*Impact of harvest times on the quality characteristics of oils recovered from different safflower (*Carthamus tinctorius*) cultivars sown in spring and autumn*

Belgin Cosge Senkal, Mustafa Kiralan & Mohamed Fawzy Ramadan

European Food Research and Technology
Zeitschrift für Lebensmittel-Untersuchung und -Forschung A

ISSN 1438-2377
Volume 242
Number 3

Eur Food Res Technol (2016)
242:371-381
DOI 10.1007/s00217-015-2547-2

Springer

Eur Food Res Technol (2016) 242:371–381
DOI 10.1007/s00217-015-2547-2

ORIGINAL PAPER

Impact of harvest times on the quality characteristics of oils recovered from different safflower (*Carthamus tinctorius*) cultivars sown in spring and autumn

Belgin Cosge Senkal[1] · Mustafa Kiralan[2] · Mohamed Fawzy Ramadan[3]

Received: 12 May 2015 / Revised: 31 August 2015 / Accepted: 5 September 2015 / Published online: 12 October 2015

Abstract This study was carried out to investigate the impact of harvest time (HT) and sowing time (ST) on the oil content, fatty acid composition, physicochemical properties, antiradical potential and oxidative stability of oils recovered from different safflower cultivars. In this work, three safflower cultivars (cv. Yenice, cv. Dinçer and cv. Remzibey-05) were grown in spring and autumn and harvested at three different times (2 weeks after flowering, 4 weeks after flowering and at maturity). Examined parameters of safflower seeds and oil samples from different cultivars varied according to cultivar, ST and HT. Moisture content was higher in the seeds from autumn sowing than spring sowing. The highest oil content (25.8 %) was recorded for Dinçer cultivar. The main four fatty acids (palmitic, stearic, oleic and linoleic) accounted for about 99 % of total fatty acids. The peroxide value PV (0.72 meqO_2/kg) of oil from autumn sowing was higher than the PV (0.46 meqO_2/kg) from spring sowing. Rancimat value of seed oil from Remzibey-05 (6.38 h) cultivar was the highest followed by Yenice (5.08 h) and Dinçer (5.41 h) cultivars. The radical scavenging activity (76.8 %) of the oils from spring sowing was higher than the radical scavenging activity (73.0 %) of the oils from autumn sowing. The findings showed that the oxidative stability of oils from autumn sowing was stronger than that of oils from spring sowing. In addition, delaying HT has decreased oxidative stability of oils.

Keywords Sowing date · Fatty acid · Oil content · Oil stability · Radical scavenging activity

Introduction

The genus Carthamus from the Compositae family comprises 16 recognized species wherein safflower (*Carthamus tinctorius* L.) is the only cultivated species of this genus [1, 2]. Safflower is an annual herb that cultivated for its oil, meal and flower [3, 4]. Safflower is commercially considered as an underutilized oilseed crop, whereas the annual world production of safflower oil is low (around 140.000 tons) compared to 38 million tons of soybean oil [5, 6].

Safflower seeds of normal-hull types had an oil level of 25–37 %; but in very thin hull types, this level was increased to 46–47 % [7, 8]. The fatty acid profile of edible oil determines its commercial uses. Safflower is a crop with variable fatty acid profiles wherein standard safflower oil contains up to 8 % palmitic acid, 3 % stearic acid, 20 % oleic acid and 75 % linoleic acid. Sources of variation for very high oleic acid content (>85 %) were also reported [9–11]. Safflower oil is one of the richest sources of linoleic acid among the commercially edible oils [12]. Safflower oil from high linoleic cultivars has long been utilized for industrial applications such as preparing varnish. High-oleic safflower oil is used as frying oil, while high-linoleic oil is being used as valuable edible oil [7, 8, 12–15]. Genotype during oil formation exerts the main impact on the levels of oleic and linoleic acids [11].

✉ Mohamed Fawzy Ramadan
hassanienmohamed@yahoo.com

Belgin Cosge Senkal
bcosgesenkal@gmail.com

[1] Field Crops Department, Faculty of Agriculture and Natural Science, Bozok University, Yozgat, Turkey

[2] Department of Food Engineering, Faculty of Architecture and Engineering, Abant İzzet Baysal University, Bolu, Turkey

[3] Agricultural Biochemistry Department, Faculty of Agriculture, Zagazig University, Zagazig 44519, Egypt

Sowing time (ST) and harvest time (HT) are considered to have a great impacts on safflower oil properties and fatty acid profile. Therefore, information on how HT and ST affect fatty acid profile is quite important and optimizing HT and ST is of major importance in different areas. The ratio of oleic and linoleic acids in seed oils is dependent on environmental conditions, especially moisture and temperature, during seed maturation [16]. Yau [17] stated that later sowing of spring safflower in semiarid and high-elevation Mediterranean environment resulted in lower seed yield as later flowering does not allow to escape from the terminal drought and heat.

Turkey has favorable agricultural conditions for the cultivation of a variety of oilseeds. However, to date, limited research was done on safflower in Turkey because of its low acreage and lesser economic importance [8, 18]. Safflower has been grown for centuries in the semiarid conditions of Anatolia [3]. Information on ST and HT for safflower is limited in this region. Therefore, the goal of this investigation was to study the effects of harvest time (HT) and sowing time (ST) on the oil content, fatty acid profile, physicochemical properties, antiradical potential and oxidative stability of oil recovered from different safflower cultivars grown in Ankara (Turkey).

Materials and methods

The study was carried out at the experimental fields of Field Crops Department at Agricultural Faculty of Ankara University (32°51′E; 39°57′N; 860 m above sea level) during 2008–2009. In the experimental area, total rainfall, mean relative humidity and temperature in 2008 and 2009 were recorded to be 267.7 and 433.2 mm, 57.04 and 59.65 %, and 12.73 and 12.67 °C, respectively.

Three safflower cultivars were used including Yenice (spineless, orange colored), Dinçer (spineless, red colored) and Remzibey-05 (spiny, yellow colored). All cultivars that developed at Anatolia Agricultural Research Institute (Turkey) have become adapted well to dryland conditions of Central Anatolia. These varieties were sown in 30-cm row spacing and 3-m row length on December 5, 2008, in autumn, and April 10, 2009, in spring. The experiment was planned as four replications in completely randomized design in split plots. Intra-row spacing was stabilized at 10 cm by thinning (May 8, 2009, for autumn sowing and June 4, 2009, for spring sowing). Crop management practices such as irrigation and weed control were performed as needed during the growing season. Harvest was made by hand at three different times and with intervals of 2 weeks [2 weeks after flowering (HT-1), 4 weeks after flowering (HT-2) and at maturity (HT-3)]. First harvest time in autumn and spring sowing was on August 11, 2009, and on August 20, 2009, respectively.

