic acid equivalent (mg GAE/kg dry extract).

2.3.3. Antioxidant activity tests

DPPH radical scavenging assay. The DPPH free radical removal activity of the CS seed extracts was determined by the Blois method (Blois, 1958). Prior to the procedure, the methanolic DPPH solution was prepared for analysis. 0.0065 g DPPH were weighed and completed to 250 mL with methanol (0.025 g/L methanol). For the analysis, 0.1 mL CS seed extract was prepared and a 3.9 mL DPPH solution was added and mixed using a vortex and kept for 60 minutes at room temperature in the dark. At the end of this period, the absorbance of the UV spectrophotometer was read at 515 nm. In the control sample, the spectrophotometer was reset with pure methanol using solvent instead of sample. At the end of the 60 min, the amount of DPPH inhibited in the reaction medium was determined using Equation 1.

$$I = \frac{A_2 - A_1}{A_2} \times 100 \qquad \text{Eqn. 1}$$

I = DPPH inhibited by the sample, %
A_1 = absorbance of the sample
A_2 = absorbance of the control

ABTS assay. ABTS analysis was performed using the method proposed by Re *et al.*, (1999). Measurements were carried out spectrophotometrically by observing the disappearance of the ABTS radical, a stable blue-green compound. The reaction between ABTS and potassium persulfate yields a blue-green $ABTS^{\cdot+}$ chromophore. 7 mmol of ABTS (2,2+-azinobis-3-ethylbenzothiazoline-6-sulfonic acid) and 2.45 mmol potassium persulfate were reacted at room temperature in the dark for 12-16 h to yield the stock $ABTS^{\cdot+}$ radical cation. The obtained $ABTS^{\cdot+}$ radical cation was diluted with ethanol to give 0.70 ± 0.02 absorbance at 734 nm. Then, 20 µL of extract were mixed with 1980 µL $ABTS^{\cdot+}$ radical cation for 6 minutes at room temperature in the dark and measured in the UV spectrophotometer at 734 nm. The results were calculated using the Trolox standard curve (y = 38.484x-2.602) and Equation 2, and were presented as mmol trolox eq/g dry weight.

$$\text{Inhibition \%} = \frac{A_6 - A_1}{A_1} \times 100 \qquad \text{Eqn. 2}$$

A_6: Absorbance at the 6th min
A_1: Absorbance at the 1st min

2.3.4. Determination of volatile compounds

The determination of volatile compounds was carried out by GC-MS according to Krist *et al.*, (2006), with some modifications. Analyses were performed in 3 replicates. Before starting the analysis, 0.1 mL 5-methyl 2 hexanone was completed to 10 mL with pure water by the internal standard (IS) and prepared for analysis. 3 grams of ground seeds were placed in 30 mL vials, and 10 mL pre-boiled and cooled pure water were added and homogenized using a homogenizer (Heidolph Silent Crusher M, Schwabach, Germany) at 13000 rpm. Then, the solution was added to 10 µL internal standard and a magnetic stirrer was added. After the lids of the vials were sealed and conditioned for 5 min at 40 °C in the heating block by immersing them in an appropriate fiber (50/30µm-thick, DVB/CAR/PDMS as the absorbant), they were left to absorb the volatile components in the peak space for 40 minutes in a heated magnetic stirrer set to 40 °C and 140 rpm. At the end of this period, the fiber was held at the injection port of the gas chromatography device for 5 min to pass the fiber-holding volatile components to the GC-MS system column. A TRB-5MS (30 m length, 0.250 mm internal diameter, 0.25 µm film thickness) capillary column was used in the analyses. The operating conditions were set as follows: injection block temperature of 250 °C; detector temperature of 250 °C; carrier gas was He; flow rate at 1 mL/min; temperature of the MS source was 230 °C; MS quadrupole temperature of 150 °C; injection mode was splitless; electron energy of 70 eV; mass range of 15-210 atomic mass units. The oven temperature was held at 40 °C for 2 min, raised from 40 to 70 °C with 5 °C increments per min, held at 70 °C for 1 min, raised from 70 to 240 °C with 10 °C increment per min, and held at 240 °C for 30 min. Then, identifications of the components in the chromatogram were compared with the information in the Wiley and NIST libraries and the calculated retention indexes (RI). In addition, the mass spectra of the defined components and the mass spectra of the internal standard were used to calculate the amounts (µg/kg).

2.4. Analysis of seed oils

2.4.1. Extraction of oils

The oil samples required for planned analyses including fatty acid composition, peroxide value (PV), free fatty acid (FFA), tocopherol and color parameters were obtained by cold extraction. 130 mL n-hexane were added to ground CS (35 g) and kept in the circular shaker at 180 rpm for 2 h. The extracts were filtered and the hexane was evaporated at 40 ºC in a rotary evaporator. The seed oils were stored at + 4 ºC in the dark until use.

2.4.2. Determination of FFA and PV

The methods recommended by AOCS, (1989b) were adopted to determine FFA contents (method Ca 5a-40/93) and PV (method Cd 8-53).

2.4.3. Fatty acid composition

First, fatty acid methyl esters (FAMEs) were formed as described by Basturk *et al.*, (2007). After formation of the methyl esters, 1 mL from the clear upper phase was injected into the injection port of the device, a QP 2010 Ultra Shimadzu GC-MS with MS detector combined with a FID detector. The column details and working conditions were as follows: DB-23 column (60 m x 0.25 mm, 0.25 µm); carrier gas was He at a total flow of 36.6 mL/min; the column flow was 0.66 mL/min; linear speed was 21.2 cm/sec at a split ratio of 50. The initial temperature was 80 ºC, which was increased at 10 ºC/min until the final temperature of 220 ºC; injection and detection temperatures were 250 ºC. The total analysis time was 34 min and the ion source temperature was 200 ºC. Fatty acid methyl esters were identified by chromatography with authentic standards (Sigma) and from the NIST 05 MS Library Database. Quantification of the fatty acid methyl ester profiles was made by considering the relative peak areas, expressed as the relative percentage of the individual area of each one as related to the total area of compounds in the chromatogram. FAMEs analyses were performed in 3 replicates.

2.4.4. Determination of α-tocopherol

The tocopherol content of the samples was determined on a HPLC device (Shimadzu, Kyoto, Japan) according to the AOCS Official Method (Ce 8-89) (AOCS, 2003). In CS samples, the oil samples obtained by cold extraction were diluted with n-hexane at a ratio of 1:10, then filtered through a 0.45 µm (MillipareMillex-LCR Hydrophilic PTFE) filter and injected into the device. The HPLC operating conditions were as follows: LiChrosorb Si60 column (250 × 4mm, ID) 5 µm, at a flow rate of 1 mL/min (isocratic flow); the mobile phase contained hexane: isopropyl alcohol (99:1); wavelength was 295 nm; column temperature was 25 °C. The compounds appearing in the chromatograms were identified as retention times and spectral data by comparison with standards of α-, β-, γ- and δ-tocopherols. Results were expressed in mg/kg oil. The measurements were taken in triplicate.

2.4.5. Color measurement

The L*, a*, b* color values of the samples were determined by using a colorimeter (CR-400 Konica, Minolta, Tokyo, Japan). First, calibration of the

device was carried out on a white plate and black hole provided by the manufacturer. For absolute measurements, approximately 20 mL of oil sample were placed on the measuring head and three readings were taken in different positions. The average values of L*, a*, and b* were given based on three subsequent readings.

2.5. Statistical analysis

Statistical analyses were performed using SPSS software (version 20.0 for Windows, SPSS Inc., Chicago, Illinois). The collected data from the different dependent variables were analyzed statistically according to the analysis of variance with three replicates as a general test at each location. The differences between mean values were analyzed using Duncan's multiple range tests at the 0.05 level of significance.

3. RESULTS AND DISCUSSION

3.1. Physicochemical properties of CS seeds

A proximate composition of CS seeds is given in Table 2. The crude fat content was between 11.2-24.0%, depending on harvest location. CS_1 showed the highest fat content, followed by CS_{11}. Similar ratios were obtained in previous studies. The fat content of CS was previously reported to be between 24.9 and 25.8%, by Yazicioğlu *et al.*, (1978), as 25.14% by Uslu, (2016), 30.3% by Bretagnolle *et al.*, (2016), 19.32-25.15% by Rahimi *et al.*, (2019) and between 19.08 and 23.99% by (Katar *et al.*, 2012). The fat content obtained in the present study was generally consistent with the previously reported results. However, it changed within a relatively large range depending on the harvest location.

The moisture content of the seeds was found to be in the range of 7.6-13.8%. Uslu (2016) found the moisture content as 6.08%. CS_2 showed the highest moisture content; while that of CS_{10} was the lowest. There was no significant difference among the group of samples of CS_3, CS_4 and CS_7, which was lower in moisture content compared to CS_1, CS_5, CS_6, CS_8, CS_9 and CS_{11}group. The ash contents of the samples were determined to be in the range of 5.05-7.58% in the present study. These values were similar to the ash ratio of 5.34% as determined by Uslu (2016). The protein content detected in the CS samples was in the range of 14.7-21.2%. The highest protein yields were in CS_{11}, CS_6, CS_{10} and CS_1 samples, in descending order. Protein contents were reported in previous studies as 15.54% by Uslu (2016) and 16.4-22.5% by Altınığne and Saygın (1985), and were in agreement with this study. The proximate composition of seeds may vary depending on many factors including harvest time, local weather conditions, geographical location, etc.

