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Determination of fatty acid, tocopherol and phytosterol contents of the oils of various poppy (*Papaver somniferum* L.) seeds

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RESUMEN

Determinación del contenido de ácidos grasos, tocoferoles y fitoesteroles de aceites procedentes de varias semillas de adormidera (*Papaver sommniferum* L.)

El contenido en ácidos grasos, tocoferoles y esteroles de aceites de varias semillas de adormidera fueron investigadas. Los principales ácidos grasos en el aceite de semilla de adormidera fueron el ácido linoleico (687.6-739.2 g kg^{-1}), ácido oleico (141.3-192.8 g kg^{-1}) y ácidos palmítico (76.8-92.8 g kg^{-1}). Los aceites contienen una cantidad apreciable de γ-tocoferol (195.37-280.85 mg kg^{-1}), con un valor medio de 261.31 mg kg^{-1} y α-tocoferol (21.99-45.83 mg kg^{-1}), con un valor medio de 33.03 mg kg^{-1}. La concentración total de esteroles varió desde 1099.84 mg kg^{-1} (K.pembe) a 4816.10 mg kg^{-1} (2. sınıf beyaz), con un valor medio de 2916.20 mg kg^{-1}. El principal esterol fue el β-sitosterol, que varió desde 663.91 a 3244.39 mg kg^{-1}; el campesterol, que varió desde 228.59 a 736.50 mg kg^{-1}; y el Δ^5-avenasterol, que varió desde 103.90 a 425.02 mg kg^{-1}. Las semillas estudiadas de las diferentes variedades de adormidera de Turquía pueden ser una fuente potencial de aceites con valor añadido.

PALABRAS CLAVE: Aceite – Ácido graso – Adormidera – Esteroles – Tocoferoles.

SUMMARY

Determination of fatty acid, tocopherol and phytosterol contents of the oils of various poppy (*Papaver somniferum* L.) seeds.

The fatty acid, tocopherol and sterol contents of the oils of several poppy seeds were investigated. The main fatty acids in poppy seed oils were linoleic (687.6-739.2 g kg^{-1}), oleic (141.3-192.8 g kg^{-1}) and palmitic (76.8-92.8 g kg^{-1}). The oils contained an appreciable amount of γ-tocopherol (195.37-280.85 mg kg^{-1}), with a mean value of 261.31 mg kg^{-1} and α-tocopherol (21.99-45.83 mg kg^{-1}), with a mean value of 33.03 mg kg^{-1}. The concentrations of total sterol ranged from 1099.84 mg kg^{-1} (K.pembe) to 4816.10 mg kg^{-1} (2. sınıf beyaz), with a mean value of 2916.20 mg kg^{-1}. The major sterols were β-sitosterol, ranging from 663.91 to 3244.39 mg kg^{-1}; campesterol, ranging from 228.59 to 736.50 mg kg^{-1}; and Δ^5-avenasterol, ranging from 103.90 to 425.02 mg kg^{-1}. The studied varieties of poppy seeds from Turkey were found to be a potential source of valuable oil.

KEY-WORDS: Fatty acid – Oil – Poppy – Sterol – Tocopherol.

1. INTRODUCTION

Poppy (*Papaver somniferum*) is cultivated as an annual crop in countries such as China, India, Czech Republic - Slovakia or Turkey. It is grown mainly for its contents of opium and oil seeds. The seeds are used almost exclusively for their oil (Karaefe, 1992; Nergiz and Ötleş, 1994; Bozan and Temelli, 2003). In many plants, the seed lipid composition differs considerably from the lipids contained in green photosynthetic tissue. Unusual fatty acids are often present in significant percentages in the seed oil (Smith, 1970). Phytosterols, commonly found in foods such as wheat germ, soybeans and corn oil are also phytochemicals. The health aspects of β-sitosterols, the most common phytosterol, have recently been reported in several studies (Awad *et al*., 1996; Lopez Ortiz *et al*., 2006). Also, plant seed and kernels are important. Tocopherols are particularly important functional components in foods. Phytosterols and tocopherols are components present in the unsaponifiable lipid fraction of foods.