Composition and characteristics of safflower seed oils

Moisture content (%) of grinded safflower seeds was determined by Precisa XM 60 moisture instrument at 105 °C. The oils recovered from different cultivars were extracted using hexane according to AOCS method Ba 3-38 [19].

Fatty acid methyl esters (FAME) were prepared according to the AOAC method [20] and analyzed by Shimadzu (Kyoto, Japan) gas chromatography equipped with DB 23 capillary column (30 m × 0.25 mm, film thickness 0.25 μm) and FID (flame ionization detector). Helium at a flow rate of 1.0 mL/min was used as a carrier gas. Injector and detector temperatures were 230 and 240 °C, respectively. Column temperature was kept at 190 °C for 30 min. A sample of 1 μL was injected by the autosampler with a split mode (split ratio of 1:80). The fatty acid identification was based on the comparison of their relative retention times with the corresponding fatty acid methyl ester standards. Individual reference methyl ester standards (myristic acid ($C_{14:0}$), palmitic acid ($C_{16:0}$), stearic acid ($C_{18:0}$), oleic acid ($C_{18:1}$), linoleic acid ($C_{18:2}$), arachidic acid ($C_{20:0}$), gadoleic acid ($C_{20:1}$), behenic acid ($C_{22:0}$) and lignoceric acid ($C_{24:0}$)) as well as FAME mix (37 components, FAME mix, Sigma-Aldrich GmbH, Steinheim, Germany) were used for identification.

Free fatty acid (as percent oleic acid) and peroxide value (PV) were determined according to AOCS methods Ca 5a-40 and Cd 8-53 [19], respectively. Oxidative stability of the oil samples was measured by Rancimat method at 110 °C using an automated Metrohm Rancimat apparatus (Model 743, Herisau, Switzerland). Rancimat value was determined according to AOCS Official Method Cd 12b-92 [19]. Refractive index (RI) was measured at 20 °C, using a refractometer. The absorbance values were measured in UV region at 232 and 270 nm. The results are expressed as the specific absorbance values K_{232} and K_{270} as described by AOCS [19].

DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging capacity of safflower oil samples was determined according to the method of Kalantzakis et al. [21]. The reaction was initiated by mixing 1 mL of the oil, previously diluted with ethyl acetate (1:10 w/w), with 4 mL of DPPH (10^{-4} M). The reaction mixture was then shaken vigorously for 10 s in a Vortex apparatus, and the tube was maintained in the dark for 30 min, after which a steady state was reached. The absorbance of the mixture was measured at 515 nm against a blank solution. The radical scavenging activity (RSA) toward [DPPH] was expressed as the % reduction in DPPH concentration (% $[DPPH]_{red}$) by

the constituents of the oils: % $[DPPH]_{red} = 100 - (1 [DPPH]_{30}/[DPPH]_0)$, where $[DPPH]_0$ and $[DPPH]_{30}$ were the concentrations of DPPH in the control sample ($t = 0$) and in the test mixture after the 30-min reaction, respectively.

Statistical analysis

All data were subjected to analysis of variance, and differences were compared with the Duncan's multiple range test ($P < 0.05$). For statistical analysis was used the program TARIST [22].

Results

Moisture content of safflower seeds

Moisture content of safflower seeds was influenced by ST and HT, wherein the difference of moisture content among cultivars was statistically significant. Moisture content in safflower seeds (Table 1) was higher in autumn sowing (5.28 %) than in spring one (5.08 %). The highest moisture content (6.21 %) was obtained from the HT-1 of cv. Yenice sown in autumn (Table 2). For three cultivars, the first HT had the highest moisture content among harvest times.

Table 1 Effect of ST and HT on seed moisture content, seed oil content and fatty acid profile of oils of different safflower cultivars

	Varieties	Sowing time		Harvest time		
		Autumn	Spring	HT-1	HT-2	HT-3
Moisture content (%)	Yenice	5.48 a*	5.48 a	5.90 a	4.91	5.62 a
	Dinçer	4.97 c	4.97 b	5.12 c	4.88	4.91 b
	Remzibey-05	5.40 b	4.79 c	5.35 b	4.97	4.96 b
	Average	5.28 a	5.08 b	5.46 a	4.92 c	5.17 b
	$LSD_{(0.05)}$	V × ST: 0.038		V × HT: 0.152		
Oil content (%)	Yenice	25.30	23.51 b	24.24 b	25.05 a	23.93 c
	Dinçer	25.11	25.83 a	24.86 ab	23.19 b	28.37 a
	Remzibey-05	24.68	25.34 b	25.73 a	24.24 ab	25.06 b
	Average	25.03	24.89	24.94 b	24.16 c	25.78 a
	$LSD_{(0.05)}$	V × ST: 0.846		V × HT: 1.123		
$C_{16:0}$	Yenice	5.04 c	5.26 c	5.13 c	5.15 c	5.17 c
	Dinçer	5.94 a	6.19 a	6.07 a	6.01 a	6.13 a
	Remzibey-05	5.54 b	5.54 b	5.55 b	5.49 b	5.59 b
	Average	5.51 b	5.66 a	5.58 b	5.55 c	5.63 a
	$LSD_{(0.05)}$	V × ST: 0.006		V × HT: 0.009		
$C_{18:0}$	Yenice	2.03 a	2.07 a	2.04 a	2.01 a	2.10 a
	Dinçer	1.86 c	1.82 c	1.83 c	1.85 c	1.84 c
	Remzibey-05	1.98 b	1.96 b	1.96 b	1.99 b	1.95 b
	Average	1.96 a	1.95 b	1.94 c	1.95 b	1.96 a
	$LSD_{(0.05)}$	V × ST: 0.002		V × HT: 0.003		
$C_{18:1}$	Yenice	9.34 c	8.96 c	9.41 c	9.07 c	8.96 c
	Dinçer	10.27 b	10.43 b	10.96 b	9.79 b	10.29 b
	Remzibey-05	24.25 a	28.97 a	25.57 a	28.84 a	25.43 a
	Average	14.62 b	16.12 a	15.31 b	15.90 a	14.89 c
	$LSD_{(0.05)}$	V × ST: 0.009		V × HT: 0.010		
$C_{18:2}$	Yenice	82.56 a	82.70 a	82.39 a	82.75 a	82.74 a
	Dinçer	80.86 b	79.46 b	78.56 b	81.27 b	80.65 b
	Remzibey-05	67.01 c	62.29 c	65.71 c	62.42 c	65.82 c
	Average	76.81 a	74.82 b	75.55	75.48	76.40
	$LSD_{(0.05)}$	V × ST: 1.411		V × HT: 1.458		

Values followed by the same letters within column are not significantly different

* Significant at $p \leq 0.05$

Table 2 Effect of HT on seed moisture content, seed oil content and fatty acid profile of safflower oils from different cultivars

