Oil Content and Fatty Acid Composition of Some Safflower (*Carthamus tinctorius* L.) Varieties Sown in Spring and Winter

Belgin COŞGE[1] Bilal GÜRBÜZ*[1] Mustafa KIRALAN[2]

[1] University of Ankara, Faculty of Agriculture, Department of Field Crops, Diskapi-Ankara, TURKEY
[2] University of Ankara, Faculty of Agriculture, Department of Food Engineering, Diskapi-Ankara, TURKEY

* Corresponding Author
e-mail: gurbuz@agri.ankara.edu.tr

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Abstract

Oil content and fatty acid composition were examined for Yenice (spineless), Dinçer (spineless) and Remzibey-05 (spiny) safflower varieties planted winter and spring seasons in 2004-2005. Oil content was affected by sowing time and variety. Oil content in three varieties ranged from 24.53 % to 28.47 % in winter sowing and from 21.23 % to 25.76 % in spring sowing. A significant sowing time x variety interaction for oil content was not observed. The sowing time x variety interaction was not significant for all fatty acids examined. Only the stearic acid among major fatty acids (palmitic, stearic oleic, and linoleic acids) and the linolenic acid were influenced ($P<0.01$ and $P<0.05$, respectively) by sowing time. The stearic acid content in varieties increased with the ratio of 0.18 % in winter sowing time. The linolenic acid was higher of 0.02 % in spring sowing. It was recorded that there was a negative correlation between the palmitic and the stearic acids in winter ($r= -0.063$) and spring ($r= -0.806$, $P<0.01$) sowings. Also, there was an inverse relationship ($r= - 0.999$, $P<0.01$) between the oleic and linoleic acids in both all varieties and two sowing times. The results of the study have been demonstrated the sowing time and variety may have an important effect on oil quality and content of safflower seed. Therefore, winter sowing time may be recommended in Ankara conditions.

Key words: Sowing time, safflower variety, Ankara conditions, fatty acids, oil content.

INTRODUCTION

Safflower (*Carthamus tinctorius* L., Asteraceae) an annual oilseed crop has been cultivated on small plots in the world. Today, Turkey imports about 50 % of vegetable oil consumed, safflower is one of the alternative oil crops, particularly in dry land due to tolerance to cold, drought and salinity stress. Since it is resistant to drought, it could be grown successfully on dry lands of Central Anatolia and surrounding regions which have insufficient precipitation such as Ankara, Eskişehir, Konya and Çankırı provinces.

According to hull types of seeds, the seed oil content ranges from 20 % to 45 %. The oil is high in linoleic acid, an unsaturated fatty acid that aids in lowering the cholesterol level in the blood. In addition, this oil is used in soft margarines and as salad oil besides being used raw for edible purposes [1]. Because of rapid drying, the oil is in high demand in paint and emulsion industries [2].

Safflower has spiny and spineless varieties. Spiny varieties have spines on the leaves and the modified leaves associated with flower heads. Generally, varieties with reduced or absent spines have been lower in oil content than spiny types. Safflower oil quality is high due to its fatty acids composition [3]. As known, the fatty acid composition of vegetable oil is a main factor affecting on its commercial uses. Standard safflower oil contains about 6-8 % palmitic acid, 2-3 % stearic acid, 16-20 % oleic acid, and 71-75 % linoleic acid [4]. In addition, very low levels of miristic (0.24 %) and behenic (0.43 %) acids were recorded in its oil [5]. High oleic safflower oil contents over 85 % oleic acid [6,7].

Oil content and fatty acid synthesis of crops are influenced by a lot of factors such as genotype, ecology, morphology, physiology and management (timeliness of field operations, variety, plant density, fertilization etc.) [5].Safflower oil can show differences in response to sowing time which can be a major factor that affects both oil quality and fatty acid composition. For example, the cooler growing temperatures reduce stearic and oleic acids while linoleic acid [8]. Therefore, determination of optimum sowing time is likely to be of critical importance.