3.2. Total phenolic content and antioxidant activity of CS seeds

TPC and antioxidant activity of CS seeds are given in Table 3. The highest TPC were found in CS_1, CS_7, CS_{10} and CS_{11} samples, in descending order. The two groups that differed were CS_1, CS_2, CS_4, CS_5, CS_7, CS_8, CS_{10} and CS_{11}, which were significantly different from CS_3, CS_6 and CS_9 ($P < 0.05$). Sarikahya *et al.,* (2015) determined the total amount of phenolic compounds as 57-3037 mg GAE/kg in the aerial parts of ten different *Cephalaria* species, except for *C. syriaca*. Of these species, *C.tchihatchewii*, *C.aristata* and *C. speciosa* were found to have the highest phenolic contents (3037, 2907 and 2658 mg

TABLE 2. Proximate composition of CS seeds

Sample	Oil %	Protein (%)	Moisture%	Ash%
CS_1	23.99 ± 0.52^{f}	20.00 ± 1.94^{de}	10.85 ± 0.88^{de}	6.26 ± 0.52^{abc}
CS_2	19.22 ± 0.27^{e}	16.46 ± 0.35^{ab}	13.75 ± 0.89^{f}	5.64 ± 0.52^{ab}
CS_3	16.67 ± 0.59^{d}	19.51 ± 1.15^{cde}	9.82 ± 0.21^{bcd}	6.65 ± 0.59^{bc}
CS_4	19.33 ± 0.49^{e}	15.40 ± 0.37^{a}	9.53 ± 0.54^{bc}	5.59 ± 0.34^{ab}
CS_5	18.52 ± 0.42^{e}	14.67 ± 1.00^{a}	11.14 ± 0.25^{e}	6.88 ± 0.58^{bc}
CS_6	15.03 ± 0.54^{cd}	21.08 ± 0.83^{e}	10.98 ± 0.31^{de}	6.78 ± 0.91^{bc}
CS_7	13.29 ± 0.28^{bc}	16.38 ± 0.31^{ab}	8.97 ± 0.48^{b}	6.97 ± 0.62^{bc}
CS_8	11.95 ± 2.01^{ab}	18.61 ± 0.16^{cd}	10.20 ± 0.16^{cde}	7.58 ± 0.58^{c}
CS_9	11.18 ± 0.82^{a}	17.61 ± 0.20^{bc}	10.38 ± 0.31^{cde}	7.25 ± 0.54^{c}
CS_{10}	19.85 ± 0.38^{e}	20.48 ± 0.55^{de}	7.62 ± 0.28^{a}	5.05 ± 1.19^{a}
CS_{11}	22.47 ± 1.00^{f}	21.22 ± 1.12^{e}	10.62 ± 0.48^{cde}	6.54 ± 0.25^{abc}

*Small letters indicate significant differences within each column for the mean ± SD values calculated from three determinations by one-way ANOVA and Duncan's test ($P \leq 0.05$). *Cephalaria syriaca* L. samples according to location; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

TABLE 3. **Total phenolic content and antioxidant activity of CS seeds**

Sample	Total Phenolic Content (mg GAE/kg dry seeds)	DPPH (Inhibition %)	ABTS (mMolTrol. eq./gDW)
CS_1	11907 ± 2068^{c*}	45.35± 4.17^{d}	23.68 ± 1.33^{c}
CS_2	9805 ± 1335^{bc}	20.95± 2.90^{a}	38.24 ± 1.87^{e}
CS_3	6408 ± 565^{ab}	20.60 ± 0.00^{a}	23.34 ± 1.61^{c}
CS_4	10406 ± 1322^{c}	18.80 ± 1.13^{a}	28.89 ± 3.35^{d}
CS_5	8452 ± 1523^{bc}	21.45 ± 1.20^{ab}	32.27 ± 1.23^{d}
CS_6	4758 ± 1602^{a}	20.75 ± 2.33^{a}	9.84 ± 0.25^{b}
CS_7	11802 ± 1482^{c}	67.25 ± 3.46^{e}	41.77 ± 0.31^{e}
CS_8	9363 ± 1787^{bc}	29.50 ± 0.28^{c}	38.35 ± 1.26^{e}
CS_9	4339 ± 580^{a}	26.00 ± 0.99^{bc}	0.00 ± 0.00^{a}
CS_{10}	11046 ± 2596^{c}	22.95 ± 0.21^{ab}	25.08 ± 2.45^{c}
CS_{11}	10081 ± 329^{c}	42.90 ± 0.14^{d}	37.90 ± 1.28^{e}

*Small letters indicate significant differences within each column for the mean ± SD values calculated from three determinations by one-way ANOVA and Duncan's test ($P \leq 0.05$). *Cephalaria syriaca* L. samples according to location; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

GAE/kg, respectively). The CS seeds in the present study were found to be higher in TCP values.

The DPPH analysis revealed that the samples showed inhibition (radical scavenging effect) between 18.8 and 67.3%. The highest radical scavenging effect was determined in CS_7, followed by CS_1 and CS_{11}. Rahimi *et al.,* (2019) studied the effect of different fertilizers on the antioxidant capacity of the *Cephalaria syriaca* plant and concluded that the antioxidant activity of the samples (DPPH) was between 47.10-60.16%. According to Kaur and Kapoor (2002), DPPH inhibition activity can be classified into three major groups as high (≥ 50%), moderate (20-50%) and low (≤ 20%). Therefore, CS_4 was in the low activity group, CS_7 was in the high one and the others were in the moderate activity group.

ABTS is often used to test the initial radical scavenging activity of antioxidant compounds or plant extracts. The $ABTS^+$ that was obtained as a result of the oxidation of ABTS with potassium persulfate was presented as an excellent tool to determine the antioxidant activity of hydrogen donor antioxidants and chain-breaker antioxidants (Leong and Shui, 2002). The ABTS results (TEAC values) for the seeds, except for CS_9, were found between 9.8 and 41.8 mmol Trolox eq/g DW values. The highest TEAC value was found in CS_7, while the lowest was found in CS_6. In the case of CS_9, no antioxidant activity (TEAC) was detected.

3.3. Volatile compounds in CS seeds

The volatile compounds of the CS seeds are given in Table 4; while the GC chromatograms of volatile compounds and detailed information are given in Figure 2. 30 different volatile compounds were detected in the CS seeds collected from the 11 different locations. These consisted of 10 aldehydes, 13 alcohols, 2 monoterpenes, 2 ketones, 1 hydrocarbon, and 1 ester in addition to 1 unidentified species. The total amount of aldehydes in the samples varied between 72.3 and 521.6 µg/kg. Total aldehyde values were ordered as $CS_8 > CS_6 > CS_1 > CS_9 > CS_7 > CS_{11} > CS_4 > CS_2 > CS_3 > CS_{10} > CS_5$. The most dominant aldehydes were hexanal, 2-hexenal, butanal 3-methyl, benzaldehyde and acetaldehyde. Nonanal was not detected in CS_1, CS_2, CS_3, CS_4, CS_{10} or CS_{11} samples. The highest amount of detected aldehyde was hexanal (11.90-162.65 µg/kg). The second most dominant component in this group was acetaldehyde and was found in the range of 12.60-54.80 µg/kg. The acetaldehyde contents were not different among the samples of CS_2, CS_3, CS_4, CS_6, CS_9, CS_{10} and CS_{11}; whereas differences among other samples were significantly different ($P < 0.05$). Benzaldehyde was found in all samples and its content was significantly different ($P < 0.05$). Butanal 3-methyl was the other dominant aldehyde and was detected in the range of 6.6-82.4 µg/kg, significantly different among the samples ($P < 0.05$). As seen in Table 4, the total amount of alcohols was higher than aldehydes (81.00-1227.75 µg/kg). The most dominant compounds in the alcohol group were hexanol, myrtenol and 1-butanol 3-methyl, respectively. The highest value was found in CS_8; whereas the lowest value was found in CS_6. While the differences among the hexanol values in CS_1, CS_2, CS_3, CS_6, CS_{10} and CS_{11} samples were not significant, the mean values for other samples were significantly different ($P < 0.05$). Myrtenol was detected in all the samples and ranged from 2.6 to 126.3 µg/kg ($P < 0.05$). In monoterpenes, the α-thujene values varied in the range of 0.9-20.6 µg/kg and differed statistically in

all samples except for CS_1, CS_2 and CS_3 ($P < 0.05$). Another monoterpene, β-pinene, was found to be in the range of 1.10-44.55 µg/kg in all samples ($P < 0.05$). α-thujene and β-pinene were determined to be the highest in CS_8 (20.60 and 44.55 µg/kg, respectively). Metantetranitro was detected in all samples between 10.80 and 34.85 µg/kg ($P < 0.05$). In general, the total amount of volatile compounds was at the highest level in CS_8, collected from the Şanlıurfa province. According to the literature, there was no study on the volatile compounds of CS seeds. As one exception, Sarıkahya *et al.*, (2013) investigated the volatile compounds of the essential oil from 10 endemic *Cephalaria* species, but did not include CS grown in Turkey- A total of 28 components were identified including geraniol, α-cedrene and *p*-cymene.

3.4. Fatty acid composition of CS seed oils

The fatty acid composition of CS seed oils is given in Table 5. Chromatograms and detailed information are given in Figure 3. The most abundant fatty acid in the CS seed oil was oleic acid (C18:1) followed by linoleic (C18:2), myristic (C14:0) and palmitic (C16:0) acids. Oleic acid varied between 28.10 and 33.22% and linoleic acid was in the range of 26.84–31.70% with no statistically significant difference. Yazicioğlu *et al.*, (1978) reported that the oleic acid of oil from CS seeds collected from Kayseri and Diyarbakır (Turkey) was 25.5 and 20.6%; while linoleic acid was 36.3 and 37.6%, respectively. The amounts of oleic acid found in the present study were higher; whereas linoleic acid was lower than these findings. Bretagnolle *et al.*, (2016) reported that oleic and linoleic acids were 19.3 and 42.9%, respectively.