	Varieties	HT-1		HT-2		HT-3		Average
		Autumn	Spring	Autumn	Spring	Autumn	Spring	
Harvest time								
Moisture content (%)	Yenice	6.21 a*	5.60 a	4.85	4.97	5.39 a	5.86 a	5.48
	Dinçer	5.32 c	4.92 b	4.78	4.97	4.81 b	5.02 b	4.97
	Remzibey-05	5.75 b	4.95 b	4.88	5.07	5.57 a	4.35 c	5.09
	Average	5.76	5.15	4.84	5.00	5.25	5.08	
	$LSD_{(0.05)}$	V × ST × HT: 0.215						
Oil content (%)	Yenice	24.86	23.62 b	24.62 a	25.49 a	26.43 b	21.43 c	24.41
	Dinçer	24.30	25.42 a	21.72 b	24.66 ab	29.32 a	27.41 a	25.47
	Remzibey-05	24.47	26.99 a	24.88 a	23.60 b	24.69 c	25.43 b	25.01
	Average	24.54	25.34	23.74	24.58	26.81	24.75	
	$LSD_{(0.05)}$	V × ST × HT: 1.589						
$C_{16:0}$	Yenice	5.06 c	5.21 c	5.03 c	5.27 c	5.04 c	5.29 c	5.15
	Dinçer	5.92 a	6.22 a	5.91 b	6.10 a	5.99 a	6.26 a	6.07
	Remzibey-05	5.59 b	5.50 b	5.38 b	5.60 b	5.64 b	5.53 b	5.54
	Average	5.52	5.64	5.44	5.66	5.56	5.69	
	$LSD_{(0.05)}$	V × ST × HT: 0.012						
$C_{18:0}$	Yenice	2.07 a	2.02 a	1.99 a	2.03 a	2.03 a	2.17 a	2.05
	Dinçer	1.83 c	1.83 c	1.91 c	1.79 c	1.84 c	1.84 c	1.84
	Remzibey-05	1.96 b	1.96 b	1.99 b	2.00 b	1.98 b	1.91 b	1.97
	Average	1.95	1.94	1.97	1.94	1.95	1.97	
	$LSD_{(0.05)}$	V × ST × HT: 0.04						
$C_{18:1}$	Yenice	9.56 c	9.27 c	9.09 c	9.05 c	9.37 c	8.55 c	9.15
	Dinçer	11.02 b	10.91 b	9.65 b	9.93 b	10.13 b	10.46 b	10.35
	Remzibey-05	23.40 a	27.73 a	28.53 a	29.15 a	20.83 a	30.03 a	26.61
	Average	14.66	15.97	15.75	16.04	13.44	16.35	
	$LSD_{(0.05)}$	V × ST × HT: 0.015						
$C_{18:2}$	Yenice	82.29 a	82.49 a	82.87 a	82.64 a	82.52 a	82.97 a	82.63
	Dinçer	80.15 b	76.98 b	81.44 a	81.10 a	80.98 a	80.31 b	80.16
	Remzibey-05	67.85 c	63.57 c	62.84 b	61.99 b	70.33 b	61.30 c	64.65
	Average	76.76	74.35	75.72	75.24	77.94	74.86	
	$LSD_{(0.05)}$	V × ST × HT: 2.062						

Values followed by the same letters within column are not significantly different

* Significant at $p \leq 0.05$

Oil content

The differences among the oil contents of safflower cultivars were not statically significant for autumn and spring sowing, respectively. The highest oil content (25.83 %) was recorded for cv. Dinçer, followed by the other cultivars. Concerning the effect of HT, the highest oil content (25.78 %) was recorded in HT-3 followed by HT-1. The oil contents of safflower seeds from three different HT varied among cultivars, wherein the highest oil contents were recorded for HT-2 (25.05 %), HT-3 (28.37 %) and HT-1 (25.73 %), for cv. Yenice, cv. Dinçer and cv. Remzibey-05, respectively (Table 1). In V × ST × HT interaction, the highest oil content (29.32 %) was obtained from HT-3 of cv. Dinçer sown in autumn. On the other hand, the lowest oil content (21.43 %) was recorded in HT-3 of cv. Yenice sown in spring (Table 2).

Fatty acid composition

The fatty acid compositions of safflower seed oil from the different studied cultivars were various. Amounts of the main four fatty acids (namely palmitic, stearic, oleic and linoleic) constitute 98.61–99.47 % of the total FAME. Miristic ($C_{14:0}$), palmitic ($C_{16:0}$), palmitoleic ($C_{16:1}$), heptadecanoic ($C_{17:0}$), heptadecenoic ($C_{17:1}$), stearic ($C_{18:0}$), oleic ($C_{18:1}$), linoleic ($C_{18:2}$), linolenic ($C_{18:3}$), arasidic ($C_{20:0}$), gadoleic ($C_{20:1}$), behenic ($C_{22:0}$) and lignoceric ($C_{24:0}$) acids

were determined in the investigated oil samples. The value of $C_{14:0}$, $C_{16:1}$, $C_{17:0}$, $C_{18:3}$, $C_{20:0}$, $C_{20:1}$, $C_{22:0}$ and $C_{24:0}$ acids was below 1 %. The highest value of $C_{16:0}$ (6.07 %) was recorded in cv. Dinçer among cultivars. It was observed that spring sowing increased the content of $C_{16:0}$ in the seed oil. Different HT affected considerably the $C_{16:0}$ contents of the seed oils from cultivars. $C_{16:0}$ content was the highest in HT-3 for the three cultivars. $C_{16:0}$ contents of the cultivars exhibited rising tendency from the first HT to the last HT in both autumn and spring sowing (Table 1). As for V × ST × HT interaction, the highest $C_{16:0}$ content (6.26 %) was obtained from the HT-3 of cv. Dinçer sown in spring (Table 2). $C_{18:0}$ contents in the examined oils were higher in autumn sowing than that observed in spring sowing. The highest $C_{18:0}$ content (2.07 %) was recorded in cv. Yenice sown in autumn. It was observed that the cultivars responded differently to harvest times. The highest $C_{18:0}$ content in cv. Yenice and cv. Remzibey-05, and cv. Dinçer obtained from HT-3 and HT-2, respectively. $C_{18:0}$ content increased in parallel with the delayed HT, except for HT-3 of autumn sowing, in both spring and autumn sowing times (Table 1). As for V × ST × HT interaction, the highest $C_{18:0}$ content (2.17 %) was reported in HT-3 of cv. Yenice sown in spring (Table 2). The highest $C_{18:1}$ content (26.61 %) was recorded in cv. Remzibey-05 (oleic acid type) among three cultivars (Table 2). $C_{18:1}$ content of cultivars sown in spring was 1.5 % higher than in the cultivars sown in autumn (Table 1). Also, differences were observed in $C_{18:1}$ content of cultivars according to harvest times. When delaying the HT, $C_{18:1}$ content reduced in cv. Yenice. While the lowest $C_{18:1}$ content was obtained from HT-2 in cv. Dinçer, the highest $C_{18:1}$ content was obtained from HT-2 in cv. Remzibey-05. The lowest $C_{18:1}$ content (13.44 %) was obtained from HT-3 of autumn sowing. In V × ST × HT interaction, the highest $C_{18:1}$ content (30.03 %) was obtained from HT-3 of spring sowing of cv. Remzibey-05, while the lowest $C_{18:1}$ content (8.55 %) was obtained from HT-2 of spring sowing of cv. Yenice (Table 2). Mean $C_{18:2}$ contents (Table 2) of cv. Yenice, cv. Dinçer and cv. Remzibey-05 were 82.63, 80.16 and 64.65 %, respectively (Yenice and Dinçer cultivars are linoleic acid type, while cv. Remzibey-05 is oleic acid type). In investigating the effects of different harvest times on $C_{18:2}$ content, the highest $C_{18:2}$ level was obtained from HT-3. However, these differences among harvest times were not statistically significant. When examining the cultivars that harvested in different times, the highest $C_{18:2}$ level (average 82 %) was reported in HT-2 and HT-3 for cv. Yenice. The lowest values were observed in HT-2 (62.42 %) and HT-1 (65.71 %) of cv. Remzibey-05 (Table 1). V × ST × HT interaction affected greatly $C_{18:2}$ contents of the cultivars. The highest $C_{18:2}$ level (82.97 %) was obtained from HT-3 of cv. Yenice sown in spring. $C_{18:2}$ level of this cultivar increased in parallel with delay of HT in cv. Yenice sown in spring. But, $C_{18:2}$ level decreased with delay of HT in cv. Remzibey-05 sown spring. In addition, the lowest $C_{18:2}$ level (61.30 %) was recorded in HT-3 of this one (Table 2).