Poppy seed oil appears to be of good quality for human consumption since it is generally rich in polyunsaturated fatty acids (Kryzmanski and Jonsson, 1989; Luthra and Singh, 1989; Bozan and Temelli, 2003). In Europe, poppy seeds are mostly used for confectionary, similar to the use of sesame seeds and are used extensively in baking and sprinkling on rolls and bread. It was reported that the seeds of *P.somniferum* were useful for the relief of dysentry, consipation, cough and asthma (Raie and Salma, 1985).

The seeds are a good source of energy. Also, oil cake is a good fodder for cattle (Harvey, 1988; Duke, 1989). Poppy seeds are used in Turkey almost exclusively for the extraction of oil. They are also used by the peasant people in pastry making. Some studies on the composition of poppy seed were carried out (Nergiz and Ötleş, 1994; Bozan and Temelli, 2003; Özcan and Atalay, 2006; Bozan and Temelli, 2008). These works reported mainly on the fatty acid and tocopherol compositions of poppy

seed oil but there is very limited knowledge about the sterols.

The aim of this study was to determine the chemical properties of various poppy seeds obtained from the Afyon province of Turkey concerning the fat content and the composition of fatty acids, tocopherols and sterols. Eight different varieties collected from the Afyon province in Turkey were used in this study.

2. MATERIAL AND METHODS

2.1. Materials

Different poppy seeds were obtained from the Afyon province in Turkey in the year 2006. Seeds were transferred to the laboratory in polypropylene bags under cool conditions. They were cleaned in an air screen cleaner to remove all foreign matter such as dust, dirt, stones and chaff and immature and broken seeds were discarded as well. Then, seeds were kept in glass jars at +4 °C until analysis.

Campesterol, stigmasterol and cholestanol (internal standard) were purchased from Sigma-Aldrich Chem.Co. (St. Louis, MO, USA). Bis (trimethylsilyl)-trifluoroacetamide (BSTFA) with 1% trimethyl-chlorosilane (TMCS) was commercially available from Supelco (Bellefonte, PA, USA). β-sitosterol and all other chemicals were analytical grade and obtained from Merck (Darmstadt, Germany). A mix of 37 FAME (C_4- C_{24}) was purchased from Supelco (Bellefonte, PA, USA). α, β and γ-tocopherol were obtained from Sigma-Aldrich Chem.Co. (St. Louis, MO, USA).

2.2. Oil extraction

15 g of seed sample were ground and subjected to oil extraction using a Soxhlet apparatus (Gerhardt) according to AOCS Official methods Am 2-93 (Anonymous, 2003).

2.3. Fatty acid analysis

The methyl esters of the fatty acids were prepared according to IUPAC (Anonymous, 1987) and analyzed using a Shimadzu GC-2010 gas chromatograph equipped with a DB-23 column (60m x 0.25mm i.d. and 0.25 μm film thickness) (J&W). Injector, column and detector temperatures were 230, 190 and 240 °C, respectively. Split ratio was 80:1. Carrier gas was helium at 1.0 ml/min ratio.

2.4. Tocopherol analysis

The sample was prepared by dissolving 1g of oil in 9ml of hexane and injected into a normal phase HPLC to analyze tocopherols (Anonymous, 2003), using a Shimadzu SCL-10A HPLC system. The chromatographic separation was done with a Lichrosorb Si60-5 (250 x 4.6 mm id, particle size S-5μm) (Hichrom, Reading, UK). The column temperature was maintained at 25°C. Separation of the tocopherols was based on isocratic elution with n-hexane (99%) and *iso*-propanol (1%) at 1 mL/min. The eluate was monitored at 295 nm. Tocopherols were quantified based on peak areas compared with an external standard α, β and γ-tocopherol.

2.5. Sterol analysis

Preparation of unsaponifiable matter from 5g of oil and determination of the composition of the sterol fractions were done according to the AOCS Official Method Ch 6-91 (Anonymous, 2003). Derivatives of the sterols (silylethers) were analyzed using a gas chromatography (Shimadzu GC 2010) equipped with a fused silica capillary column HP-5 (30m × 0.25mm ID and 0.25 μm film thickness) (Chrom Tech., Apple Walley, MN) and quantified using cholestanol (Sigma) as an internal standard. The impurity (cholesterol) of the internal standard was taken into account in the calculations. Identifications of individual peaks were carried out using available reference standards and comparing known retention times of the sterols in olive oil. The split ratio was 80:1 and the carrier gas was helium at 0.8 mL/min. Injector, column and detector (FID) temperatures were 280, 260 and 290 °C, respectively. Three injections of 1 μL were made for each oil.