The highest myristic acid content was found in the CS_9 sample with 17.30%; whereas the lowest value was found in CS_7 at 14.60%, with no statistical difference (Table 5). Yazicioğlu *et al*., (1978) determined that myristic acid was in the range of 18.4 and 20.5%. In our study, palmitic acid varied between 11.20 and 12.30%, which was not statistically different. Palmitic acid was reported to be 8.8-10.0% by Yazicioğlu *et al.*, (1978) and 9.5% by Bretagnolle *et al.*, (2016) in previous studies. We found that stearic acid (C18: 0) was in the range of 3.80-5.20%. Stearic acid was reported to be in the range of 1.9-2.0% by Yazicioğlu *et al.*, (1978), and 2.5% by Bretagnolle *et al.*, (2016). The difference between the samples in terms of linolenic acid was statistically significant ($P < 0.05$). The highest linolenic acid content (1.20%) was found in CS_8; while the lowest value (0.30%) was determined in CS_2 and CS_3. Sarikahya *et al.,* (2015) studied the fatty acid composition of the aerial parts of 10 different *Cephalaria* species, not including CS. In all the species studied, oleic acid was in the range of 10.28–31.65%; while linoleic acid was in the range of 17.81-37.67%; palmitic acid in the range of 10.54-23.81%; lauric acid in the range of 0.44-2.15%; myristic acid in the range of 2.54-12.79%; stearic acid in the range of 2.35-4.61%; and linolenic acid in the range of 6.29-36.65%. Sarikahya *et al.*, (2015) studied the aerial parts, which usually include leaves, flowers, branches, etc. However, in this study, the fatty acid composition of the seeds was studied, which is the main reason why the results are different from those previously reported. On the other hand, the differences in fatty acid profiles of CS seed oils may be due to factors including species, location, collection time and extraction technique.

The Total saturated fatty acids (∑SFA) of the oil samples ranged between 33.2 and 37.4%; while total monounsaturated fatty acids (∑MUFA) varied between 30.5 and 35.1% and total polyunsaturated fatty acids (∑PUFA) were in the range of 27.30–32.90%. Bretagnolle *et al.,* (2016) determined ∑SFA, ∑MUFA and ∑PUFA to be 35.3, 21.1 and 43.3%, respectively. The American Heart Association and the National Academy of Sciences (First National Academy of Medicine) have recently given dietary recommendations, focusing not only on the amount of fatty acids, but also on the dietary fatty acid types, and often recommend replacing them for MUFA and PUFAs (Krauss *et al.*, 2000). The present study showed that CS species had approximately equal ratios of SFA, MUFA and PUFA. On the other hand, the total content of unsaturated fatty acids was found to be higher than saturated fatty acids, which is generally desirable as a high consumption of saturated fatty acids is shown to be associated with hearth and coronary diseases (Chowdhury *et al.,* 2014). These fatty acids play key roles in human health and growth. It has also been reported that they have positive effects on the prevention and treatment of diseases such as heart and joint diseases, immune system diseases and cancer (Cabre *et al.*, 2012; Gerber, 2012). All of the samples examined can be considered as potentially good for health as the ratio of UFA/SFA in all CS seed oils was greater than 1, and some were close to 2 (Kostić *et al.,* 2017).

3.5. Peroxide value, free fatty acids and α-tocopherol contents of CS seed oils

The PV of CS seed oils were found between 2.46 and 5.39 meqO_2/kg (Table 6). These values were less than 10 meqO_2/kg (as proposed by the CODEX-STAN 210–1999, Turkish Codex Standards). There was no significant difference among CS_1, CS_3, CS_4, CS_6, CS_7, CS_9, CS_{10}, and CS_{11}. The only samples that were significantly different from that group were CS_2, CS_5, and CS_8 ($P < 0.05$).

According to O'Brien, (2004), PV is one of the most commonly used parameters to characterize oil quality. PV in the range of 1 to 5 meqO_2/kg is

TABLE 4. **Volatile compounds (µg/kg) identified in *Cephalaria syriaca* seeds**

Compounds	RI	CS_1	CS_2	CS_3	CS_4	CS_5
Aldehydes						
Acetaldehyde	622	**54.80** ± 6.12^{d}	26.20 ± 1.84^{b}	24.95 ± 2.01^{b}	25.60 ± 2.56^{b}	13.70 ± 0.74^{a}
Propanal, 2-methyl	638	8.65 ± 1.22^{e}	7.30 ± 0.49^{de}	6.00 ± 1.03^{cd}	4.40 ± 0.61^{bc}	4.65 ± 0.75^{c}
Butanal, 3-methyl	670	25.85 ± 3.83^{cd}	22.95 ± 2.53^{cd}	18.95 ± 2.22^{bc}	24.90 ± 2.81^{cd}	6.60 ± 0.62^{a}
Butanal, 2-methyl	674	7.20 ± 1.10^{bc}	6.05 ± 0.21^{b}	6.60 ± 0.45^{bc}	9.75 ± 1.07^{c}	7.50 ± 0.37^{bc}
Pentanal	695	2.75 ± 0.83^{a}	6.55 ± 0.68^{c}	6.95 ± 0.88^{c}	6.70 ± 0.57^{c}	4.45 ± 0.51^{b}
2-Butenal, 2-methyl	732	2.00 ± 0.18^{a}	2.05 ± 0.20^{a}	1.65 ± 0.34^{a}	1.25 ± 0.24^{a}	2.20 ± 0.23^{a}
Hexanal	790	25.20 ± 2.97^{ab}	33.35 ± 2.36^{bc}	29.10 ± 2.55^{bc}	42.10 ± 4.82^{c}	29.15 ± 2.97^{bc}
2-Hexenal	841	1.00 ± 0.11^{a}	---	---	1.45 ± 0.31^{a}	---
Benzaldehyde	948	22.90 ± 2.26^{d}	8.20 ± 0.82^{b}	5.50 ± 0.48^{ab}	6.00 ± 0.99^{ab}	2.65 ± 0.38^{a}
Nonanal	1090	---	---	---	---	1.35 ± 0.27^{a}
Sum		**150.35 ± 3.00^{f}**	**112.65 ± 2.25^{c}**	**99.70 ± 1.61^{b}**	**122.15 ± 2.91^{d}**	**72.25 ± 1.85^{a}**
Alcohols						
Ethanol	626	7.00 ± 1.17^{cd}	8.55 ± 0.72^{de}	12.35 ± 0.78^{f}	4.35 ± 0.57^{b}	5.70 ± 0.71^{bc}
Silanediol, dimethyl-	690	5.10 ± 0.96^{bc}	2.85 ± 0.66^{a}	6.95 ± 0.99^{d}	**7.25** ± 0.65^{d}	9.05 ± 0.93^{e}
1-Butanol, 3-Metil	724	9.65 ± 1.19^{ab}	6.20 ± 1.03^{a}	3.25 ± 0.68^{a}	10.90 ± 1.70^{ab}	6.60 ± 0.99^{a}
1-Butanol, 2-methyl	727	4.60 ± 0.81^{ab}	2.50 ± 0.44^{a}	2.45 ± 0.52^{a}	4.65 ± 0.52^{ab}	2.20 ± 0.27^{a}
1-Pentanol	756	5.65 ± 0.59^{ab}	4.80 ± 0.58^{ab}	5.45 ± 0.54^{ab}	5.10 ± 0.52^{ab}	14.60 ± 0.72^{c}
1-Pentanol, 4-methyl	827	4.65 ± 0.59^{b}	2.15 ± 0.16^{a}	4.95 ± 0.96^{b}	1.85 ± 0.40^{a}	---
1-Pentanol, 3-methyl	834	13.50 ± 1.95^{cd}	4.05 ± 0.45^{a}	3.00 ± 0.27^{a}	9.65 ± 1.63^{bc}	2.30 ± 0.30^{a}
2-Hexen-1-ol, (E)	855	1.50 ± 0.01^{a}	1.50 ± 0.16^{a}	---	---	0.60 ± 0.03^{a}
Hexanol	857	75.80 ± 10.86^{a}	44.30 ± 3.37^{a}	56.70 ± 5.77^{a}	86.64 ± 7.10^{ab}	168.90 ± 19.23^{c}
1-Octen-3-ol	968	3.20 ± 0.41^{a}	4.35 ± 0.99^{a}	---	4.40 ± 0.40^{a}	1.95 ± 0.24^{a}
Benzenemethanol	1022	4.10 ± 0.76^{ab}	---	---	---	---
Isopinocarveol	1124	0.40 ± 0.08^{a}	---	---	---	---
Myrtenol	1182	57.15 ± 6.65^{de}	23.95 ± 2.67^{bc}	15.35 ± 1.67^{ab}	14.80 ± 1.88^{ab}	6.15 ± 0.86^{a}
Sum		**192.30 ± 4.72^{e}**	**105.20 ± 1.74^{b}**	**110.45 ± 2.57^{b}**	**149.59 ± 2.67^{d}**	**218.05 ± 3.76^{f}**
Monoterpenes						
α-Thujene	921	---	---	---	10.55 ± 1.92^{b}	0.90 ± 0.13^{a}
β-Pinene	962	1.20 ± 0.27^{a}	4.35 ± 0.62^{ab}	1.10 ± 0.13^{a}	17.10 ± 1.41^{e}	4.05 ± 0.34^{ab}
Sum		**1.20 ± 0.14^{a}**	**4.35 ± 0.42^{ab}**	**1.10 ± 0.14^{a}**	**27.65 ± 1.99^{f}**	**4.95 ± 0.30^{bc}**
Ketones						
2-propane	630	5.30 ± 0.41^{b}	8.60 ± 0.64^{de}	10.35 ± 1.74^{ef}	**13.00** ± 1.46^{g}	5.95 ± 0.68^{bc}
Acetone	881	1.50 ± 0.17^{bc}	1.20 ± 0.15^{ab}	1.90 ± 0.33^{c}	0.90 ± 0.16^{ab}	2.55 ± 0.37^{d}
Sum		**6.80 ± 0.54^{b}**	**9.80 ± 0.55^{cd}**	**12.25 ± 1.88^{de}**	**13.90 ± 1.64^{e}**	**8.50 ± 1.03^{bc}**
Hidrokarbon						
Hexane	647	19.35 ± 2.26^{ab}	75.60 ± 5.37^{e}	32.35 ± 3.99^{c}	40.90 ± 3.24^{d}	26.90 ± 3.93^{bc}
Ester						
Acetic acid, ethyl ester	655	3.95 ± 0.98^{bcd}	3.60 ± 0.44^{b}	3.80 ± 0.30^{bc}	8.05 ± 1.12^{f}	5.60 ± 0.83^{de}
Other						
Methane, tetranitro	617	18.30 ± 1.48^{b}	19.25 ± 2.21^{b}	**34.85** ± 3.46^{e}	24.90 ± 2.70^{cd}	25.50 ± 2.66^{cd}