In the recent years, due to inadequate support by Ministry of Agriculture, low yield and lack of research about adaptability of new cultivars, improvement and cultivation techniques, and safflower production has been limited in Turkey.

The objective of this study was to evaluate the effects of spring and winter sowing times on oil content and fatty acid composition of three safflower varieties (a spiny type and two spineless types).

MATERIALS AND METHODS

Field experiments were conducted 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) in 2004-2005. The characteristics of experimental area were as follows: clay and loam, pH 7.96, lime 4.91 %, clay 40.40 %, sand 28.54 %, silt 31.02 %, organic matter 1.12 %, total nitrogen 0.113 %, phosphor 16.66 ppm and, potassium 405 ppm. Temperature, rainfall, and relative humidity during the crop cycle, and total and mean values of these meteorological data for two sowing times are presented in Table 1.

Table 1. Time course of some climatic parameters in two experimental years

Years	Months	Average temperature (°C)	Relative humidity (%)	Rainfall (mm)
2004	November	7.2	66.8	35.2
	December	2.3	72.8	8.7
2005	January	3.5	69.4	19.3
	February	2.5	67.0	27.4
	March	6.1	65.0	67.6
	April	11.6	58.9	78.6
	May	16.6	58.3	86.7
	June	19.5	54.7	37.1
	July	25.0	51.1	11.9
	August	25.4	51.7	0.1

Three safflower varieties were used as the study material such as Yenice (spineless, orange colored), Dinçer (spineless, red colored) and Remzibey-05 (spiny, yellow colored). All varieties which developed at Anatolia Agricultural Research Institute in Turkey have become adapted well to dry land conditions of Central Anatolia. They were sown on 19 November 2004 and 20 May 2005, with 30 cm row spacing. Intra row spacing was stabilized at 10 cm (average 130 plants/m^2) by thinning (17 May 2005 for winter sowing -6 July 2005 for spring sowing). Irrigation was applied only on 1 July 2005 in all trial area. Weed control was made by manual weeding in the inter row and in the row. Harvest was made by hand on 31 August 2005. Twenty plants per plot were selected as randomly and were harvested separately. Seeds obtained from these plants were used for analysis.

Lipid Extraction

The seeds were finely grounded and the oil was extracted with n-hexane in a Soxhlet extractor for 5 h. Recovered crude oils were taken to dryness on a rotator at 35 °C. After determination of the oil yield (in the dry matter), Fatty acids were esterified as methyl esters [9] and analysed by Thermo Quest Trace 2000 GC with equipped with DB-23 capillary column (30 m x 0.25 µm) and FID dedector. Helium was used as carrier gas at a flow rate of 1 mL/min. Injector and dedector temperature were 230 and 240 °C, respectively. Column temperature was kept at 200 °C for 30 min. Samples of 0.5 µL was injected by hand and in the split mode (1:80). FAMEs were identified by comparison of their retention times with those of the reference standards. The content (percentage by weight) of fatty acids was calculated from their corresponding integration data.

Experimental Design and Statistical Analysis

The experiment was carried out using a randomized complete block design with three replications. The experimental plots consisted of five rows; each was 5 m long and 0.3 m with. Data collected were subjected to analysis of variance using Tarist statistical program, and differences between means were compared by the LSD test using the same program [10].

RESULTS

Oil content

Oil content was influenced ($P<0.05$) by sowing time and variety (Table 2). A significant sowing time x variety interaction for oil content was not observed. It was determined that oil content increased average 3.50 % in winter sowing. While the lowest increasing ratio (2.71 %) was recorded in Remzibey-05 a spiny variety and having the highest oil content, the highest increasing ratio (4.49 %) was obtained in Dinçer variety, followed by Yenice (3.30 %). variety. In other words, oil content of Remzibey -05 variety affected slightly by sowing time. Oil ratio ranged from 24.53 % to 28.47 % in winter sowing and from 21.23 % to 25.76 % in spring sowing (Table 2).