2.6. Statistical analysis

Data for each of the 8 cultivars (n = 2) were recorded as means ± standard errors and analyzed by SPSS (SPSS Inc., Chicago, IL) for Windows (ver. 10.1.). One-way analysis of variance (ANOVA) and Duncan's multiple range test were carried out to test any significant differences between cultivars.

3. RESULTS AND DISCUSSION

The oil contents of the poppy seeds are given in Table 1. The oil yields, the major fraction, of poppy seeds varied from 483 to 527 g kg^{-1} of the dry weight. Because of economical value of the oil, these seeds could be used as potential sources of oils. Ofis 96 Sarı had the highest oil content (527 g kg^{-1}), followed by Sarı (520 g kg^{-1}), Türk Bayrağı (516 g kg^{-1}), Pembe (509 g kg^{-1}), 2. Sınıf Beyaz (504 g kg^{-1}), Gri 2. Sınıf (500 g kg^{-1}), 3. Sınıf Beyaz (485 g kg^{-1}) and K. Pembe (483 g kg^{-1}). From these varieties, the oil contents of Gri 2. Sınıf, Pembe and 2. Sınıf Beyaz were almost the same (500, 509 and 504 g kg^{-1}, respectively). Srinivas and Narasinga

Table 1
Oil and tocopherol contents of various poppy seeds and their oils

Varieties	Oil content (Mean g kg^{-1})	α-tocopherol (Mean mg kg^{-1})	γ-tocopherol (Mean mg kg^{-1})
Ofis 96 Sarı	527 ± 1.7^{ea}	31.16 ± 1.58^{b}	280.85 ± 7.24^{c}
Gri 2. Sınıf	499.7 ± 1.0^{b}	21.99 ± 0.18^{a}	272.31 ± 0.27^{bc}
Türk Bayrağı	516.3 ± 4.6^{cde}	33.73 ± 0.86^{b}	259.03 ± 11.04^{b}
3. Sınıf Beyaz	484.9 ± 1.5^{a}	24.17 ± 1.17^{a}	277.61 ± 1.04^{bc}
Pembe	508.6 ± 6.2^{bcd}	43.47 ± 0.93^{c}	263.91 ± 0.41^{bc}
Sarı	520.2 ± 5.3^{de}	32.83 ± 0.26^{b}	266.83 ± 6.49^{bc}
K. Pembe	483.1 ± 0.0^{a}	45.83 ± 0.59^{c}	274.55 ± 4.61^{bc}
2. Sınıf Beyaz	503.7 ± 7.1^{bc}	31.08 ± 0.02^{b}	195.37 ± 1.11^{a}

[a] Different superscript letters in the same column indicate significant difference between values at $p < 0.05$ level and values are mean ± standard deviation of duplicate determination.

(1981) reported 46.2-49.4% oil in poppy seed. Özcan and Atalay (2006) had reported that seeds of some poppy varieties contained oil between 32.4% and 45.5%. Ryan *et al*. (2007) determined the total oil content of various seeds, grains and legumes, and reported 39.5% oil in poppy seed. Bozan and Temelli (2008) found higher oil contents than other researchers as 49.2 – 50.6%. The results in this work are generally in agreement with these results; however, some of our findings were little higher than those of both Srinivas and Narasinga (1981), Ryan *et al*. (2007) and Özcan and Atalay (2006). These differences among the oil contents of poppy varieties are probably due to growing, climatic and environmental conditions.