Free fatty acid (FFA) content

In our study, the highest FFA value (0.82 %) was recorded in cv. Yenice sown in spring followed by autumn sowing of the same cultivar (0.69 %). The lowest FFA values (0.52 and 0.57 %) were recorded in cv. Remzibey-05 and cv. Dinçer sown in autumn, respectively. Yenice cultivar had the highest FFA content among examined cultivars. The FFA values from HT-1, HT-2 and HT-3 were 0.57, 0.72 and 0.63 %, respectively. It was observed that V × HT interaction affected importantly the FFA content. The FFA contents of the oil samples are higher in HT-2 according to other HTs and the FFA values of oils from Yenice cv. are higher among cultivars. The FFA values from their spring sowings of three cultivars were higher than the FFA values from their autumn sowings in the other harvest times, except for HT-1 (Table 3). Also, the FFA content in the oil from HT-3 of cv. Yenice sown in spring was the highest (0.95 %), while the lowest FFA value (0.45 %) was obtained from HT-3 of cv. Remzibey-05 sown in autumn (Table 4).

Peroxide value (PV)

The PV (0.72 meqO_2/kg) of safflower seed oil from autumn sowing was higher than the one (0.46 meqO_2/kg) from spring sowing. As for V × ST interaction, the highest PV (0.83 meqO_2/kg) was recorded in cv. Yenice sown in autumn, followed by cv. Dinçer (0.70 meqO_2/kg) sown in autumn. The lower PV was reported in cv. Yenice and cv. Dinçer sown in spring. When investigating the differences among cultivars, the highest PV was obtained from cv. Yenice. The oils from the other cultivars had less PV than the oil from cv. Yenice. Concerning the harvest times, the highest PV was found in the seed oil from HT-3. According to V × HT, the highest PV was for the oil from HT-1 of cv. Yenice and the lowest PV was for the oil from HT-1 of cv. Dinçer (Table 3). In V × ST × HT interaction, the highest PV was obtained from seed oil of HT-1 from cv. Yenice sown in autumn, followed by seed oils of HT-2 cv. Dinçer and Remzibey-05 sown in autumn. The lowest PV was recorded in HT-2 of cv. Yenice sown in spring, followed by HT-1 of cv. Yenice and cv. Dinçer sown in spring (Table 4).

Rancimat value

The differences in the Rancimat values among cultivars were studied (Table 4), wherein the Rancimat value of seed oil from cv. Remzibey-05 (6.38 h) was higher than

Table 3 Oil characteristics and stability from different safflower cultivars as affected by ST and HT

	Varieties	Sowing time		Harvest time		
		Autumn	Spring	HT-1	HT-2	HT-3
Free fatty acid contents (%)	Yenice	0.69 a*	0.82 a	0.79 a	0.83 a	0.63 a
	Dinçer	0.57 b	0.65 b	0.55 b	0.70 b	0.58 b
	Remzibey-05	0.52 c	0.61 c	0.57 b	0.63 c	0.50 c
	Average	0.59 b	0.69 a	0.63 b	0.72 a	0.57 c
	$LSD_{(0.05)}$	V × ST: 0.023		V × HT: 0.045		
Peroxide value ($meqO_2/kg$)	Yenice	0.83 a	0.44 b	0.72 a	0.49 b	0.70 a
	Dinçer	0.70 b	0.45 b	0.46 c	0.66 a	0.60 b
	Remzibey-05	0.64 c	0.50 a	0.55 b	0.63 a	0.53 c
	Average	0.72 a	0.46 b	0.57 b	0.59 ab	0.61 a
	$LSD_{(0.05)}$	V × ST: 0.031		V × HT: 0.039		
Rancimat value	Yenice	4.97	5.19	5.21 c	4.87 c	5.18 c
	Dinçer	5.28	5.55	5.49 b	5.39 b	5.36 b
	Remzibey-05	6.23	6.60	6.35 a	6.52 a	6.26 a
	Average	5.49	5.68	5.64	5.54	5.56
	$LSD_{(0.05)}$	V × ST: 0.424		V × HT: 0.147		
Refractive index	Yenice	1.4650 c	1.4705 a	1.4673 a	1.4694 a	1.4667 c
	Dinçer	1.4671 b	1.4674 b	1.4667 b	1.4657 c	1.4693 b
	Remzibey-05	1.4706 a	1.4667 c	1.4660 c	1.4690 b	1.4709 a
	Average	1.4675 b	1.4682 a	1.4666 c	1.4680 b	1.4689 a
	$LSD_{(0.05)}$	V × ST: 0.0003		V × HT: 0.0003		
K_{232}	Yenice	2.11 c	2.55 a	2.04 a	2.72 a	2.23 c
	Dinçer	2.19 b	2.25 b	2.06 a	2.10 b	2.51 a
	Remzibey-05	2.31 a	1.91 c	1.82 b	2.11 b	2.41 b
	Average	2.20 b	2.24 a	1.97 c	2.31 b	2.38 a
	$LSD_{(0.05)}$	V × ST: 0.027		V × HT: 0.026		
K_{270}	Yenice	2.43 a	1.68 c	1.78 b	2.30 b	2.09 a
	Dinçer	2.34 b	1.77 b	1.39 c	2.79 a	1.99 b
	Remzibey-05	1.27 c	1.92 a	1.83 a	1.63 c	1.33 c
	Average	2.01 a	1.79 b	1.67 c	2.24 a	1.80 b
	$LSD_{(0.05)}$	V × ST: 0.028		V × HT: 0.028		
DPPH assay (%)	Yenice	70.30 b	77.72 a	76.59 a	71.59 b	73.85 c
	Dinçer	70.25 b	74.69 b	74.15 b	68.13 c	75.14 b
	Remzibey-05	78.47 a	78.03 a	73.79 b	79.71 a	81.25 a
	Average	73.01 b	76.82 a	74.84 b	73.14 c	76.75 a
	$LSD_{(0.05)}$	V × ST: 0.755		V × HT: 0.813		

