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Some Chemical and Physical Properties, Fatty Acid Composition and Bioactive Compounds of Wheat Germ Oils Extracted From Different Wheat Cultivars

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ABSTRACT

Fatty acid composition, antioxidant activity, total phenolics and α-tocopherol contents of wheat germ oils obtained from two bread wheats (*Triticum aestivum* L.) and one durum wheat (*Triticum durum* L.) species commonly cultivated in Turkey were investigated in this study. Fourteen different fatty acids were determined in wheat germ oil samples in which linoleic acid (53.88-57.55%), oleic acid (16.56-20.38%) and palmitic acid (16.66-17.70%) were found as predominant fatty acid types. Among the major fatty acids, linoleic acid was the primary fatty acid in bread wheat germ oils whereas oleic and palmitic acids were the predominant fatty acids in durum wheat samples. The antioxidant activity of the wheat germ oil samples ranged between 0.94-1.01 μmol g^{-1} whereas the total phenolic and the α-tocopherol between 67.79-126.51 mg GAE 100 g^{-1} and 1343 to 2176 mg kg^{-1}, respectively. The lowest antioxidant activity and total phenolic content were detected in bread wheat germ oil while the other bread wheat and the durum wheat exhibited the highest antioxidant activity and total phenolic content, respectively.

Keywords: Wheat; Germ oil; Fatty acids; Antioxidant activity; Total phenolic compound

Farklı Buğday Çeşitlerinden Ekstrakte Edilen Rüşeym Yağlarının Kimi Kimyasal ve Fiziksel Özellikleri, Yağ Asidi Kompozisyonu ve Biyoaktif Bileşikleri

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ÖZET

Bu çalışmada, Türkiye'de yaygın olarak yetiştirilmekte olan iki ekmeklik (*Triticum aestivum* L.) ve bir makarnalık (*Triticum durum* L.) buğday çeşitlerinden elde edilen rüşeym yağlarının; yağ asidi kompozisyonu, antioksidan aktivite,

toplam fenolik madde ve α-tokoferol miktarları araştırılmıştır. Ruşeym yağı örneklerinde toplam 14 farklı yağ asidi tespit edilmiş olup, bütün numunelerde hakim yağ asitleri; linoleik asit (% 53.88-57.55), oleik asit (% 16.56-20.38) ve palmitik asit (% 16.66-17.70) olarak saptanmıştır. Ruşeym yağı örneklerinin antioksidan aktivitelerinin 0.94 μmol g^{-1} ile 1.01 μmol g^{-1}, toplam fenolik madde miktarlarının 67.79 mg GAE 100 g^{-1} ile 126.51 mg GAE 100 g^{-1} ve α-tokoferol içeriklerinin 1343 mg kg^{-1} ile 2176 mg kg^{-1} arasında değiştiği tespit edilmiştir. Antioksidan aktivite ve toplam fenolik madde miktarı bakımından en düşük oranın ekmeklik çeşitte, en yüksek antioksidan aktivitenin ise diğer ekmeklik çeşitte bulunduğu ve en yüksek toplam fenolik maddenin makarnalık çeşitte bulunduğu görülmüştür.

Anahtar Kelimeler: Buğday; Rüşeym yağı; Yağ asidi; Antioksidan aktivite; Toplam fenolik bileşikler

1. Introduction

Cereals and cereal-based foods are the major nutritional sources for human in Turkey as well as in the world. Wheat is placed on the top among the cereal plants consumed (Çifci & Doğan 2013). *Triticum aestivum* (bread type), *Triticum durum* (durum) and *Triticum compactum* (biscuit, Topbaş wheat) are major wheats grown in Turkey and all over the world (Hoseney 1994; Bushuk 1998). Wheats having horny endosperm are generally used for production of leavened foods such as bread, pastry and bagel while the ones having floury endosperm are utilized for bakery products such as biscuit, cracker, waffle and cake, which are produced with chemical leavening agents. Durum wheat is used for production of semolina for pasta and spaghetti, and granular products including bulgur and kuskus. Since production level of Topbaş wheat is very low, bread type wheat which has low protein level and quality is preferred for biscuit production (Hoseney 1994; Elgün & Ertugay 1995; Bushuk 1998; Morris 2004). Indeed, differences in hardness among *Triticum aestivum* L. or between *T. aestivum* L. and *T. turgidum* L. ssp. durum wheat cultivars determine not only their milling properties, but also the properties of flour or semolina endosperm particles, their preferential use in cereal-based applications, and the quality of the latter (Pauly et al 2013).