*Small letters indicate significant differences in the same row for the mean± SD values calculated from three determinations by one-way CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman. Major consitutents are

CS_6	CS_7	CS_8	CS_9	CS_{10}	CS_{11}
22.80 ± 2.15^{b}	12.60 ± 1.84^{a}	46.80 ± 3.90^{c}	21.95 ± 2.28^{b}	28.70 ± 2.80^{b}	22.55 ± 2.32^{b}
11.00 ± 1.54^{f}	4.85 ± 0.30^{c}	**12.65** ± 1.30^{f}	4.00 ± 0.33^{bc}	2.00 ± 0.14^{a}	2.60 ± 0.24^{ab}
21.80 ± 2.81^{bc}	38.75 ± 0.72^{e}	**82.40** ± 9.57^{f}	31.35 ± 3.21^{de}	13.40 ± 1.63^{ab}	25.25 ± 1.97^{cd}
7.90 ± 0.41^{bc}	13.90 ± 1.02^{d}	**35.30** ± 3.44^{f}	9.65 ± 0.83^{c}	3.00 ± 0.59^{a}	20.35 ± 2.05^{e}
6.00 ± 0.48^{bc}	4.45 ± 0.62^{b}	**16.70** ± 1.20^{d}	2.85 ± 0.27^{a}	---	2.25 ± 0.18^{a}
---	1.60 ± 0.37^{a}	**10.50** ± 1.17^{b}	1.60 ± 0.16^{a}	1.20 ± 0.17^{a}	---
69.25 ± 5.84^{d}	23.25 ± 2.57^{ab}	**162.65** ± 16.39^{e}	32.25 ± 3.22^{bc}	24.10 ± 2.08^{ab}	11.90 ± 0.23^{a}
3.40 ± 0.44^{a}	18.20 ± 0.69^{a}	**107.40** ± 77.46^{b}	22.95 ± 2.39^{a}	0.70 ± 0.03^{a}	5.05 ± 0.48^{a}
6.00 ± 0.59^{ab}	16.10 ± 0.88^{c}	**38.40** ± 3.89^{f}	18.00 ± 1.51^{c}	5.60 ± 0.65^{ab}	31.45 ± 1.80^{e}
4.65 ± 0.51^{b}	1.80 ± 0.25^{a}	**8.75** ± 1.00^{c}	1.00 ± 0.04^{a}	---	---
152.80 ± 2.64^{f}	**135.50 ± 3.24^{e}**	**521.55 ± 9.89^{g}**	**145.60 ± 2.29^{f}**	**78.70 ± 2.32^{a}**	**121.40 ± 2.38^{d}**
10.45 ± 1.06^{ef}	5.80 ± 0.45^{bc}	**17.25** ± 1.88^{g}	6.15 ± 0.95^{bc}	5.90 ± 0.55^{bc}	2.00 ± 0.14^{a}
3.80 ± 0.45^{ab}	3.20 ± 0.11^{a}	6.20 ± 1.00^{cd}	3.80 ± 0.65^{ab}	4.10 ± 0.44^{ab}	3.00 ± 0.20^{a}
15.55 ± 1.48^{b}	32.35 ± 3.61^{c}	**80.95** ± 7.78^{e}	47.65 ± 3.97^{d}	6.70 ± 0.91^{a}	40.75 ± 4.09^{d}
7.05 ± 0.66^{b}	13.30 ± 2.93^{c}	**35.70** ± 3.48^{d}	14.00 ± 1.50^{c}	1.20 ± 0.14^{a}	7.55 ± 0.82^{b}
5.85 ± 0.55^{b}	3.30 ± 0.31^{ab}	**30.00** ± 3.39^{d}	5.25 ± 0.51^{ab}	6.00 ± 1.22^{b}	2.85 ± 0.27^{a}
1.90 ± 0.40^{a}	2.40 ± 0.38^{a}	**12.90** ± 0.57^{c}	4.70 ± 0.72^{b}	1.50 ± 0.27^{a}	4.15 ± 0.42^{b}
4.50 ± 0.52^{a}	15.15 ± 1.51^{d}	**45.65** ± 4.53^{e}	16.50 ± 1.60^{d}	6.00 ± 0.58^{ab}	10.50 ± 0.91^{c}
2.75 ± 0.86^{a}	15.50 ± 1.50^{b}	**82.85** ± 7.45^{d}	27.20 ± 2.60^{c}	0.60 ± 0.03^{a}	7.25 ± 0.74^{a}
35.90 ± 3.45^{a}	90.95 ± 10.54^{ab}	**684.20** ± 64.83^{d}	138.20 ± 13.48^{bc}	44.70 ± 4.36^{a}	59.20 ± 6.60^{a}
3.30 ± 0.58^{a}	90.35 ± 9.66^{c}	**72.00** ± 6.79^{b}	7.15 ± 1.06^{a}	1.70 ± 0.18^{a}	4.55 ± 0.34^{a}
1.70 ± 0.23^{a}	8.05 ± 0.76^{bc}	**16.35** ± 1.78^{d}	10.45 ± 1.10^{c}	---	8.65 ± 3.45^{c}
---	11.35 ± 1.00^{c}	**17.40** ± 1.17^{d}	4.95 ± 0.65^{b}	---	1.95 ± 0.16^{a}
30.70 ± 3.38^{c}	46.10 ± 4.70^{d}	**126.30** ± 12.02^{f}	65.50 ± 7.21^{e}	2.60 ± 0.47^{a}	57.20 ± 5.81^{de}
123.45 ± 3.90^{c}	**337.80 ± 5.26^{g}**	**1227.75 ± 9.23^{i}**	**351.50 ± 5.81^{h}**	**81.00 ± 1.41^{a}**	**209.60 ± 2.81^{f}**
9.21 ± 2.26^{b}	17.70 ± 1.47^{c}	**20.60** ± 1.48^{c}	3.60 ± 0.31^{a}	2.70 ± 0.47^{a}	1.80 ± 0.20^{a}
8.85 ± 0.75^{cd}	25.60 ± 2.90^{f}	**44.55** ± 3.34^{g}	9.95 ± 1.22^{d}	1.30 ± 0.13^{a}	5.85 ± 0.47^{bc}
18.06 ± 1.30^{e}	**43.30 ± 1.29^{g}**	**65.15 ± 3.20^{h}**	**13.55 ± 1.90^{d}**	**4.00 ± 0.17^{ab}**	**7.65 ± 0.44^{c}**
12.60 ± 1.64^{fg}	7.20 ± 0.85^{bcd}	10.50 ± 0.86^{ef}	2.50 ± 0.49^{a}	8.20 ± 1.13^{cde}	5.90 ± 0.48^{bc}
1.50 ± 0.23^{bc}	1.20 ± 0.18^{ab}	**7.75** ± 0.66^{e}	1.20 ± 0.10^{ab}	1.00 ± 0.03^{ab}	0.60 ± 0.04^{a}
14.10 ± 2.22^{e}	**8.40 ± 0.66^{bc}**	**18.25 ± 1.80^{f}**	**3.70 ± 0.13^{a}**	**9.20 ± 0.20^{bc}**	**6.50 ± 0.16^{b}**
15.00 ± 1.53^{a}	27.60 ± 2.69^{c}	**46.65** ± 4.17^{d}	12.80 ± 1.24^{a}	25.00 ± 2.25^{bc}	---
6.10 ± 0.59^{e}	5.30 ± 0.61^{cde}	**11.80** ± 1.15^{g}	4.10 ± 0.38^{bcd}	2.50 ± 0.27^{ab}	1.20 ± 0.13^{a}
20.85 ± 1.80^{bc}	22.30 ± 0.72^{bc}	28.95 ± 1.61^{d}	10.80 ± 1.56^{a}	13.55 ± 1.51^{a}	13.25 ± 1.29^{a}

ANOVA and Duncan's test ($P \leq 0.05$). *Cephalaria syriaca* L. samples according to location; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, given in bold font.