Values followed by the same letters within column are not significantly different

* Significant at $p \leq 0.05$

the ones of the oils from cv. Yenice (5.08 h) and cv. Dinçer (5.41 h). In V × HT interaction table, the highest value (6.52 h) was obtained from HT-2 of cv. Remzibey-05, and the lowest value (4.87 h) was obtained from HT-2 of cv. Yenice (Table 3). Rancimat values obtained from autumn and spring sowings were similar (average 5.60 h). The average value from harvest times was 5.59 h (Table 4). The oil obtained from cv. Remzibey-05 was found to be more oxidatively stable than the oils obtained from the other two cultivars. The reason for that might be the high oleic acid level in the oil cv. Remzibey-05 cultivar.

Refractive index (RI)

In our study, the highest RI was recorded in the oil from cv. Remzibey-05, followed by cv. Dinçer and cv. Yenice, respectively. As for sowing times, the RI of the oils from spring sowing was higher than the one of the oils from

Table 4 Oil characteristics and stability from different safflower cultivars as affected by HT

	Varieties	HT-1		HT-2		HT-3		Average
		Autumn	Spring	Autumn	Spring	Autumn	Spring	
Harvest time								
Free fatty acid contents (%)	Yenice	0.83 a*	0.76 a	0.72 a	0.95 a	0.53 a	0.74 a	0.75
	Dinçer	0.59 b	0.50 b	0.64 b	0.76 b	0.47 ab	0.69 a	0.61
	Remzibey-05	0.58 b	0.55 b	0.53 c	0.72 b	0.45 b	0.56 b	0.56
	Average	0.67	0.60	0.63	0.81	0.48	0.66	
	$LSD_{(0.05)}$	V × ST × HT: 0.064						
Peroxide value (meq O_2/kg)	Yenice	1.06 a	0.38 b	0.69 b	0.30 c	0.75 a	0.65 a	0.64
	Dinçer	0.52 c	0.39 b	0.82 a	0.50 a	0.76 a	0.45 c	0.57
	Remzibey-05	0.59 b	0.51 a	0.82 a	0.44 b	0.52 b	0.54 b	0.57
	Average	0.72	0.43	0.77	0.41	0.68	0.54	
	$LSD_{(0.05)}$	V × ST × HT: 0.055						
Rancimat value	Yenice	4.97	5.44	4.84	4.90	5.12	5.24	5.08
	Dinçer	5.36	5.62	5.22	5.57	5.26	5.45	5.41
	Remzibey-05	6.16	6.63	6.41	6.70	6.13	6.47	6.38
	Average	5.50	5.89	5.49	5.60	5.50	5.63	
	$LSD_{(0.05)}$	----------						
Refractive index	Yenice	1.4659 b	1.4686 a	1.4627 c	1.4761 a	1.4664 c	1.4669 c	1.4678
	Dinçer	1.4651 c	1.4684 b	1.4654 b	1.4660 b	1.4707 b	1.4679 b	1.4672
	Remzibey-05	1.4660 a	1.4659 c	1.4721 a	1.4659 c	1.4736 a	1.4682 a	1.4686
	Average	1.4657	1.4676	1.4667	1.4693	1.4702	1.4677	
	$LSD_{(0.05)}$	V × ST × HT: 0.0004						
K_{232}	Yenice	1.88 c	2.20 a	2.29 b	3.15 a	2.15 c	2.30 b	2.33
	Dinçer	2.09 a	2.03 b	2.04 c	2.16 b	2.46 b	2.56 a	2.22
	Remzibey-05	2.01 b	1.62 c	2.35 a	1.87 c	2.59 a	2.24 c	2.11
	Average	1.99	1.95	2.22	2.39	2.40	2.37	
	$LSD_{(0.05)}$	V × ST × HT: 0.037						
K_{270}	Yenice	1.97 a	1.60 b	3.17 b	1.43 c	2.15 a	2.03 a	2.06
	Dinçer	1.53 b	1.25 c	3.37 a	2.22 a	2.14 a	1.85 b	2.06
	Remzibey-05	1.53 b	2.13 a	1.29 c	1.96 b	0.99 b	1.67 c	1.59
	Average	1.67	1.66	2.61	1.87	1.76	1.85	
	$LSD_{(0.05)}$	V × ST × HT: 0.040						
DPPH assay (%)	Yenice	79.38 a	73.80 a	61.49 c	81.69 b	70.02 c	77.68 b	74.01
	Dinçer	73.48 b	74.82 a	63.66 b	72.60 c	73.62 b	76.66 b	72.47
	Remzibey-05	78.95 a	68.64 b	73.90 a	85.52 a	82.57a	79.94 a	78.25
	Average	77.27	72.42	66.35	79.94	75.40	78.09	
	$LSD_{(0.05)}$	V × ST × HT: 1.149						

Values followed by the same letters within column are not significantly different

* Significant at $p \leq 0.05$

autumn sowing. The differences among the cultivars were statistically significant. The highest RI in the examined oils was obtained from HT-3. Concerning V × HT interaction, the highest and lowest values were recorded in the oils from HT-3 of cv. Remzibey-05 and 2.HT of cv. Dinçer, respectively. In ST × HT interaction table, the RI of the oils from spring sowing was higher than the oils from autumn sowing in the other harvest times, except for HT-3. As for V × ST × HT interaction, the highest RI value was recorded in the oil from HT-2 of cv. Yenice sown in spring (Tables 3, 4).