Wheat germ is one of the by-products of wheat milling. Germ constitutes 2-3% of the wheat grain and contains approximately 8-14% oil in its composition. Several health benefits of wheat germs were attributed to germ oil, such as the plasma and hepatic cholesterol lowering effect and anti-aging properties. These beneficial effects were suggested to be related to the presence of several bioactive compounds at high concentrations in germ oil (Kahlon 1989). Additionally, wheat germ has high vitamin content especially vitamins E and B (Pomeranz 1987) and it is one of the richest natural sources of α-tocopherol (Dunford 2001). Tocopherols constitute approximately 18% of the non-saponifying components of the germ oil (Azzi & Stocker 2000). For these reasons, determination of physicochemical and functional properties of the germ or germ oil is important for the utilization purpose of it since due to its functional porperties many foods could be enriched with addition of this nutritive by-product.

In this study, the fatty acid composition as well as antioxidant activity, total phenolic and α-tocopherol contents were investigated as significant bioactive characteristics, and components of germ oils which were obtained from *Triticum aestivum* L. (bread wheat) and *Triticum durum* L. (durum wheat), commonly cultivated wheat species in Turkey. The origin of the wheat determines the biochemical characteristics of the germ. For this reason, the chemical composition of germ samples obtained from different wheat species, especially fatty acid composition and several nutritional parameters were investigated in order to determine the differences among different wheat varieties.

2. Material and Methods

2.1. Materials

In this study, two cultivars of bread wheat [*Triticum aestivum* L; Bezostaja-1 (B) and Esperia (E)] and

one cultivar of durum wheat [*Triticum durum* L; Ç-1252(C)] were used as representative samples. Wheat germ samples coded as B and C were obtained from Tekbasak Flour Industry Co. (Afyonkarahisar, Turkey), and samples coded as E were obtained from Marmara Flour Industry Co. (Ankara, Turkey). Figure 1 represents the germ production process from wheat samples.

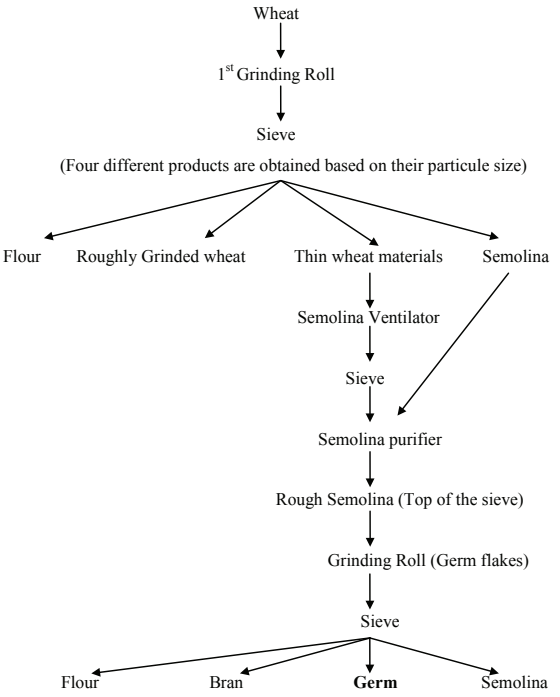

Figure 1- Process flow chart for the production of wheat germ

Şekil 1- Buğday ruşeymi eldesi için proses akım şeması

2.2. Analysis of the germ samples

Soxhlet method was used for the determination of the oil content and, the moisture content was determined according to the standard method of AACC (2000). Kjeldahl method using a semi-automized device (Foss) was used for the determination of the nitrogen content, and protein calculated as N% x 5.7. Total ash content of the samples was determined according to the method reported by Özkaya & Özkaya (1990) and AACC (2000).

2.3. Analysis of the germ oil samples

Germ oil was extracted from the germ samples according to the methodology described by Megahad & El Kinawy (2002) with slight modifications. Briefly, 200 mL of hexane was added to 50 g of ground germ and then the mixtures were blended at 200 rpm for 4 hours at room temperature, the solution was filtered and hexane was then regained using a rotary evaporator at 35 ^{o}C.