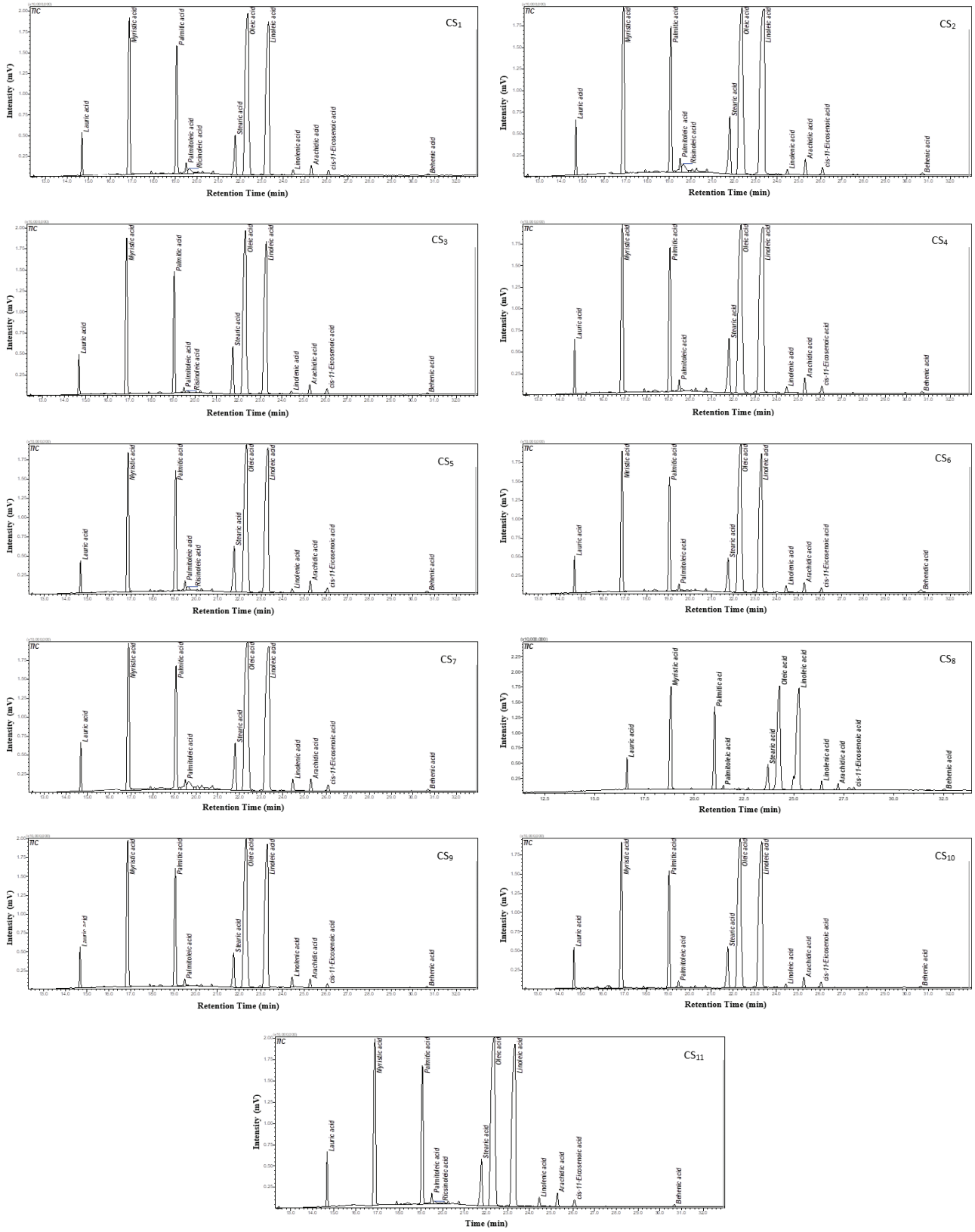

FIGURE 2. **GC chromatograms of fatty acid esters obtained from *Cephalaria syriaca seed oils.*** *Cephalaria syriaca* L. samples according to locations; CS1: Mardin, CS2: Van, CS3: Gaziantep, CS4: Bitlis, CS5: Erzincan, CS6: Diyarbakir, CS7: Agri, CS8: Sanliurfa, CS9: Siirt, CS10: Mus, CS11: Batman

TABLE 5. **Fatty acid composition (%) of the *Cephalaria syriaca* seed oils**

Fatty acids	CS_1	CS_2	CS_3	CS_4	CS_5	CS_6	CS_7	CS_8	CS_9	CS_{10}	CS_{11}
Lauric (C12)	2.40 ± 0.23^{ab}	2.40 ± 0.3^{ab}	2.60 ± 0.30^{b}	2.40 ± 0.17^{ab}	1.90 ± 0.14^{a}	2.32 ± 0.23^{ab}	2.50 ± 0.18^{b}	2.30 ± 0.23^{ab}	2.60 ± 0.21^{b}	2.46 ± 0.28^{ab}	2.70 ± 0.20^{b}
Miristic (C14)	16.20 ± 2.15^{a}	14.80 ± 2.26^{a}	17.10 ± 0.30^{a}	15.20 ± 2.72^{a}	14.80 ± 1.17^{a}	16.38 ± 2.19^{a}	14.60 ± 2.33^{a}	14.70 ± 2.12^{a}	17.30 ± 2.12^{a}	16.44 ± 2.31^{a}	16.30 ± 2.36^{a}
Palmitic (C16)	12.00 ± 1.54^{a}	11.40 ± 2.06^{a}	11.60 ± 2.14^{a}	11.70 ± 1.17^{a}	12.30 ± 0.56^{a}	11.83 ± 2.49^{a}	11.20 ± 1.19^{a}	11.20 ± 2.88^{a}	12.20 ± 1.84^{a}	11.32 ± 2.57^{a}	11.60 ± 3.25^{a}
Palmitoleic (C16:1)	1.90 ± 0.06^{c}	2.30 ± 0.3^{d}	0.50 ± 0.04^{a}	0.80 ± 0.07^{ab}	0.80 ± 0.05^{ab}	0.89 ± 0.1^{b}	2.70 ± 0.27^{e}	0.60 ± 0.08^{ab}	0.70 ± 0.08^{ab}	0.58 ± 0.07^{ab}	0.70 ± 0.08^{ab}
Stearic (C18)	4.00 ± 0.56^{abc}	4.90 ± 0.33^{abc}	5.10 ± 0.27^{bc}	4.80 ± 0.41^{abc}	5.20 ± 0.71^{c}	3.91 ± 0.41^{ab}	4.50 ± 0.38^{abc}	4.20 ± 0.27^{abc}	3.80 ± 0.57^{a}	4.55 ± 0.92^{abc}	4.30 ± 0.49^{abc}
Oleic (C18:1)	32.70 ± 2.79^{a}	28.10 ± 2.76^{a}	32.20 ± 2.67^{a}	29.10 ± 2.29^{a}	31.10 ± 2.12^{a}	33.22 ± 2.69^{a}	29.20 ± 2.81^{a}	31.00 ± 2.26^{a}	30.70 ± 2.97^{a}	30.97 ± 2.96^{a}	32.80 ± 2.70^{a}
Linoleic (C18:2)	27.00 ± 2.25^{a}	31.20 ± 2.29^{a}	27.00 ± 2.39^{a}	31.70 ± 2.19^{a}	29.50 ± 2.23^{a}	26.84 ± 2.43^{a}	27.20 ± 2.16^{a}	31.70 ± 2.40^{a}	28.50 ± 2.79^{a}	30.30 ± 2.55^{a}	26.90 ± 2.47^{a}
Linolenic (C18:3)	0.50 ± 0.02^{ab}	0.30 ± 0.01^{a}	0.30 ± 0.03^{a}	0.40 ± 0.04^{a}	0.40 ± 0.04^{a}	0.78 ± 0.01^{cd}	1.00 ± 0.13^{de}	1.20 ± 0.21^{e}	1.00 ± 0.01^{de}	0.33 ± 0.06^{a}	0.70 ± 0.27^{bc}
Arachidic (C20)	0.90 ± 0.03^{a}	1.10 ± 0.30^{a}	1.00 ± 0.13^{a}	1.10 ± 0.13^{a}	1.10 ± 0.24^{a}	1.02 ± 0.13^{a}	0.90 ± 0.08^{a}	0.80 ± 0.10^{a}	0.90 ± 0.11^{a}	0.95 ± 0.13^{a}	1.10 ± 0.26^{a}
cis11eicosenoik (C20:1)	0.50 ± 0.04^{a}	0.60 ± 0.07^{a}	0.60 ± 0.06^{a}	0.60 ± 0.01^{a}	0.60 ± 0.08^{a}	0.56 ± 0.07^{a}	0.60 ± 0.06^{a}	0.60 ± 0.08^{a}	0.50 ± 0.06^{a}	0.62 ± 0.08^{a}	0.60 ± 0.07^{a}
Others	1.90 ± 0.25^{ab}	2.90 ± 0.27^{b}	2.00 ± 0.25^{ab}	2.20 ± 0.16^{ab}	2.30 ± 0.21^{ab}	2.25 ± 0.30^{ab}	5.60 ± 1.70^{c}	1.70 ± 0.16^{ab}	1.80 ± 0.25^{ab}	1.48 ± 0.33^{a}	2.30 ± 0.30^{ab}
∑SFA	35.50 ± 4.05^{a}	34.60 ± 0.52^{a}	37.40 ± 2.54^{a}	35.20 ± 2.25^{a}	35.30 ± 1.40^{a}	35.46 ± 0.21^{a}	33.70 ± 1.79^{a}	33.20 ± 4.86^{a}	36.80 ± 3.49^{a}	35.72 ± 1.34^{a}	36.00 ± 5.06^{a}
∑MUFA	35.10 ± 2.89^{a}	31.00 ± 3.13^{a}	33.30 ± 2.69^{a}	30.50 ± 2.21^{a}	32.50 ± 1.98^{a}	34.67 ± 2.66^{a}	32.50 ± 2.60^{a}	32.20 ± 2.43^{a}	31.90 ± 3.11^{a}	32.17 ± 2.94^{a}	34.10 ± 2.86^{a}
∑PUFA	27.50 ± 2.26^{a}	31.50 ± 2.31^{a}	27.30 ± 2.36^{a}	32.10 ± 2.23^{a}	29.90 ± 2.19^{a}	27.62 ± 2.42^{a}	28.20 ± 2.29^{a}	32.90 ± 2.19^{a}	29.50 ± 2.77^{a}	30.63 ± 2.60^{a}	27.60 ± 2.21^{a}
∑UFA	62.60 ± 4.32^{a}	62.50 ± 3.42^{a}	60.60 ± 3.56^{a}	62.60 ± 2.27^{a}	62.40 ± 4.21^{a}	62.29 ± 2.74^{a}	60.70 ± 2.26^{a}	65.10 ± 3.15^{a}	61.40 ± 2.1^{a}	62.80 ± 1.85^{a}	61.70 ± 4.12^{a}
UFA/SFA	1.8	1.8	1.6	1.8	1.8	1.8	1.8	2.0	1.7	1.8	1.7