Absorbance values

The highest and lowest values of K_{232} in cultivars sown in autumn were obtained from the oils of cv. Remzibey-05

and cv. Yenice, respectively. These values in cultivars sown in spring were recorded for cv. Yenice and cv. Remzibey-05, respectively. K_{232} value of the oils from cv. Dinçer and cv. Remzibey-05 has increased in parallel with the advancement of HT. However, this value for cv. Yenice was recorded in HT-2. In HT × ST interaction, the highest and lowest values were obtained from HT-3 of autumn sowing and HT-1 of spring sowing, respectively (Table 3). According to V × ST × HT interaction, the highest K_{232} value was recorded for HT-2 of cv. Yenice sown in spring, followed by HT-3 of cv. Remzibey-05 sown in autumn and HT-2 of cv. Dinçer sown in spring. K_{270} value in the oils of safflower cultivars, in the autumn sowing, was higher than in the spring sowing. The lowest value was recorded in the oil from cv. Remzibey-05 among the three cultivars, wherein K_{270} value of the others was the same. According to V × ST interaction, the highest value was obtained from cv. Yenice sown in autumn, while the lowest value was obtained from cv. Remzibey-05 sown in autumn. In investigating the values as affected by HT, K_{270} values of cv. Yenice and cv. Dinçer increased in HT-2 (to 2.30 from 1.78, to 2.79 from 1.39, respectively), but decreased in HT-3. Also, the value of K_{270} decreased depending on delay in HT for cv. Remzibey-05. The values of K_{270} were 1.67 in HT-1, 2.61 in HT-2 and 1.76 for HT-3 in cultivars sown in autumn, and 1.66 in HT-1, 1.87 in HT-2 and 1.85 for HT-3 in cultivars sown in spring. According to data in Table 4, the highest (3.17) and the lowest (0.99) K_{270} values were recorded in HT-2 of cv. Yenice sown in autumn and HT-3 of cv. Remzibey-05 sown in autumn, respectively.

Free radical scavenging activity

The sowing times affected the antiradical activities of safflower oils, wherein the antiradical potential (76.82 %) of the oils from spring sowing was higher than the antiradical potential (73.01 %) of the oils from autumn sowing (Table 3). The antiradical activity of the oil from cv. Remzibey-05 was the highest (78.25 %) among the cultivars (Table 4). Concerning the antiradical activities of the oils in terms of V × ST interaction, the highest antiradical activity (78.47) was obtained from cv. Remzibey sown in autumn, while the lowest antiradical potential (70.25 %) was recorded in cv. Dinçer sown in autumn. In addition, the highest antioxidant potential was recorded in HT-3 (Table 3).

Discussion

Turkey has favorable agricultural conditions for the production of a wide variety of oilseeds. Generally, moisture content decreases during safflower development [8]. Similarly, Rahamatalla et al. [23] stated that when the seeds were harvested at different stages of growth and development (10, 20, 30 and 40 days after flowering), moisture content significantly decreased with time. By delaying HT, moisture content in safflower seed was reduced only in cv. Remzibey-05 (Table 2). Gecgel et al. [8] stated that ST and HT are important factors effecting moisture levels of safflower seeds. In our study, the first two harvests and the third harvest were made in August and September, respectively. In September, the temperature was lower and the rainfall and relative humidity were higher than that of August.

The oil contents of safflower cultivars are ranged from 25 to 35 % [11, 24–26]. The oil content of safflower seeds is influenced by many factors such as genotype, ecology, morphology, physiology and cultural applies (fertilization, ST and HT) [10, 27]. Previous studies indicated that safflower oil content increased significantly in the 30th day after flowering and reached a maximum value in maturity [8, 28]. The oil contents from safflower cultivars (Yenice, Dinçer and Remzibey-05) were in agreement with the literature values.

The suitability of a edible oil for a particular use is determined by its fatty acid profile which is variable depending on plant species [1]. Safflower seed oil exhibits highly variability in terms of fatty acids composition. Also, it has been reported that this variability is inherited [29–31]. Standard safflower oil contains 6–8 % $C_{16:0}$, 2–3 % $C_{18:0}$, 16–20 % $C_{18:1}$ and 71–75 % $C_{18:2}$ [31]. Safflower oil contains the unsaturated fatty acids such as linoleic acid and oleic acid and the saturated fatty acids such as stearic acid and palmitic acid. Oleic acid has good frying characteristics such as stability and a bland flavor [11], while linoleic acid reduces the cholesterol level in the blood [10]. Matthaus et al. [32] reported that fatty acid and tocopherol contents differ significantly among the safflower cultivars. Three types of tocopherols were detected in safflower oil in various levels α-tocopherol, β-tocopherol and γ-tocopherol, accounted for up to 70.93 mg/100 g, 2.16 mg/100 g and 0.45 mg/100 g oils, respectively.

Some studies conducted have shown that $C_{18:0}$ and $C_{16:0}$ contents in safflower oil can increase up to 11 and 10 %, respectively [9, 33]. The sum of $C_{16:0}$ and $C_{18:0}$ was below in safflower comprising high oleic and linoleic acids as reported by Velasco and Fernández-Martínez [31]. $C_{16:0}$, $C_{18:0}$, $C_{18:1}$ and $C_{18:2}$ contents of cv. Dinçer were recorded as 7.03 % and 6.76, 2.49 and 2.50 %, 14.3 and 12.3 %, and 75.6 and 76.9 % by Yeilaghi et al. [12] and Aydeniz et al. [34], respectively. Temperature during growing season has great impact on the fatty acid composition of safflower oil [35]. The oils from seeds grown under higher temperatures had lower $C_{18:2}$ and higher $C_{18:1}$ [36]. In addition, the quality of safflower seed varies according to oil content, fatty acid composition, genotype, location, climatic conditions

and applied cultural practices [7, 37]. Levels of $C_{16:0}$, $C_{18:0}$, $C_{18:1}$ and $C_{18:2}$ acids were affected by ST and HT. Also, there was an inverse relationship between the development of $C_{18:1}$ and $C_{18:2}$ acids [8]. Similar findings were recorded in our study.

As the main physicochemical characteristics of the safflower oil, RI of 1.473–1.476, free acidity of 0.15–0.60 %, saponification value of 186–194 mg KOH/g oil, iodine value of 141–147 g/100 g oil, unsaponifiable matter of 0.3–0.6 %, PV of 0–1.0 $meqO_2$/kg oil, moisture and volatile matter content of 0.03–0.1 % have been reported [34]. Rahamatalla et al. [28] stated that the FFA of safflower oils ranged from 0.16 to 0.24 %, and this value in the oil from cv. Dinçer was 0.47 % as recorded by Aydeniz et al. [34]. Generally, levels of FFA are 1–2 % in crude safflower oils [38]. On the other hand, FFA content of oils is influenced by several factors such as quality of seeds and oil processing technique. In this study, the FFA levels of the safflower oils, recorded below 1 %, are in agreement with those findings (Tables 3, 4).