The fatty acid composition of the oils is given in Tables 2 and 3. Linoleic acid (C18:2) was the most abundant polyunsaturated fatty acid in most foods. Results showed that the oils of all poppy seeds used in this experiment had high linoleic acid contents (687.6-739.2 g kg^{1}), with a mean value of 712.3 g kg^{-1}. Another quantitatively high unsaturated fatty acid in the oils was oleic acid in a range from 141.3 g kg^{-1} (Ofis 96 Sarı) to 192.8 g kg^{-1} (Pembe), with a mean value of 161.0 g kg^{-1}. Palmitic acid, which is the most abundant saturated fatty acid, amounted to between 76.8 g kg^{-1} (Pembe) and 92.8 g kg^{-1} (Gri 2. Sınıf), with a mean value of 87.0 g kg^{-1}. Stearic acid was found in small amounts in a range of 21.8 g kg^{-1} (Ofis 96 Sarı) to 25.5 g kg^{-1} (2. Sınıf Beyaz), with a mean value of 23.0 g kg^{-1}. As can be observed, the fatty acid compositions of poppy seed oils were similar to the compositions of many other crop seed oils which contain more linoleic and less oleic acid. But poppy seed oils contain more linoleic acid than the oils of some other crops. Therefore, from a nutritional point of view, poppy seed oil is also a good source of essential fatty acids, especially linoleic acid, as compared to the other edible oil seeds (Nergiz and Ötleş, 1994; Femenia *et al*., 1995; Allam, 2001; Özcan and Atalay, 2006; Ryan *et al*., 2007). The proportions of linoleic acid of the poppy seed oils were also higher than in other fruit seed oils (pomegranate, 3.7%; mahaleb, 35.4%; cherry laurel, 53.7%; date pit, 49.54%, walnut, 13.8-33.0%) (Zwarts *et al*.,1999; Allam, 2001; Colombini *et al*., 2005; Yücel, 2005). Özcan and Atalay (2006) reported that the seed oils of several poppy varieties contained 12.85-18.70% palmitic, 2.40-4.30% stearic, 13.11-24.13% oleic, 52.60-71.50% linoleic and 0.16-0.50% linolenic acids. Ryan *et al*. (2007) reported that poppy seed oil contained 12.20% palmitic, 0.27% palmitoleic, 2.30% stearic, 22.19% oleic, 59.87% linoleic, 1.30% linolenic, 0.67% arachidic, 0.16% gadoleic and 0.29% erucic acids. The fatty acid composition of a poppy seed variety was also determined by Bozan and Temelli (2008), which consisted of 9.79% palmitic, 1.93% stearic, 13.03% oleic, 74.47% linoleic and 0.60% linolenic acids.

Its high content of linoleic acid makes the poppy seed more suitable for development as a high linoleic acid crop. The proportion of oleic and linoleic acid determines the quality of oil and its use (Green, 1986; Haris *et al*., 1980; Singh *et al*., 1998). In general, high amounts of linolenic acid are unsuitable for oil-food products due to its instability and reversion of flavor associated with autoxidation (Green, 1986; Singh *et al*., 1998). So, poppy seed may be a suitable oil seed crop for the food industry due to its very low content of linolenic and high content of linoleic acids (Singh *et al*. 1998). Our results were found similar to the results of Nergiz and Ötleş (1994), Bozan and Temelli (2003), Bozan and Temelli (2008) and Baydar and Turgut (1999). Crops having such oil quality have considerable agricultural significance in the market for edible vegetable oil which is expanding rapidly (Singh *et al*., 1998).

In addition to the fatty acid composition, the composition of tocopherol is an important characteristic feature to describe the identity of vegetable oils. The tocopherol contents of the poppy seed oils investigated in this study are given in Table 1. The poppy seed oils contained an appreciable amount of γ-tocopherol (195.37 – 280.85 mg kg^{-1}) with a mean value of 261.31 mg kg^{-1} and α-tocopherol (21.99-45.83 mg kg^{-1}), with a mean value of 33.03 mg kg^{-1}. K. Pembe contained the highest α-tocopherol (45.83 mg kg^{-1}) while Ofis 96 Sarı had the highest γ-tocopherol (280.85 mg kg^{-1}) content. Our findings for γ-tocopherol are higher than those of Ryan *et al*.