*Small letters indicate significant differences in the same row for the mean ± SD values calculated from three determinations by one-way ANOVA and Duncan's test ($P \leq 0.05$). *Cephalaria syriaca* L. samples according to location; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

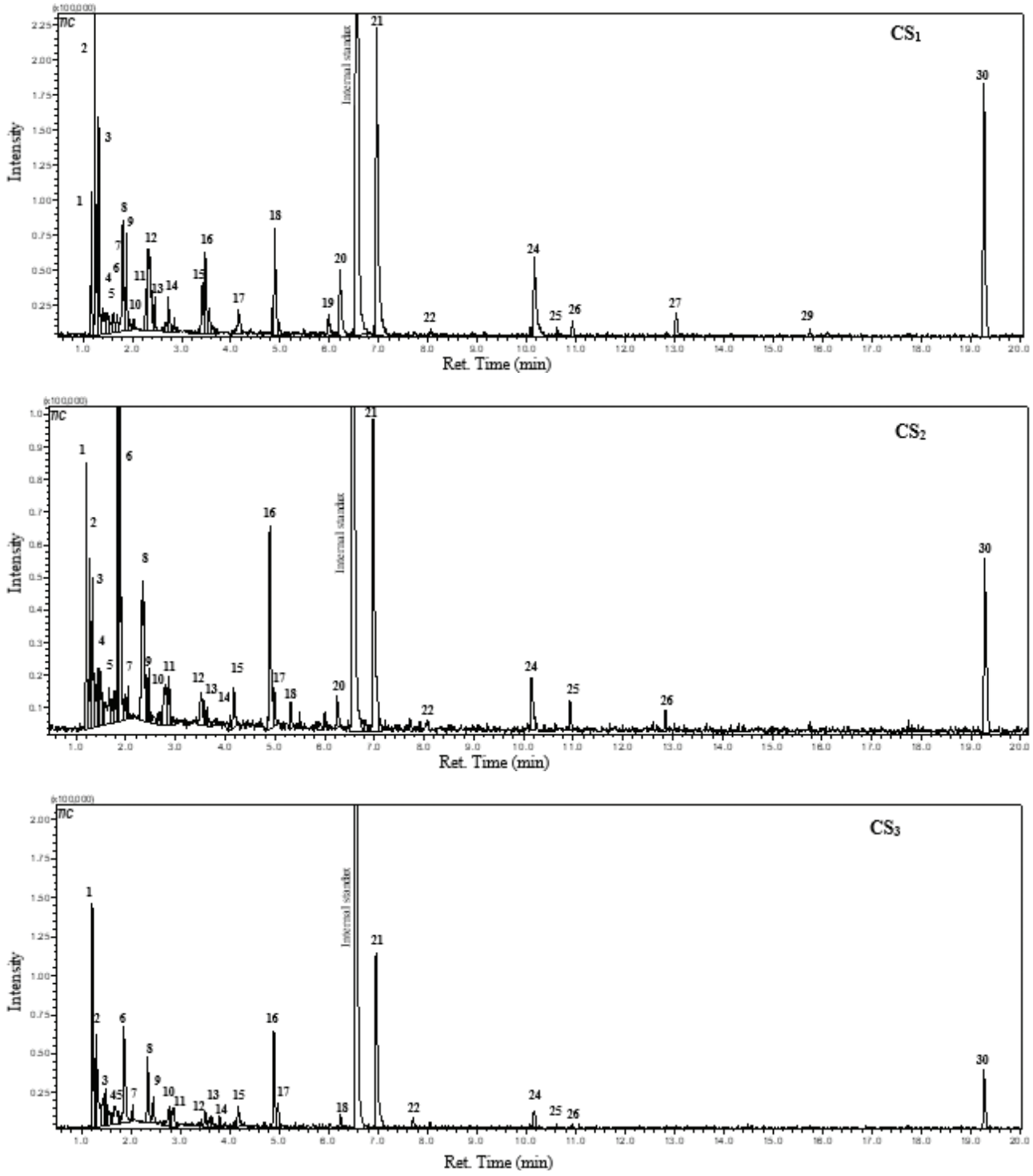

FIGURE 3. **GC-MS chromatograms of volatile compounds of *Cephalaria syriaca* seeds.**
1: Methane, tetranitro-; 2: Acetaldehyde; 3: Ethanol; 4: 2 propane; 5: Propanal, 2-methyl-; 6: Butanal, 2-methyl-; 7: Acetic acid, ethyl ester; 8: Butanal, 3-methyl-; 9: Butanal, 2-methyl-; 10: Silanediol, dimethyl-; 11: Pentanal; 12: 1-Butanol, 3-Methyl-; 13: 1-Butanol, 2-methyl-; 14: 2-Butenal, 2-methyl-; 15: 1-Pentanol; 16: Hexanal; 17: 1-Pentanol, 4-methyl-; 18: 1-Pentanol, 3-methyl-; 19: 2-Hexenal; 20: 2-Hexen-1-ol; 21: Hexanol; 22: Acetone; 23: alpha.-Thujene; 24: Benzaldehyde; 25: .beta.-Pinene; 26: 1-Octen-3-ol; 27: Benzenemethanol; 28: Nonanal; 29: Isopinocarveol; 30: Myrtenol. *Cephalaria syriaca* L. samples according to locations; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