Peroxide number is a test applied to determine deterioration in oils upon oxidation [14]. The PV for the safflower oil samples recorded to be 4.58 $meqO_2$/kg by Ben Moumen et al. [39], 4.00–4.30 $meqO_2$/kg by Rahamatalla et al. [28], 2.27 $meqO_2$/kg by Rafiquzzaman et al. [40], 6.44 $meqO_2$/kg by Hernández [41] and 3.81 $meqO_2$/kg by Aydeniz et al. [34]. The results of the present study are lower than these findings. Ben Moumen et al. [39] stated that the extraction method used to obtain the oil from safflower seeds affected the PV of the oil. According to CODEX-STAN 210-1999, maximum permissible level of PV for safflower oil is 10 $meqO_2$/kg. The PV from safflower oil samples in our study was lower than this level.

The oxidative stability of safflower oils was determined with the Rancimat test. According to the results of Rancimat test, Vosoughkia et al. [42] stated that the stability of the investigated safflower oils varied from 3.41 to 3.83 h. In our study, 4.84 h was the minimum Rancimat value recorded, while maximum value was 6.47 h. As known, while the level of unsaturated fatty acids is increasing, oxidative stability of the oil is decreasing [43]. The oil recovered from cv. Yenice and cv. Dinçer cultivars has higher linoleic acid content; therefore, the oxidative degradation of these oils was faster than the oil recovered of cv. Remzibey-05 cultivar.

Refractive index value of standard safflower oil ranges from 1.467 to 1.470 [44]. Rahamatalla et al. [28] reported that the RI values of the oils from the seeds of four safflower cultivars collected at different times (10, 20, 30 and 40 days) after flowering varied from 1.467 to 1.472. The RI values obtained from our study are in agreement with the literature data [34, 45].

K_{232} and K_{270} are parameters which measure the oxidation of the oils. Primary and secondary oxidation products are absorbed at 232 and 270 nm, respectively [46]. In our study, K_{232} value recorded 2.20 and 2.24 in autumn and spring sowings, respectively (Table 2). The oilseed crops are potential sources of antioxidants. There are several methods for determination of antioxidant properties of plant materials [47, 48]. The free radical scavenging capacity in the oil seed crops is determined using DPPH assay in many studies [49, 50]. According to the results of the present study, the oils from all safflower cultivars (especially cv. Remzibey-05) exhibited strong radical scavenging activity.

In conclusion, the examined parameters in seed and oil samples of three safflower cultivars varied according to cultivar, sowing and harvest time. The findings showed that oxidative stability of oils from autumn sowing was stronger than that of oils from spring sowing. Also, delaying harvest time has decreased oxidative stability of oils.

Acknowledgments The authors acknowledge the Scientific and Technological Research Council of Turkey (TUBITAK) for supporting this study (Project No: TOVAG 108 O 855).

Compliance with ethical standards

Conflict of interest None.

Compliance with Ethics Requirements This article does not contain any studies with human or animal subjects.

References

1. Sabzalian MR, Saeidi G, Mirlohi A (2008) Oil content and fatty acid composition in seeds of three safflower species. J Am Oil Chem Soc 85:717–721
2. Cazzato E, Laudadio V, Corleto A, Tufarelli V (2011) Effects of harvest date, wilting and inoculation on yield and forage quality of ensiling safflower (*Carthamus tinctorius* L.) biomass. J Sci Food Agric 91:2298–2302
3. Isigigur A, Karaosmanoglu F, Aksoy HA (1995) Characteristics of safflower seed oils of Turkish origin. J Am Oil Chem Soc 72:1223–1225
4. Ragni M, Tufarelli V, Pinto F, Giannico F, Laudadio V, Vicenti A, Colonna MA (2015) Effect of dietary safflower cake (*Carthamus tinctorius* L.) on growth performances, carcass composition and meat quality traits in garganica breed kids. Pak J Zool 47:193–199
5. FAOSTAT (2012) Statistical database of the Food and Agriculture Organization (FAO) of the United Nations. http://faostat.fao.org/
6. Fernández-Cuesta A, Velasco L, Ruiz-Méndez MV (2014) Novel safflower oil with high γ-tocopherol content has a high oxidative stability. Eur J Lipid Sci Technol 116:832–836
7. Nagaraj G (1993) Safflower seed composition and oil quality review. In: Proceedings of the III international safflower conference, 14–18 June 1993, Beijing, China, pp 58–71
8. Gecgel U, Demirci M, Esendal E, Tasan M (2007) Fatty acid composition of the oil from developing seeds of different