The free fatty acids, peroxide, refractive index and iodine values of germ oil samples were determined according to previously described methods of AOCS Official Method Ca 5a-40, AOCS Official Method Cd8a-53 and AOCS Official Method Cc 7-25, respectively (AOCS 1989).

The color of the wheat germ oil samples was determined by measuring *L, a, b* values with a Minolta equipment. In order to achieve this, the *L, a* and *b* values of germ oil samples were measured and the recorded values were averaged.

The fatty acid composition of the germ oil samples and their quantities were determined with gas chromatography (GC, Agilent Technogies 6890 N Network GC System) equipped with a Flame Ionization Detector (FID). The germ oil samples obtained by cold extraction were esterified and injected into the GC according to the method of AOAC (1990). Supelco SP-2380 analytical column was used and oven operating temperature was started up with 165 °C for 30 min and reached to a final temperature of 200 °C for 5 min. The carrier gas was hydrogen and dry air with a mobility of 30 mL min^{-1} and 300 mL min^{-1}, respectively with a split ratio of 70:1. The fatty acids found in germ samples were expressed as % ratio.

The DPPH (1,1-diphenyl-2-picrylhydrazyl) method was used to determine the antioxidant activity of the wheat germ oil samples (Brand-Williams et al 1995; Pokorny et al 2001; Yu et al 2002). The DPPH radical scavenging activity was calculated as percent inhibition of the reaction (Equation 1).

$$\text{DPPH Radical scavenging activity}, \% = \frac{\text{Abs}_{\text{Control}} - \text{Abs}_{\text{Sample}}}{\text{Abs}_{\text{Control}}} \times 100 \quad (1)$$

The extract or standard material concentration that provides 50% inhibition of the DPPH is defined as IC_{50}. This value was calculated by plotting the studied concentrations against the % free radical scavenging activity and the results were given as IC_{50}, μmol g^{-1}.

The total phenolic content of the wheat germ oil samples was determined with a modified Folin-Ciocalteu method using gallic acid as standard (Singleton & Rossi 1965). The total phenolic content was expresedas mg gallic acid 100 g^{-1} sample.

The α-tocopherol content of the wheat germ oil samples was determined according to AOCS (1999) method by using High Performance Liquid Chromatography (Shimadzu LC-10A). The injection volume was 10 μL. The mobile phase was methanol and the elution was performed at a flow-rate of 1.0 mL min^{-1}. The temperature of the analytical column (Nucleodur C_{18}) was kept at 30 °C. To determine α-tocopherol in the samples, α-tocopherol standard solutions were always analyzed together with the samples, and peak-area ratios were used for calculations following the internal standard method. Detection was performed with an UV/Visible-Diode array detector at 290 nm.

2.4. Statistical analysis

The results were presented as mean±standard deviation. The SAS 8.0 package software was used for the statistical analysis. The data obtained at each analysis were analysed by Duncan's new multiple range test with a confidence interval of 95%.

3. Results and Discussion

3.1. Chemical properties of wheat germ samples

The moisture, oil, protein and ash contents of germ samples obtained from different wheat species are given in Table 1.

Table 1- Some chemical properties of the wheat germ samples

Çizelge 1- Buğday ruşeymi örneklerinin bazı kimyasal özellikleri

Sample	*Moisture (%)*	*Oil (%)*	*Protein (%)*	*Ash (%)*
B*	11.59^{b}±0.05	11.67^{a}±0.49	27.70^{a}±0.04	5.03^{a}±0.01
C	11.58^{b}±0.02	10.44^{a}±0.04	23.99^{b}±0.38	4.58^{c}±0.06
E	12.96^{a}±0.50	9.68^{a}±0.71	27.26^{a}±0.61	4.87^{b}±0.03

*, different lowercase superscript letters in the same column show significant differences among the samples ($P<0.05$)

Moisture content of the germ samples was determined in the range of 11.58% (C) and 12.96% (E). As seen from the Table 1, moisture content of the B and C samples was very close to each other. As is known, wheat is conditioned prior to grinding in order to maintain uniform moisture content.