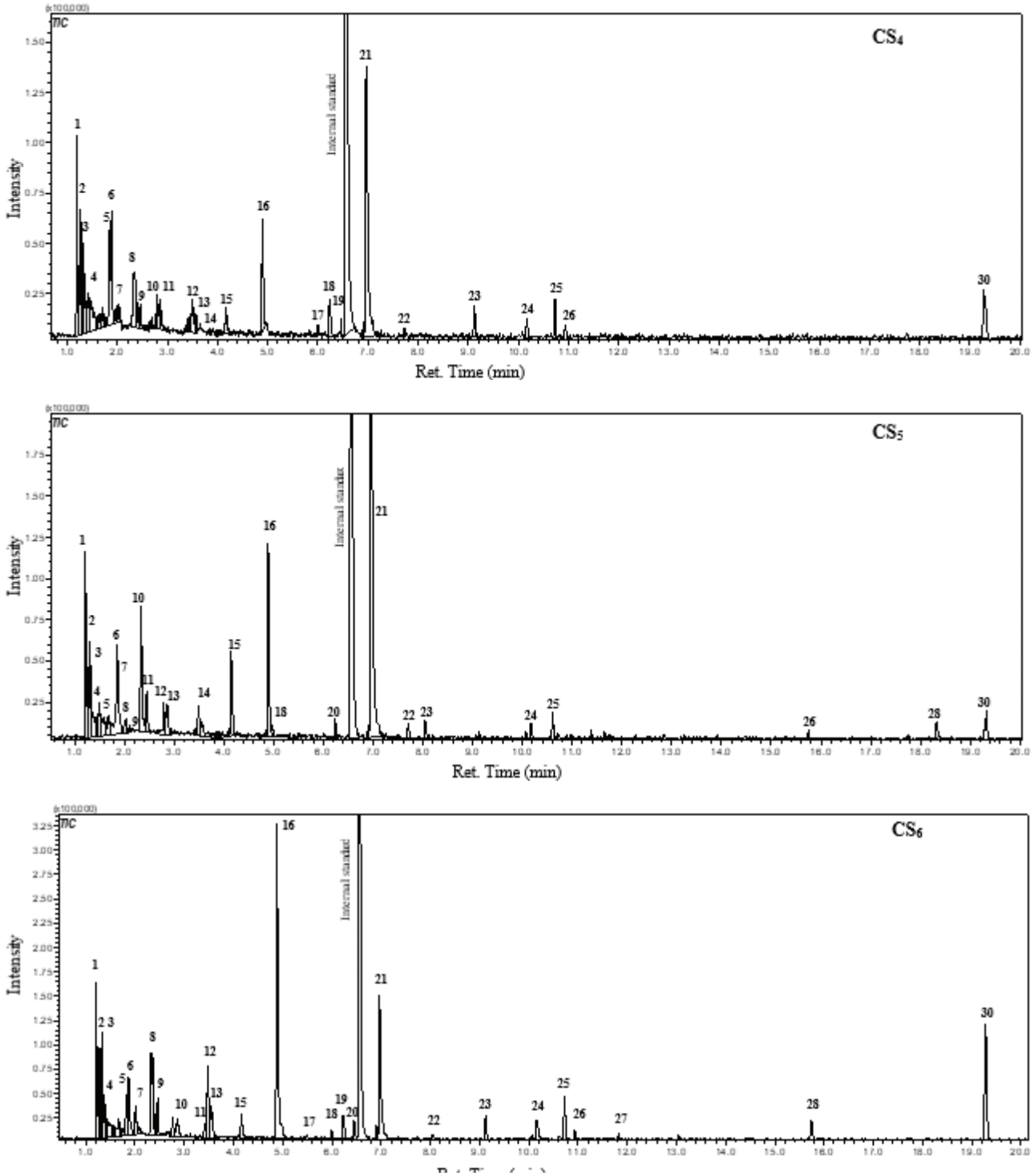

FIGURE 3 **(continued). GC-MS chromatograms of volatile compounds of *Cephalaria syriaca* seeds.**
1: Methane, tetranitro-; 2: Acetaldehyde; 3: Ethanol; 4: 2 propane; 5: Propanal, 2-methyl-; 6: Butanal, 2-methyl-; 7: Acetic acid, ethyl ester; 8: Butanal, 3-methyl-; 9: Butanal, 2-methyl-; 10: Silanediol, dimethyl-; 11: Pentanal; 12: 1-Butanol, 3-Methyl-; 13: 1-Butanol, 2-methyl-; 14: 2-Butenal, 2-methyl-; 15: 1-Pentanol; 16: Hexanal; 17: 1-Pentanol, 4-methyl-; 18: 1-Pentanol, 3-methyl-; 19: 2-Hexenal; 20: 2-Hexen-1-ol; 21: Hexanol; 22: Acetone; 23: alpha.-Thujene; 24: Benzaldehyde; 25: beta.-Pinene; 26: 1-Octen-3-ol; 27: Benzenemethanol; 28: Nonanal; 29: Isopinocarveol; 30: Myrtenol. *Cephalaria syriaca* L. samples according to locations; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

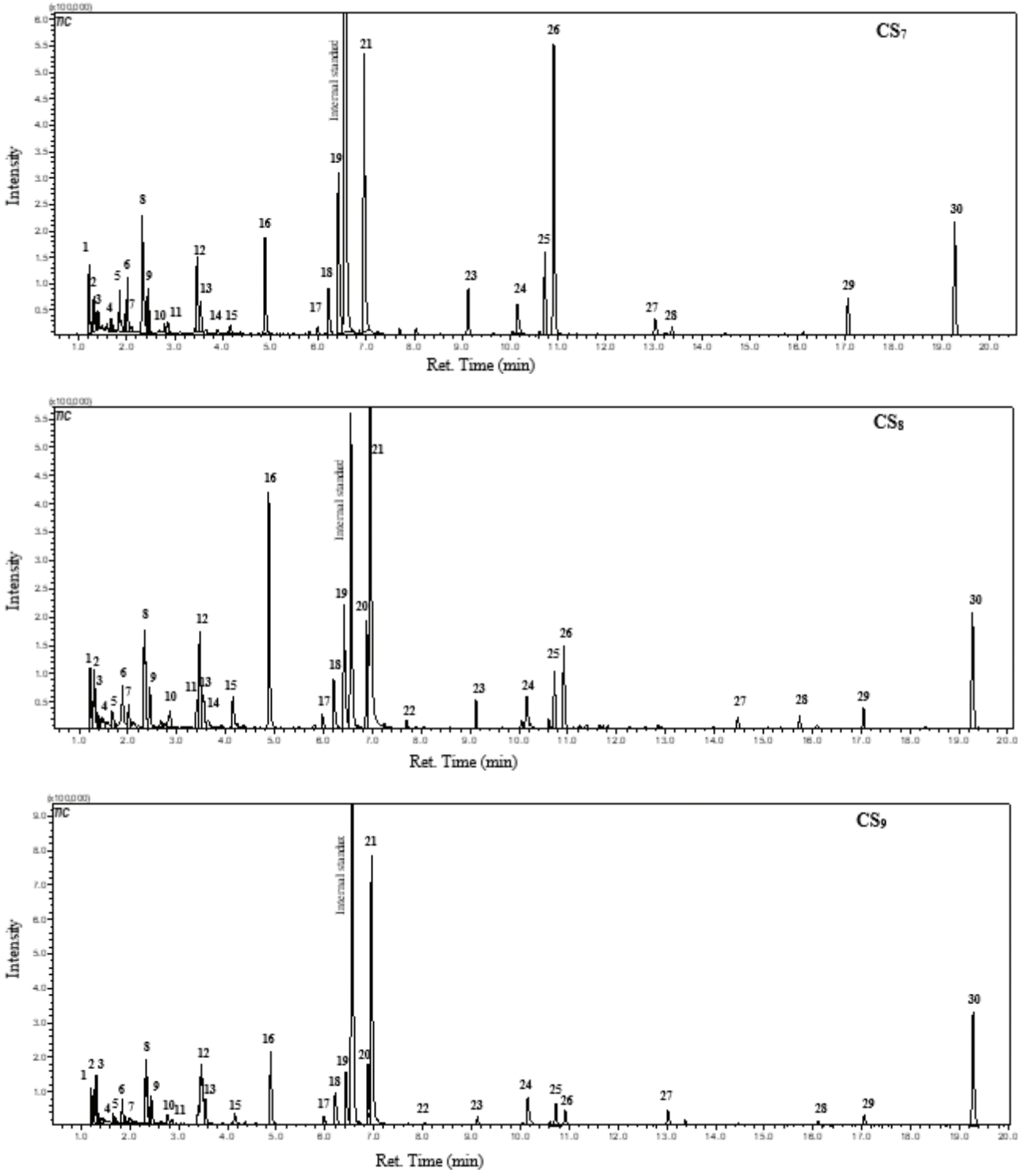

FIGURE 3 **(continued). GC-MS chromatograms of volatile compounds of *Cephalaria syriaca* seeds.**
1: Methane, tetranitro-; 2: Acetaldehyde; 3: Ethanol; 4: 2 propane; 5: Propanal, 2-methyl-; 6: Butanal, 2-methyl-; 7: Acetic acid, ethyl ester; 8: Butanal, 3-methyl-; 9: Butanal, 2-methyl-; 10: Silanediol, dimethyl-; 11: Pentanal; 12: 1-Butanol, 3-Methyl-; 13: 1-Butanol, 2-methyl-; 14: 2-Butenal, 2-methyl-; 15: 1-Pentanol; 16: Hexanal; 17: 1-Pentanol, 4-methyl-; 18: 1-Pentanol, 3-methyl-; 19: 2-Hexenal; 20: 2-Hexen-1-ol; 21: Hexanol; 22: Acetone; 23: alpha.-Thujene; 24: Benzaldehyde; 25: beta.-Pinene; 26: 1-Octen-3-ol; 27: Benzenemethanol; 28: Nonanal; 29: Isopinocarveol; 30: Myrtenol. *Cephalaria syriaca* L. samples according to locations; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