Table 2
Saturated fatty acid compositions of poppy seed oils

	Fatty acids (g kg^{-1})							
Varieties	**C14:0**	**C15:0**	**C16:0**	**C17:0**	**C18:0**	**C20:0**	**C23:0**	**C24:0**
Ofis 96 Sarı	0.46 ± 0.012^{aba}	0.14 ± 0.008^{d}	84.83 ± 0.542^{bc}	0.56 ± 0.004^{b}	21.79 ± 0.043^{a}	1.03 ± 0.023^{a}	3.44 ± 0.012^{g}	1.49 ± 0.042^{b}
Gri 2. Sınıf	0.59 ± 0.048^{c}	0.14 ± 0.011^{cd}	92.80 ± 1.609^{e}	0.55 ± 0.007^{b}	21.95 ± 0.069^{a}	1.04 ± 0.002^{a}	1.28 ± 0.030^{b}	1.68 ± 0.039^{c}
Türk Bayrağı	0.45 ± 0.005^{ab}	0.12 ± 0.003^{ab}	81.22 ± 0.435^{b}	0.50 ± 0.002^{a}	23.35 ± 0.459^{b}	1.10 ± 0.094^{a}	1.12 ± 0.010^{a}	1.39 ± 0.069^{b}
3. Sınıf Beyaz	0.50 ± 0.024^{b}	0.15 ± 0.002^{cd}	91.40 ± 1.353^{de}	0.57 ± 0.009^{b}	22.01 ± 0.056^{a}	1.16 ± 0.025^{a}	1.38 ± 0.048^{c}	1.39 ± 0.016^{b}
Pembe	0.40 ± 0.010^{a}	0.13 ± 0.004^{bc}	76.67 ± 1.006^{a}	0.52 ± 0.004^{a}	22.15 ± 0.060^{a}	1.10 ± 0.054^{a}	1.13 ± 0.026^{a}	1.02 ± 0.003^{a}
Sarı	0.50 ± 0.001^{b}	0.14 ± 0.005^{cd}	88.44 ± 0.393^{cd}	0.56 ± 0.003^{b}	23.20 ± 0.134^{b}	1.43 ± 0.343^{a}	2.46 ± 0.011^{f}	1.85 ± 0.049^{d}
K. Pembe	0.40 ± 0.034^{a}	0.11 ± 0.008^{a}	81.38 ± 1.502^{b}	0.56 ± 0.003^{b}	23.67 ± 0.114^{b}	1.73 ± 0.552^{a}	1.56 ± 0.011^{d}	1.09 ± 0.062^{a}
2. Sınıf Beyaz	0.50 ± 0.009^{b}	0.16 ± 0.003^{d}	99.10 ± 1.938^{f}	0.62 ± 0.012^{c}	25.50 ± 0.567^{c}	1.39 ± 0.012^{a}	2.29 ± 0.024^{e}	1.13 ± 0.048^{a}

[a] Different superscript letters in the same column indicate significant difference between values at $p < 0.05$ level and values are mean ± standard deviation of duplicate determination.