Fatty acid composition

The $C_{16:0}$, $C_{18:0}$, $C_{18:1}$, and $C_{18:2}$ acids were the principal fatty acids for all sunflower varieties analyzed. The values of $C_{14:0}$, $C_{16:1}$, $C_{18:3}$, $C_{20:0}$, and $C_{20:1}$ did not exceed 1 % (Table 3).

Table 2. Oil content of safflower varieties (%)

Sowing time	Varieties			Mean
	Dinçer	Remzibey-05	Yenice	
Winter	26.92	28.47	24.53	26.64 a[1]
Spring	22.43	25.76	21.23	23.14 b
Mean	24.68 a	27.11 ab	22.88 b	
$LSD_{(0.05)}$	Variety: 3.284	Sowing time: 2.681		

[1] There was no statistical difference among the same letters.

Table 3. Fatty acid composition of safflower varieties (%)

Fatty acids	Sowing time	Varieties			Mean
		Dinçer	Remzibey-05	Yenice	
Myristic ($C_{14:0}$)	Winter	0.12	0.10	0.11	0.11
	Spring	0.17	0.11	0.11	0.13
	Mean	0.15	0.11	0.11	
Palmitic ($C_{16:0}$)	Winter	6.50	6.08	5.62	6.07
	Spring	6.87	6.30	5.78	6.32
	Mean	6.69 a[1]	6.19 b	5.70 c	
	$LSD_{(0.05)}$	Variety: 0.395			
Palmitoleic ($C_{16:1}$)	Winter	0.14	0.12	0.10	0.12
	Spring	0.12	0.12	0.09	0.11
	Mean	0.13 a	0.12 a	0.10 b	
	$LSD_{(0.05)}$	Variety: 0.020			
Stearic ($C_{18:0}$)	Winter	2.18	2.31	2.22	2.24 a
	Spring	1.93	2.08	2.18	2.06 b
	Mean	2.06 b	2.20 a	2.20 a	
	$LSD_{(0.05)}$	Variety: 0.103	Sowing time: 0.084		
Oleic ($C_{18:1}$)	Winter	11.54	36.63	9.98	19.38
	Spring	13.88	27.58	11.07	17.51
	Mean	12.71	32.11	10.53	
	$LSD_{(0.05)}$	Variety: 5.041			
Linoleic ($C_{18:2}$)	Winter	78.94	54.20	81.54	71.56
	Spring	76.54	63.25	80.17	73.32
	Mean	77.74	58.73	80.86	
	$LSD_{(0.05)}$	Variety: 5.099			
Linolenic ($C_{18:3}$)	Winter	0.07	0.06	0.07	0.07
	Spring	0.09	0.08	0.09	0.09
	Mean	0.08	0.07	0.08	
	$LSD_{(0.05)}$		Sowing time: 0.014		
Arachidic ($C_{20:0}$)	Winter	0.25	0.33	0.22	0.27
	Spring	0.29	0.33	0.27	0.30
	Mean	0.27	0.33	0.25	
	$LSD_{(0.05)}$	Variety: 0.080			
Eicosonaic ($C_{20:1}$)	Winter	0.12	0.18	0.15	0.15
	Spring	0.13	0.16	0.10	0.13
	Mean	0.13	0.17	0.13	

1 There was no statistical difference among the same letters.

The sowing time x variety interaction was not significant for all fatty acids examined. The $C_{14:0}$ and $C_{20:1}$, two minor fatty acids, was influenced by neither sowing time nor variety. These two fatty acids in varieties ranged from 0.10 to 0.18 percent. Only the $C_{18:0}$ among major fatty acids was affected ($P<0.01$) by sowing time. The $C_{18:0}$ content in varieties increased average 0.18 % in winter sowing time. The $C_{18:3}$ content of three varieties was similar and influenced ($P<0.05$) by sowing time. The $C_{18:3}$ was higher of 0.02 % in spring sowing. Differences observed the $C_{16:0}$ and $C_{18:2}$ contents and the $C_{16:1}$, $C_{18:0}$, $C_{18:1}$, and $C_{20:0}$ contents among three varieties were found to be significant ($P<0.01$ and $P<0.05$, respectively).