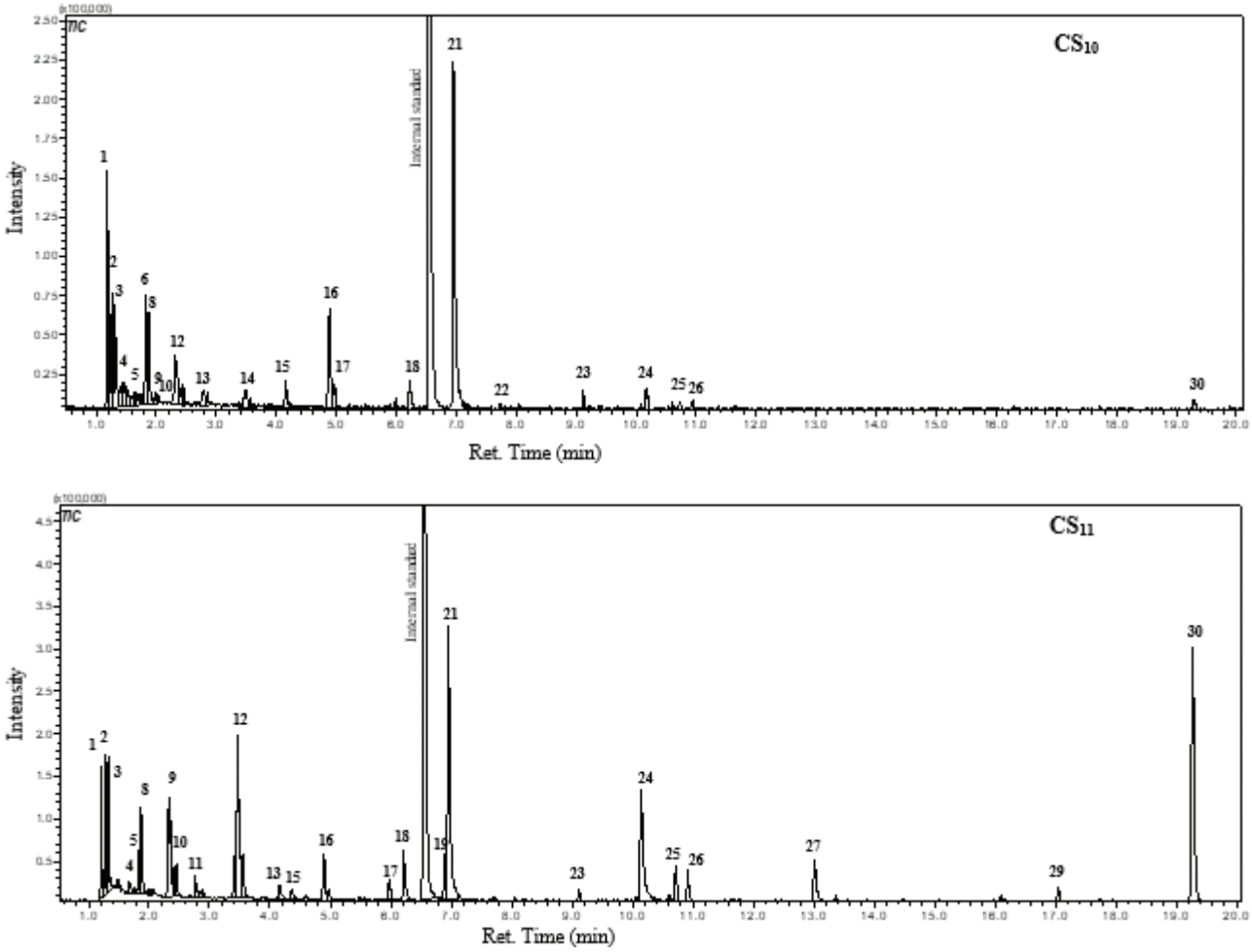

FIGURE 3 **(continued). GC-MS chromatograms of volatile compounds of *Cephalaria syriaca* seeds.**
1: Methane, tetranitro-; 2: Acetaldehyde; 3: Ethanol; 4: 2 propane; 5: Propanal, 2-methyl-; 6: Butanal, 2-methyl-; 7: Acetic acid, ethyl ester; 8: Butanal, 3-methyl-; 9: Butanal, 2-methyl-; 10: Silanediol, dimethyl-; 11: Pentanal; 12: 1-Butanol, 3-Methyl-; 13: 1-Butanol, 2-methyl-; 14: 2-Butenal, 2-methyl-; 15: 1-Pentanol; 16: Hexanal; 17: 1-Pentanol, 4-methyl-; 18: 1-Pentanol, 3-methyl-; 19: 2-Hexenal; 20: 2-Hexen-1-ol; 21: Hexanol; 22: Acetone; 23: alpha.-Thujene; 24: Benzaldehyde; 25: beta.-Pinene; 26: 1-Octen-3-ol; 27: Benzenemethanol; 28: Nonanal; 29: Isopinocarveol; 30: Myrtenol. *Cephalaria syriaca* L. samples according to locations; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

classified as the indication of a low level of oxidation; while PV between 5 and 10 meqO_2/kg is classified as moderate oxidation and PV in the range of 10-20 meqO_2/kg is classified as having a high level of oxidation. In this study, all the samples, except for CS_5 and CS_8, can be considered to not exceed the level of low oxidation as those samples were high in UFA compared to other samples.

FFA were found in the range of 0.27-0.83 (as % oleic acid) except for CS_5. In the case of CS_5, this value was determined to be 2.38. In the literature, there was no study investigating the FFA or PV of CS seed oil. CS seed oils were found to contain α-tocopherol between 54 and 467 mg/kg; whereas other tocopherol analogs were not found (Table 6). The highest α-tocopherol was detected in CS_6 (467 mg/kg); whereas the lowest was found in CS_7 (54 mg/kg). The range of α-tocopherols in our study is much higher than that in the refined oils of corn (3.11-4.46 mg/kg), soybean (1.19-1.42 mg/kg), sunflower (9.52-11.4 mg/kg) and canola (3.82-4.95 mg/kg) (Castelo-Branco *et al.*, 2016). Compared with other common vegetable oils, CS seed oil can be considered a good source of α-tocopherol. The differences in the contents of α-tocopherol in the CS seed oils under study may be due to differences in cultivar, variety and origin of the investigated CS seeds. According to the literature, there was no study investigating the α-tocopherol content of CS seed oil.

3.6. Color parameters of CS seed oils

The color characteristics of foods are important and greatly affect consumer preference (Faustman and Cassens, 1990). The L*, a* and b*

TABLE 6. **Peroxide value, free fatty acid and α-tocopherol content of *Cephalaria syriaca* seed oils**

Sample	PV ($meqO_2/kg$)	FFA free fatty acid (oleic acid %)	α-tocopherol (mg/kg)
CS_1	2.64 ± 0.04^{ab}	0.28 ± 0.04^{a}	368 ± 15.13^{d}
CS_2	3.97 ± 0.13^{bc}	0.28 ± 0.01^{a}	70 ± 2.33^{ab}
CS_3	3.93 ± 1.50^{abc}	0.28 ± 0.00^{a}	395 ± 18.53^{d}
CS_4	3.86 ± 0.02^{abc}	0.27 ± 0.08^{a}	464 ± 15.77^{f}
CS_5	5.39 ± 0.67^{d}	2.38 ± 0.27^{e}	332 ± 10.75^{c}
CS_6	3.82 ± 0.11^{ab}	0.27 ± 0.06^{a}	467 ± 12.3^{f}
CS_7	3.43 ± 0.70^{ab}	0.70 ± 0.01^{cd}	54 ± 1.98^{a}
CS_8	5.30 ± 0.59^{cd}	0.83 ± 0.13^{d}	85 ± 3.04^{b}
CS_9	2.80 ± 0.02^{ab}	0.56 ± 0.16^{bc}	458 ± 12.59^{ef}
CS_{10}	2.46 ± 0.70^{a}	0.28 ± 0.07^{a}	382 ± 11.53^{d}
CS_{11}	3.91 ± 0.01^{abc}	0.42 ± 0.08^{ab}	433 ± 12.88^{e}

*Small letters indicate significant differences within each column for the mean ± SD values calculated from three determinations by one-way ANOVA and Duncan's test ($P \leq 0.05$). *Cephalaria syriaca* L. samples according to location; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

TABLE 7. **Color values of *Cephalaria syriaca* seed oils**

Sample	L*	a*	b*
CS_1	23.73 ± 0.14^{d}	-0.94 ± 0.10^{a}	10.15 ± 0.10^{de}
CS_2	23.83 ± 0.49^{de}	-1.01 ± 0.20^{a}	13.32 ± 0.74^{f}
CS_3	24.80 ± 0.28^{e}	0.02 ± 0.13^{b}	10.22 ± 0.02^{de}
CS_4	24.23 ± 0.71^{de}	0.88 ± 0.23^{c}	9.39 ± 0.07^{d}
CS_5	24.87 ± 0.12^{e}	-0.81 ± 0.01^{a}	10.60 ± 0.04^{e}
CS_6	20.23 ± 0.04^{c}	1.69 ± 0.08^{d}	7.99 ± 0.21^{c}
CS_7	18.63 ± 1.03^{a}	1.81 ± 0.02^{d}	4.73 ± 0.33^{a}
CS_8	20.13 ± 0.21^{c}	2.37 ± 0.40^{e}	8.16 ± 0.74^{c}
CS_9	18.79 ± 0.21^{ab}	2.04 ± 0.35^{de}	5.94 ± 0.27^{b}
CS_{10}	24.00 ± 0.39^{de}	0.60 ± 0.02^{c}	10.06 ± 0.19^{de}
CS_{11}	19.75 ± 0.03^{bc}	1.71 ± 0.48^{d}	6.44 ± 0.54^{b}

*Small letters indicate significant differences within each column for the mean ± SD values calculated from three determinations by one-way ANOVA and Duncan's test ($P \leq 0.05$). *Cephalaria syriaca* samples according to location; CS_1: Mardin, CS_2: Van, CS_3: Gaziantep, CS_4: Bitlis, CS_5: Erzincan, CS_6: Diyarbakir, CS_7: Agri, CS_8: Sanliurfa, CS_9: Siirt, CS_{10}: Mus, CS_{11}: Batman.

color parameters of the seed oil samples are given in Table 7. L* values significantly varied between 18.63 and 24.87 ($P < 0.05$). The highest L* value (maximum brightness) was found in CS_5 seed oil; whereas the lowest was in CS_7. a* values were found between -1.01 and 2.37 ($P < 0.05$). CS_8 had the highest redness; whereas CS_2 had the lowest. In addition, CS_1, CS_2, and CS_5 samples were on the green side of the scale. Differences between b* values were significant ($P < 0.05$). As indicated in Table 7, the b* values of the samples were in the range of 4.73-13.32. The highest b* value was in CS_2, while the lowest was detected in CS_7. Differences between these parameters were associated with location, soil and climatic conditions, probably due to geographic locations from where the plants were collected.

4. CONCLUSIONS

The results obtained in this study revealed that CS seeds were high in oil content, varying in the range of 11.2-24.0%, which seems to be a significant source of oleic and linoleic acids. Extraction yield of the oil samples varied according to location, and CS_1 and CS_{11} samples in particular are significantly different form all the other samples. It was determined that the PV and FFA levels of the oil samples were within the limits given in the standards. CS_{11}, CS_6, CS_{10} and CS_1 were found to have the highest protein contents (21% on average). It was seen that the highest levels of TPC and antioxidant capacity among the CS seeds were found in the samples CS_1, CS_7, and CS_{11}. A total of 30 different volatile compounds were identified in the samples, dominated by alcohols and aldehydes. CS

seed oils were found to contain α-tocopherol between 54 and 467 mg/kg; whereas other tocopherol analogs were not found. The results of this study showed that CS seeds can be considered as an alternative raw material for the production of edible oil. In addition, the oil can be used as a natural antioxidant and food additive for pharmacology and the food industry because of its relatively high antioxidant capacity. Further studies are needed to isolate and characterize the active compounds that are responsible from its promising antioxidant activity.

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