Table 3
Unsaturated fatty acid compositions of poppy seed oils

	Fatty acids (g kg^{-1})							
Varieties	**C16:1**	**C17:1**	**C18:1**	**C18:2**	**C18:3 *trans***	**C18:3**	**C20:1**	**C20:2**
Ofis 96 Sarı	2.53 ± 0.171^{da}	0.30 ± 0.014^{b}	141.30 ± 0.404^{a}	727.19 ± 2.007^{e}	8.53 ± 1.697^{c}	5.47 ± 0.017^{a}	0.72 ± 0.020^{b}	0.24 ± 0.026^{a}
Gri 2. Sınıf	1.62 ± 0.003^{ab}	0.35 ± 0.000^{d}	177.64 ± 0.483^{f}	693.57 ± 1.062^{b}	0.26 ± 0.019^{a}	5.55 ± 0.057^{a}	0.78 ± 0.034^{c}	0.20 ± 0.034^{a}
Türk Bayrağı	1.49 ± 0.041^{a}	0.25 ± 0.010^{a}	142.83 ± 0.143^{b}	739.24 ± 0.339^{f}	0.17 ± 0.017^{a}	5.72 ± 0.065^{b}	0.75 ± 0.017^{bc}	0.29 ± 0.007^{a}
3. Sınıf Beyaz	1.82 ± 0.075^{bc}	0.31 ± 0.006^{b}	158.30 ± 0.044^{d}	713.31 ± 1.789^{c}	0.22 ± 0.007^{a}	6.28 ± 0.019^{c}	0.62 ± 0.000^{a}	0.61 ± 0.423^{a}
Pembe	2.04 ± 0.026^{c}	0.34 ± 0.005^{cd}	192.82 ± 0.098^{g}	687.61 ± 1.303^{a}	5.40 ± 0.238^{b}	5.85 ± 0.059^{b}	0.94 ± 0.009^{d}	0.27 ± 0.028^{a}
Sarı	1.73 ± 0.028^{b}	0.31 ± 0.001^{b}	151.17 ± 0.537^{c}	720.61 ± 1.997^{d}	1.05 ± 0.502^{a}	5.58 ± 0.002^{a}	0.73 ± 0.000^{bc}	0.23 ± 0.023^{a}
K. Pembe	1.48 ± 0.034^{a}	0.31 ± 0.007^{b}	162.05 ± 0.114^{e}	718.66 ± 1.006^{d}	0.25 ± 0.024^{a}	5.75 ± 0.018^{b}	0.74 ± 0.013^{bc}	0.26 ± 0.014^{a}
2. Sınıf Beyaz	1.75 ± 0.020^{b}	0.32 ± 0.000^{bc}	161.54 ± 0.650^{e}	697.89 ± 1.721^{b}	0.25 ± 0.004^{a}	6.61 ± 0.020^{d}	0.75 ± 0.009^{bc}	0.21 ± 0.029^{a}

[a] Different superscript letters in the same column indicate significant difference between values at $p < 0.05$ level and values are mean ± standard deviation of duplicate determination.

(2007) but lower than those of Özcan and Atalay (2006) who found 26.8 – 37.2 mg/kg α-tocopherol, 309.5 – 567.3 mg/kg γ-tocopherol and 6.1 – 18.6 mg/kg β-tocopherol in seed oils of some poppy varieties. Bozan and Temelli (2008) also reported that the oil of poppy seeds contained 21.74 mg/100g γ-tocopherol and 5.53 mg/100g α-tocopherol. However, in another study, 0.2 mg/100g α-tocopherol and 4.7 mg/100g β + γ-tocopherol in poppy seed oil were determined (Ryan *et al*. 2007). Tocopherols are natural antioxidants with biological activity. The antioxidant effect is especially high if the γ- tocopherol content is high. The higher content of γ-tocopherol of the poppy seed oils can be related to their greater resistance to oxidation. The main biochemical function of tocopherols is believed to be the protection of poylunsaturated fatty acids against peroxidation (Kamal-Eldin and Andersson, 1997).

As known, phytosterols are components present in the unsaponifiable lipid fraction of foods. Phytosterols, primarily β-sitosterol, campesterol and stigmasterol are integral natural components of plant cell membranes that are abundant in vegetable oils, nuts, seeds, and grains (Weihrauch and Gardner, 1978; Lopez Ortiz *et al*., 2006; Ryan *et al*., 2007). Table 4 presents the content and the composition of sterols in the poppy seed oils. A typical chromatogram of the sterols belonging to poppy seed oils was shown in Figure 1. The amounts of total sterols ranged from 1099.84 mg kg^{-1} (K. Pembe) to 4816.10 mg kg^{-1} (2. Sınıf Beyaz) with a mean value of 2916.20 mg kg^{-1}. The major sterols were β-sitosterol, ranging from 663.91 mg kg^{-1} (K. Pembe) to 3244.39 mg kg^{-1} (2. Sınıf Beyaz); campesterol, ranging from 228.59 mg kg^{-1} (K. Pembe) to 736.50 mg kg^{-1} (2. Sınıf Beyaz); Δ^5-avenasterol, ranging from 103.90 (K. Pembe) to 425.02 mg kg^{-1} (Pembe) and stigmasterol, ranging from 30.94 mg kg^{-1} (K. Pembe) to 213.04 mg kg^{-1} (2. Sınıf Beyaz). Other sterols are lower than 100 mg kg^{-1}. From these findings, it can be concluded that poppy seed oil represents a very important dietary source of phytosterols.