Protein content of the B, C and E germ samples was determined as 27.70, 23.99 and 27.26%, respectively (Table 1). No significant difference was observed between protein contents of B and E samples ($P>0.05$) which were higher than that of C. The differences in the protein content could be attributed to the differences of wheat species, cultivation conditions and environmental factors. Previous studies reported the protein content of wheat germ to be in the range of 26-35% (Posner & Li 1991), 25-30% (Kirk & Sawyer 1991), 26% (Atwell 2001) and 26.5% (Bilgiçli et al 2006). The results obtained in the present study were in accordance with previously reported values. As seen from the findings, wheat germ is a very important protein source. They are rich in the essential amino acids which are not generally found in many cereals (Yiqiang et al 1999). Protein isolate extracted from

wheat germ meal can be utilized for some foods due to their high nutritional values (Hettiarachchy et al 1996; Ge et al 2000).

Ash contents of the wheat germ samples analyzed in the present study ranged between 4.58% (C) and 5.03% (B). The results of the present study were consistent with the previous ones (Oymak 2006; Gelmez 2008; Xie & Dunford 2011). However, lower ash content values were reported for wheat germ in the other studies (Posner & Li 1991; Atwell 2001; Jiang & Niu 2011). Ash content is an indicator of the minerals in wheat and ash is widely present in the scab and the germ parts of the wheat plant. Due to the non-uniform fractionation by sieving, the ash contents of different wheat germs may vary. The wheat germ is also rich in mineral composition. In a study conducted by Arshad et al (2007), it was demonstrated that calcium, iron and potassium levels of the cookies increased with supplementation of the wheat germ.

Oil contents of the germ samples were between 9.68% (E) and 11.67% (B). The results obtained in the present study were in accordance with previously obtained results in the literature (Kirk & Sawyer 1991; Oymak 2006; Xie & Dunford 2011). The slight differences could be resulted from wheat types, processing conditions of wheat and climatic factors directly affecting chemical composition of wheat. When considering the results obtained in the present and previous studies, it can be concluded that the wheat germ might be economically utilized as oil source.

3.2. Physicochemical properties of wheat germ oil samples

Colour values (*L, a* and *b*) of the extracted oil samples were presented in Table 2. *L, a* and *b* values of the samples ranged between 49.39-51.17, 0.75-3.92 and 32.17-35.19, respectively. There was no significant difference in color values of the three samples with the exception of sample B which had significantly lower *a* value than the other two groups. As it is seen from the results, color values of the samples were found to be very close to each other.

Free fatty acids, peroxide, iodine and refractive index values of the wheat germ oil samples extracted from different wheat varieties were given in Table 2. Free fatty acid values of the oil samples were determined to be 1.53, 1.82 and 4.95% oleic acid for B, C and E, respectively. Sample E had the highest free fatty acid value, which might result from its high unsaturated fatty acid content and low antioxidant activity. Jiang and Niu (2011) also studied free fatty acid contents of two different wheat germ oils and they found as 12.8 and 9.1% oleic acid, respectively. In the other study, Eisenmenger & Dunford (2008) studied bioactive properties of the wheat germ oil

Table 2- Some physicochemical properties of the wheat germ oils

Çizelge 2- Buğday ruşeymi yağlarının bazı fizikokimyasal özellikleri

Sample	*FFA*	*PV*	*IV*	*RI*
B*	1.53^{b}±0.10	1.68^{b}±0.11	135.32^{a}±0.01	1.4635^{b}
C	1.82^{b}±0.18	1.45^{b}±0.17	130.20^{b}±0.72	1.4602^{c}
E	4.95^{a}±0.13	2.73^{a}±0.17	135.78^{a}±0.47	1.4672^{a}
Sample	*Colour values*			
	L	*a*	*b*	
B	51.17^{a}±0.23	3.92^{a}±0.01	34.26^{a}±0.82	
C	50.93^{a}±0.88	0.75^{b}±0.04	35.19^{a}±1.12	
E	49.39^{a}±0.61	3.20^{a}±0.45	32.17^{a}±1.05	

*, different lowercase superscript letters in the same column show significant differences among the samples (P<0.05); FFA, free fatty acid (oleic acid, %); PV, peroxide value (meq O_2 kg^{-1}); IV, iodine value; RI, refractive index

extracted with hexane and they found that free fatty acid value of the oil sample was 7.9%. There are also different studies which supported our findings. El-Shami et al (2011) determined the free fatty acid values of wheat germ oils to be in the range of 4.5-5.0%. There are many factors affecting these variations since factors resulting in deterioration of oil also influence free fatty acid formation.