Results shown in Table 3 revealed that generally, the $C_{14:0}$, $C_{16:0}$, $C_{18:3}$, and $C_{20:0}$ contents in varieties were higher in spring sowing than that observed in winter sowing.

The $C_{18:0}$ content was lower in Dinçer variety having the highest the $C_{16:0}$ content than in the others for both sowings. It was recorded that there was a negative correlation between the $C_{16:0}$ and the $C_{18:0}$ in winter ($r= -0.063$) and spring ($r= -0.806$) sowings. Also, while this correlation found significant ($P<0.01$) statistically in spring sowing, its value was very low in winter sowing (Table 4).

Table 4. Correlation coefficients among the fatty acids in safflower varieties

	$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:0}$	$C_{20:1}$
$C_{14:0}$	1.000								
	1.000								
$C_{16:0}$	0.678*	1.000							
	0.475	1.000							
$C_{16:1}$	0.432	0.779*	1.000						
	0.328	0.704*	1.000						
$C_{18:0}$	-0.215	-0.063	-0.061	1.000					
	-0.163	-0.806**	-0.315	1.000					
$C_{18:1}$	-0.615	0.061	-0.017	0.443	1.000				
	-0.244	0.174	0.534	0.003	1.000				
$C_{18:2}$	0.590	-0.051	-0.011	-0.443	-0.999**	1.000			
	0.211	-0.222	-0.566	0.030	-0.999**	1.000			
$C_{18:3}$	0.408	0.089	0.028	0.086	-0.701*	0.699*	1.000		
	-0.347	-0.002	-0.540	-0.478	-0.441	0.447	1.000		
$C_{20:0}$	-0.248	0.166	0.046	0.653	0.800**	-0.808**	-0.490	1.000	
	-0.359	0.169	0.537	-0.106	0.853**	-0.849**	-0.474	1.000	
$C_{20:1}$	-0.288	-0.293	-0.363	0.609	0.258	-0.255	0.044	0.438	1.000
	-0.073	0.346	0.741*	-0.118	0.938**	-0.947**	-0.474	0.863**	1.000

* P<0.05

** P<0.01

1 First line belongs to winter sowing time, second to spring sowing time in each fatty acid

There was an inverse relationship (r= - 0.999, P<0.01) between the $C_{18:1}$ and $C_{18:2}$ acids in both all varieties and two sowing times. The $C_{18:1}$ in Remzibey-05 variety and $C_{18:2}$ inYenice (4.05 %) and Dinçer (2.50 %) varieties had the highest values (32.11 %, 80.86 % and 77.74 %, respectively). The $C_{18:1}$ content of Yenice and Dinçer varieties was higher (1.1 % and 2.34 %, respectively) in spring sowing than winter sowing. But, spring sowing affected adversely the $C_{18:1}$ content of Remzibey-05 variety and caused 9.05 % decreasing of it. On the contrary the $C_{18:1}$, the $C_{18:2}$ content of Yenice and Dinçer varieties in winter sowing decreased (1.37 % and 2.40 %, respectively, the $C_{18:2}$ content of Remzibey-05 variety increased (9.04 %) (Table 3).

It was observed that there was a high and positive correlation between $C_{16:1}$ and $C_{16:0}$, and between $C_{18:1}$ and $C_{20:0}$ in both sowing time. In addition, this correlations found significant (P<0.05 and P<0.01, respectively) statistically. Also, the $C_{20:0}$ was negatively associated with the $C_{18:2}$ in winter sowing (r= -0.808) and spring sowing (r= - 0.849). This relationship was found significant (P<0.01) statistically (Table 4).