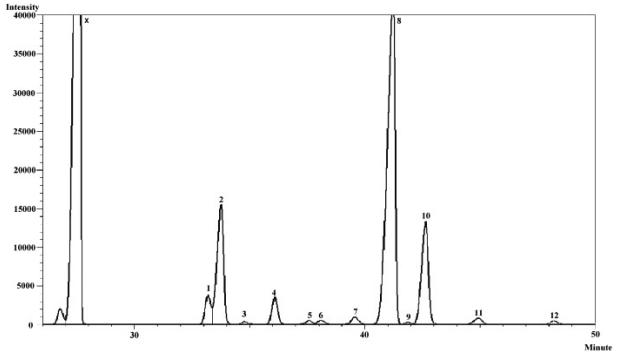

Figure 1
GC chromatogram of sterols obtained from various poppy seed oils · X) cholestenol (internal standard) 1) 24-Methylene-Cholestrol 2) Campesterol 3) Campestanol 4) Stigmasterol 5) Δ^7-Campestrol 6) $\Delta^{5.23}$-Stigmastadienol 7) Clerosterol 8) β-Sitosterol 9) Sitostanol 10) Δ^5-Avenasterol 11) $\Delta^{5.24}$-Stigmastadienol 12) Δ^7-Avenasterol.

Sterol levels in this study were found higher than the findings of Ryan *et al*. (2007), who determined 58.3 mg/100 g β-sitosterol, 9.8 mg/100g campesterol and 5.7 mg/100g stigmasterol in poppy seed oil. Sterol levels found in this study were different from other published results (Weihrauch and Gardner 1978; Savage *et al*., 1997; Ryan *et al*., 2007). Like other seed oils such as canola, corn, soybean, sunflower and safflower oils, poppy seed oil also has higher amounts of campesterol, stigmasterol and Δ^5-avenasterol contents than the fruit oils such as olive and hazelnut oils (Aparicio and McIntyre, 1998). Savage *et al*. (1997) determined that hazelnut oil grown in New Zealand contained 78-114 mg/g campesterol, 15-23 mg/g stigmasterol and 33-170 mg/g Δ^5-avenasterol. However, the stigmasterol content of poppy seed oil is lower than those of other major seed oils except canola while it is rich in campesterol as well as others. The Δ^5-avenasterol contents of poppy seed oil is higher than those of some seed oils such as sunflower, soybean and safflower oils (Aparicio and McIntyre, 1998; Codex Alimentarius Commission, 2005).

4. CONCLUSION

The present study indicates that poppy seed is a good natural source of phytosterols. In addition, the findings in this study are important for the nutrition sciences, because fatty acids, tocopherols and phytosterols, in particular, seem to have considerable effects on health. The results of the experiment have shown that poppy seeds have distinctive fatty acid, tocopherol and phytosterol profiles. The composition of the oil is comparable to the other commonly used oils or fats, such as olive, sunflower, safflower, peanut, palm olein, and therefore, the use of the oil in nutrition or technical applications is possible.

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Table 4
Sterol contents of poppy seed oils