Peroxide values (PV) of B, C and E samples were determined to be 1.68, 1.45 and 2.73 meq O_2 kg^{-1} oil (Table 2). PV of B and E samples were found to be higher than that of the durum wheat (C) germ oil. This outcome was believed to be a consequence of the higher unsaturated fatty acid content of the bread wheat germ oil samples than the durum wheat germ oil sample. The saturation level of the oil sample was previously reported to affect the oxidative stability. Higher unsaturated fatty acid content is considered as an indicator for lower oxidative stability (Nas et al 2001). PV of solvent and SC-CO_2 (supercritical carbondioxide) extracted wheat germ oil samples were reported to be 2.95 and 2.05 meq O_2 kg^{-1} oil (Jiang & Niu 2011) and to be 0.9-1.0 meq O_2 kg^{-1} oil.

El-Shami et al (2011) determined the iodine value to be in the range of 115-120 in the previous study related with the fatty acid composition and nutritional value of the wheat germ oil extracted with chloroform/methanol and hexane solvents. The results obtained in the present study were lower than the values obtained by Jiang & Niu (2011).

Another important parameter analyzed in the present study is iodine value (IV) which provides information about saturation or unsaturation level of the oils. IV of the oil samples ranged between 130.20 and 135.78 (Table 2). The IV of the samples was close to each other; however, IV of sample C was found significantly lower ($P<0.05$) than those of the other two oil samples. Jiang & Niu (2011) and El-Shami et al (2011) determined IV of wheat germ oils extracted with different solvents in the range of 142.8-148.1 and 115-120, respectively.

The refractive index (RI) value of oil increases with the increases in the amount of unsaturated fatty acids and fatty acid chain length. In addition, it is possible to predict the IV based on the refractive index value of oil; therefore, correlation between IV and RI value is generally expected. RI value of the oil samples extracted from wheat germs was found in the range of 1.4602 and 1.4672 (Table 2). Data from Table 2 also indicated that significant difference was observed among RI values of the samples ($P<0.05$). RI values of different wheat germ oils varied between 1.474 and 1.483 at 25 °C (El-Shami et al 2011). The differences in RI values in the present study could be resulted from the fatty acid composition of the oils. Many factors including wheat types, climatic conditions, environmental factors and oil extraction process could affect these variations.

3.3. Fatty acid compositions of the germ oils

The fatty acid compositions of the germ oil samples were shown in Table 3. Fourteen fatty acids were determined in the wheat germ oil samples. In the fatty acids profile, palmitic acid (C16:0), oleic acid (C18:1) and linoleic acid (C18:2) were found as the predominant fatty acids with the varying concentrations of 18.00-18.87%, 17.92-21.54% and 59.59-64.08%, respectively. On the other hand, there was no significant ($P>0.05$) difference between total SFA amounts of B and E samples whereas C sample had the highest ($P<0.05$) SFA and MUFA levels.

Fatty acid composition of wheat germ oil has also been investigated by different researchers. Dunford & Zhang (2003) reported that the wheat germ oil extracted with hexane under high pressure conditions was composed of 56% linoleic acid. It was also reported that 81% of the fatty acid of the wheat germ oil was constituted by unsaturated fatty acids, 64% of which was polyunsaturated ones. The fatty acid composition of wheat germ oil was comprised of palmitic acid (16.72%), oleic acid (15.79%), linoleic acid (60.23%) and linolenic acid (6.2%) (Megahad & El Kinawy 2002). Arshad et al (2008) reported that fatty acid composition of wheat germ oil consisted of linoleic acid (56.99%), palmitic acid (18.09%), oleic acid (14.69%) and linolenic acid (9.51%), 82% and 66% of which were unsaturated fatty acid and PUFA, respectively.