The other results of correlation analysis found significant statistically in Table 4 were below:

In winter sowing;

- The $C_{14:0}$ and $C_{16:1}$ had a positive effect (r= 0.678 and r= 0.779, respectively) on the $C_{16:0}$.
- The $C_{18:3}$ was negatively and positively associated (r= - 0.701) with $C_{18:1}$ and (r= 0.669) with the $C_{18:2}$.

These correlations were determined significant at 0.05 level.

In spring sowing;

- Significant (P<0.05, P<0.01, and P<0.01, respectively) positive correlations were found between the $C_{20:1}$ and the $C_{16:1}$ (r= 0.741), the $C_{18:1}$ (r= 0.938) and the $C_{20:0}$ (r= 0.863). But, the $C_{20:1}$ adversely affected the $C_{18:2}$ (r= - 0.947) at 0.01 level.

DISCUSSION

A lot of factors such as climatic factors, variety, and location etc. influence on amount of oil in safflower seed [11]. Gecgel et al. [12] revealed that while oil content of Centennial variety was higher in autumn sowing, oil content of Montola-2001 variety was higher in spring sowing. Benno safflower variety was sown in winter and spring season in Italy, and winter sowing gave higher oil yield [13]. Sabale and Deokar [14] explained that two safflower varieties were planted in 25 September, 25 October and 25 November, observed that both varieties maturated early and oil content of them increased average 6-7 % in 25 November. It is stated that varieties with reduced or absent spines have been lower in oil content than spiny types. Martinez [1] reported that Gila (spiny), Thori-78 (spineless) and PI-253-387 (spineless) safflower lines from Pakistan contained 36 %, 32 % and 30 % oil, respectively.

The content of fatty acids in safflower varieties may be exhibited great differences [4,5]. Due to the genes that control production of fatty acids, it has been possible that several type varieties such as very high $C_{18:2}$, high $C_{18:2}$ etc. have been developed [6,7]. Knowles [15] stated that palmitic, stearic, oleic and linoleic acid content of oil in selected safflower lines were

found as average 4 %, 2 %, 6 % and 88 % in very high linoleic types; 7 %, 3 %, 18 % and 73 % in high linoleic types; 6 %, 2 %, 78 % and 16 % in high oleic types; 6 %, 2 %, 47 % and 48 % in intermediate oleic types, and 6 %, 8 %, 14 % and 71 % in high stearic types, respectively.

Our results are in accordance with Ladd and Knowles [16] who reported that their safflower varieties with high levels $C_{18:0}$ contained lower in $C_{16:0}$.It is pointed out that cooler growing temperatures reduce the $C_{18:0}$ and the $C_{18:1}$ while increasing the $C_{18:2}$ and the $C_{18:3}$ [5,16]. Apparently, genotype and sowing time where it is planted are important factors affecting fatty acid composition of safflower seed. That climatic conditions, particularly temperature during growing season and development stages of seed, changed composition of fatty acids was indicated by Nagaraj and Reddy [17] and Lajara et al. [18]. Depending on high or low temperatures, fatty acids affect positively and negatively on each other [19]. Gecgel et al. [12] reported that there was an inverse relationship between the development of the $C_{18:1}$ and the $C_{18:2}$ acids.

CONCLUSION

Oil content and fatty acids were affected by sowing time and variety. Oil content from three varieties was higher in winter sowing. Also, the value of $C_{18:0}$ was increased while the value of $C_{18:3}$ was decreased by winter sowing. It was observed that responses to winter and spring sowing of spiny and spineless varieties were different. Sowing time was effective on bilateral relationships among fatty acids in varieties seed. Therefore, it is necessary to know the relationships among oil content, fatty acid composition, climatic factors especially temperature and variety in order to attain desirable results in locations where safflower was cultivated. As a result, fatty acid composition was affected by sowing time, the using of different variety and the status of spiny.

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