varieties of safflower (*Carthamus tinctorius* L.). J Am Oil Chem Soc 84:47–54
9. Fernández-Martínez J, Rio M, Haro A (1993) Survey of safflower (*Carthamus tinctorius* L.) germplasm for variants in fatty acid composition and other seed characters. Euphytica 69:115–122
10. Cosge B, Gurbuz B, Kiralan M (2007) Oil content and fatty acid composition of some safflower (*Carthamus tinctorius* L.) varieties sown in spring and winter. Int J Nat Eng Sci 1:11–15
11. Ashrafi E, Razmjoo K (2010) Effect of irrigation on oil content and composition of safflower (*Carthamus tinctorius* L.) cultivars. J Am Oil Chem Soc 87:499–506
12. Yeilaghi H, Arzani A, Ghaderian M, Fotpvat R, Feizi M, Pourdad SS (2012) Effect of salinity of seed oil content and fatty acid composition of safflower (*Carthamus tinctorius* L.) genotypes. Food Chem 130:618–625
13. Pavlov DC, Todorov NA (1996) Safflower (*Carthamus tinctorius* L.). In: Nwokolo E, Smartt J (eds) Food and feed from legumes and oilseeds. Chapman and Hall, London, pp 245–257
14. Nas S, Gökalp YH, Ünsal M (2001) Bitkisel Yağ Teknolojisi. Pamukkale Üniversitesi Mimarlık Fakültesi Matbaası, Turkey
15. Bowles VG, Mayerhofer R, Davis C, Good AG, Hall JC (2010) A phylogenetic investigation of Carthamus combining sequence and microsatellite data. Plant Syst Evol 287:85–97
16. Lajara JR, Diaz U, Diaz Q (1990) Definite influence of localization and climatic conditions on fatty acid composition of sunflower seed oil. J Am Oil Chem Soc 67:618–623
17. Yau SK (2006) Winter versus spring sowing of rain-fed safflower in a semiarid, high elevation mediterranean environment. Eur J Agron 26:249–256
18. Esendal E (2001) Safflower production and research in Turkey. In: Bergman JW, Mündel HH (eds) Proceedings of the Vth international safflower conference. Williston, North Dakota and Sidney, Montana, USA, pp 203–206
19. AOCS (2005) Official methods and recommended practices of the American oil chemists' society, 5th Ed. (Methods Ba 3-38, Ca 5a-40, Cd8-53 and Cd 12b-92). American Oil Chemists' Society Press, Champaign
20. AOAC (1990) Official methods of analysis of the association of official analytical chemists. In: Helrich K (ed) Oils and fats, 15th edn. Association of Official Analytical Chemists, Inc., Virginia, pp 963–964
21. Kalantzakis G, Blekas G, Pegklidou K, Boskou D (2006) Stability and radical-scavenging activity of heated olive oil and other vegetable oils. Eur J Lipid Sci Technol 108:329–335
22. Acikgoz N, Ilker E, Gokcol A (2004) Biyolojik araştırmaların bilgisayarda değerlendirilmeleri. University of Aegen, Bornova
23. Rahamatalla AB, Babiker EE, Krishna AG, El Tinay AH (1998) Changes in chemical composition, minerals and amino acids during seed growth and development of four safflower cultivars. Plant Foods Hum Nutr 52:161–170
24. Arslan B (2007) The determination of oil content and fatty acid compositions of domestic and exotic safflower (*Carthamus tinctorius* L.) genotypes and their interactions. Agron J 6:415–420
25. Camas N, Ayan AK, Cırak C (2005) Relationships between seed yield and some characters of safflower (*Carthamus tinctorius* L.) cultivars grown in the middle black sea conditions. In: Proceedings of VI international safflowers conference, 6–10 June 2005, Istanbul, Turkey, pp 193–198
26. Gecgel U, Demirci M, Esendal E, Tasan M (2005) Effects of sowing dates on some physical, chemical and oxidative properties of different varieties of safflower (*Carthamus tinctorius* L.). In: Proceedings of VI international safflowers conference, 6–10 June 2005, Istanbul, Turkey
27. Dajue L, Mingde Z, Ramanatha-Rao V (1993) Characterization and evaluation of safflower germplasm. Geological Publishing House, Beijing
28. Rahamatalla AB, Babiker EE, Krishna AG, El Tinay AH (2001) Changes in fatty acids composition during seed growth and physicochemical characteristics of oil extracted from four safflower cultivars. Plant Foods Hum Nutr 56:385–395
29. Knowles PF (1989) Safflower in oil crops of the world. In: Downey RK, Ashri A (eds) Robbelen G. Mcgraw Hill Publishing Co., New York, pp 365–374
30. Nagaraj G, Devi GN, Surivas CVS (2001) Safflower petals and their chemical composition. In: Proceedings of V international safflowers conference, 23–27 July 2001, USA
31. Velasco L, Fernandez-Martinez JM (2001) Breeding for oil quality in safflower. In: Bergman JW, Mündel HH (eds) Proceedings of V international safflowers conference, 23–270 July 2001, Williston, North Dakota and Sidney, Montana, USA, pp 133–137
32. Matthaus B, Özcan MM, Al Juhaimi FY (2015) Fatty acid composition and tocopherol profiles of safflower (*Carthamus tinctorius* L.) seed oils. Nat Prod Res 2:193–196
33. Johnson RC, Bergman JW, Flynn CR (1999) Oil and meal characteristics of core and non-core safflower accessions from the USDA collection. Genet Resour Crop Evol 46:611–618
34. Aydeniz B, Guneser O, Yılmaz E (2014) Physico-chemical, sensory and aromatic properties of cold press produced safflower oil. J Am Oil Chem Soc 91:99–110
35. Samanci B, Ozkaynak E (2003) Effect of planting date on seed yield, oil content and fatty acid composition of safflower (*Carthamus tinctorius* L.) cultivars grown in the Mediterranean Region of Turkey. J Agron Crop Sci 189:359–366
36. Bellaloui N, Smith JR, Ray JD, Gillen AM (2009) Effect of maturity on seed composition in the early soybean production system as measured on nearisogenic soybean lines. Crop Sci 49:608–620
37. Bayrak A (1997) Ankara ve Şanlıurfa'da denenen yazlık kışlık aspir (*Carthamus tinctorius* L.) çeşit ve hatlarının yağ asitleri bileşiminin araştırılması. Gıda Teknolojisi Derneği (GTD) Dergisi 4:269–277
38. Aghamohammadreza M, Mirhadi MJ, Delkhosh B, Omidi A (2013) Evaluation of native and exotic safflower (*Carthamus tinctorius* L.) genotypes for some important agronomic traits and fatty acid composition. Ann Biol Res 4:200–204
39. Ben Moumen A, Mansouri F, Zraibi L, Abid M, Nabloussi A, Fauconnier ML, Sindic M, El Amrani A, Caid HS (2013) Comparative study of four safflower oils (*Carthamus tinctorius* L.) varieties grown in eastern of Morocco. In: Inside food symposium, Leuven, Belgium
40. Rafiquzzaman M, Altaf Hossain M, Moynul Hasan AJM (2006) Studies on the characterization and glyceride composition of safflower (*Carthamus tinctorius*) seed oil. Bangladesh J Sci Ind Res 41:235–238
41. Hernández PBN (2013) Volatile aroma components of cold pressed virgin oils from several Venezuelan seeds. Res Rev J Food Dairy Technol 1:13–17
42. Vosoughkia M, Ghavamib M, Gharachorloo M, Mohammad S, Omidi AH (2011) Composition and oxidative stability of oils in safflower (*Carthamus Tinctorius* L.) seed varieties grown in Iran. Adv Environ Biol 5:897–902
43. Purdy RM (1985) Oxidative stability of high oleic sunflower and safflower oils. J Am Oil Chem Soc 62:523–525
44. FAO (2013) Food agriculture and organization. Codex alimentarius international food standards. Standard for named vegetable oils. Codex Stan 210-1999
45. Vasishtha AK, Bajpai M, Singh C (1994) Variation in the characteristics and oil composition in different genetic varieties of safflower. Oil Technol Assoc India 26:59–63
46. Kiralan M, Bayrak A (2013) Oxidative and antiradical stabilities of two important virgin olive oils from Ayvalik and Memecik olive cultivars in Turkey. Int J Food Prop 16:649–657

47. Ou B, Huang D, Hampsch-Woodill M, Flanagan JA, Deemer EK (2002) Analysis of antioxidant activities of common vegetables employing oxygen radical absorbance capacity (ORAC) and ferric reducing antioxidant power (FRAP) assay: a comparative study. J Agric Food Chem 50:3122–3128
48. Ismail M, Mariod A, Bagalkotar G, Sy Ling H (2010) Fatty acid composition and antioxidant activity of oils from two cultivars of cantaloupe extracted by supercritical fluid extraction. Grasas Aceites 61:37–44. doi:10.3989/gya.053909
49. Gómez-Alonso S, Fregapane G, Salvador MD, Gordon MH (2003) Changes in phenolic composition and antioxidant activity of virgin olive oil during frying. J Agric Food Chem 51:667–672
50. Žilić S, Maksimović Dragišić J, Maksimović V, Maksimović M, Basić Z, Crevar M, Stanković G (2010) The Content of antioxidants in sunflower seed and kernel. Helia 52:75–84