Varieties	Sterols (mg kg^{-1})					
	24-Methylene-Cholestrol	**Campesterol**	**Campestanol**	**Stigmasterol**	**Δ^7-Campesterol**	**$\Delta^{5.23}$-Stigmastadienol**
Ofis 96 Sarı	75.56 ± 0.90^{ba}	632.45 ± 7.55^{f}	0.72 ± 0.10^{a}	105.66 ± 1.26^{e}	13.55 ± 3.45^{bc}	10.12 ± 2.71^{ab}
Gri 2. Sınıf	69.96 ± 1.15^{b}	450.80 ± 11.00^{b}	3.77 ± 0.53^{b}	84.00 ± 1.10^{b}	21.54 ± 1.05^{d}	18.08 ± 1.73^{cd}
Türk Bayrağı	87.55 ± 1.38^{c}	689.47 ± 4.96^{g}	2.10 ± 0.02^{ab}	101.35 ± 0.78^{de}	9.45 ± 0.07^{ab}	12.66 ± 0.10^{bc}
3. Sınıf Beyaz	76.33 ± 7.88^{b}	556.25 ± 11.31^{e}	2.61 ± 0.26^{ab}	91.27 ± 1.93^{c}	19.72 ± 1.77^{cd}	18.50 ± 1.47^{cd}
Pembe	100.92 ± 0.71^{d}	482.64 ± 6.73^{c}	6.53 ± 1.79^{c}	99.25 ± 1.02^{d}	11.86 ± 2.95^{ab}	14.06 ± 3.29^{bc}
Sarı	68.28 ± 4.35^{b}	515.91 ± 4.01^{ab}	2.89 ± 0.06^{ab}	85.82 ± 3.44^{bc}	20.81 ± 0.54^{d}	20.71 ± 0.86^{e}
K. Pembe	28.21 ± 0.41^{a}	228.59 ± 4.72^{a}	1.30 ± 0.13^{a}	30.94 ± 0.14^{a}	5.42 ± 2.05^{a}	5.59 ± 1.69^{a}
2. Sınıf Beyaz	70.73 ± 1.73^{b}	736.50 ± 0.47^{ab}	2.55 ± 0.00^{ab}	213.04 ± 2.47^{f}	7.62 ± 0.05^{ab}	6.08 ± 0.15^{a}

Varieties	Sterols (mg kg^{-1})						
	Clerosterol	**β-Sitosterol**	**Sitostanol**	**Δ^5-Avenasterol**	**$\Delta^{5.24}$-Stigmastadienol**	**Δ^7-Avenasterol**	**Total**
Ofis 96 Sarı	29.63 ± 0.19^{bca}	1759.65 ± 16.55^{c}	2.16 ± 0.03^{a}	257.60 ± 3.07^{b}	16.35 ± 3.25^{ab}	9.42 ± 0.11^{c}	2912.89 ± 19.77^{cd}
Gri 2. Sınıf	25.15 ± 1.04^{b}	1717.08 ± 55.22^{c}	28.66 ± 2.64^{d}	311.37 ± 6.60^{d}	34.62 ± 0.06^{cd}	20.61 ± 0.45^{f}	2785.65 ± 80.50^{bc}
Türk Bayrağı	36.90 ± 0.28^{d}	1972.59 ± 15.21^{d}	7.15 ± 0.06^{bc}	315.19 ± 2.43^{d}	33.22 ± 0.26^{cd}	2.73 ± 0.02^{a}	3270.36 ± 25.56^{e}
3. Sınıf Beyaz	32.21 ± 2.86^{cd}	1768.39 ± 42.69^{c}	10.61 ± 1.60^{c}	303.89 ± 9.14^{cd}	25.83 ± 3.29^{abc}	15.99 ± 0.46^{e}	2921.60 ± 45.50^{d}
Pembe	31.48 ± 0.97^{c}	1591.80 ± 15.40^{b}	4.51 ± 0.80^{ab}	425.02 ± 6.64^{f}	30.28 ± 3.03^{bcd}	13.65 ± 0.13^{d}	2812.01 ± 39.88^{bcd}
Sarı	28.91 ± 1.88^{bc}	1610.94 ± 5.24^{b}	5.48 ± 1.35^{ab}	287.85 ± 1.85^{c}	43.06 ± 11.30^{d}	20.45 ± 1.34^{f}	2711.12 ± 8.11^{b}
K. Pembe	11.51 ± 2.50^{a}	663.91 ± 9.97^{a}	2.35 ± 0.13^{a}	103.90 ± 0.89^{a}	13.37 ± 1.76^{a}	4.74 ± 0.28^{b}	1099.84 ± 2.48^{a}
2. Sınıf Beyaz	56.54 ± 0.03^{e}	3244.39 ± 12.46^{e}	29.25 ± 0.14^{d}	343.39 ± 1.80^{e}	100.52 ± 1.45^{e}	5.49 ± 0.73^{b}	4816.10 ± 12.71^{f}

[a] Different superscript letters in the same column indicate significant difference between values at $p < 0.05$ level and values are mean ± standard deviation of duplicate determination.

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