Table 3- Fatty acid composition of the wheat germ oil samples (%)

Çizelge 3- Buğday rüşeymi yağı örneklerinin yağ asidi kompozisyonları (%)

Fatty acids	*Sample*		
	B	*C*	*E*
Myristic (C14:0)*	0.08^{a}±0.002	0.07^{a}±0.006	0.07^{a}±0.020
Palmitic (C16:0)	17.00^{ab}±0.04	17.70^{a}±0.08	16.66^{b}±0.46
Margaric (C17:0)	0.03^{a}±0.001	0.04^{a}±0.001	0.04^{a}±0.016
Stearic (C18:0)	0.69^{a}±0.01	0.74^{a}±0.047	0.59^{b}±0.017
Arachidic (C20:0)	0.16^{a}±0.01	0.15^{a}±0.055	0.18^{a}±0.045
Behenic (C22:0)	0.12^{a}±0.001	0.11^{a}±0.007	0.25^{a}±0.019
Lignoseric (C24:0)	0.09^{b}±0.040	0.07^{b}±0.028	0.21^{a}±0.027
Palmitoleic (C16:1) (C16:1)	0.07^{c}±0.002	0.11^{a}±0.002	0.09^{b}±0.003
Heptadecenoic (C17:1) (C17:1)	0.06^{a}±0.003	0.06^{a}±0.001	0.07^{a}±0.013
Oleic (C18:1)	16.59^{b}±0.10	20.38^{a}±0.048	16.56^{b}±0.22
Gadoleic (C20:1)	1.65^{a}±0.04	0.80^{c}±0.03	0.94^{b}±0.05
Erucic (C22:1)	0.25^{a}±0.01	0.19^{b}±0.02	0.24^{a}±0.01
Linoleic (C18:2)	56.05^{b}±0.02	53.88^{c}±0.36	57.55^{a}±0.21
Linolenic (C18:3)	7.15^{a}±0.03	5.70^{b}±0.50	6.53^{ab}±0.25
SFAs	18.18^{b}±0.09	18.87^{a}±0.12	18.00^{b}±0.24
MUFAs	18.62^{b}±0.15	21.54^{a}±0.01	17.92^{c}±0.20
PUFAs	63.20^{b}±0.05	59.59^{c}±0.13	64.08^{a}±0.04

*, different lowercase superscript letters in the same row show significant differences among the samples (P< 0.05); SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid

3.4. Bioavtive compounds of wheat germ oils

The antioxidant activity, total phenolics and α-tocopherol contents of the wheat germ oil samples were shown in Table 4. Antioxidant activity values of the germ oil samples ranged from 0.94 to 1.01 μmol g^{-1} germ oil.The sample B had the highest antioxidant activity (P<0.05). Total phenolic content of sample E was found as the lowest (P<0.05). The α-tocopherol levels varied from 1343 to 2176 mg kg^{-1} among the samples.

Antioxidant compounds neutralize free radicals in living organisms, thus, protecting the cells or facilitating cell renewal process (Gök & Serteser 2003). Antioxidant compounds react with free radicals to prevent cellular damage and tumor progression in tissues and they provide a healthy and high quality life in which the adverse effects of aging are minimal (Başer 2002).

The antioxidant activity of wheat germ oil has been widely investigated in the literature; however

Table 4- Bioactive properties of the wheat germ oils

Çizelge 4- Buğday rüşeymi yağlarının biyoaktif özellikleri

Sample	*Antioxidant activity (μmol g^{-1} germ oil)*	*Total phenolic content (mg GAE 100 g^{-1} oil)*	*α-tocopherol (mg kg^{-1})*
B*	1.01^{a}±0.01	116.42^{a}±2.79	2176^{a}±1.41
C	0.95^{b}±0.01	126.51^{a}±8.17	1343^{b}±2.83
E	0.94^{b}±0.01	67.79^{b}±6.53	1923^{a}±1.41

*, different lowercase superscript letters in the same column show significant differences among the samples (P<0.05)

germ oils obtained from Turkish wheat varieties have not been studied in terms of their antioxidant activity. Wheat germ oil has been demonstrated to have considerable antioxidant activity in the previous studies. Jiang & Niu (2011) determined the DPPH free radical scavenging activity of wheat germ oil and noted that the sample concentration of 40 mg mL^{-1} was able to inhibit 96.08% of the total DPPH radicals. Megahed et al (2011) reported that 60% free radical inhibition was achieved by the treatment with 400 µg mL^{-1} of wheat germ oil concentration. Pellegrini et al (2006) determined total antioxidant activity of white durum wheat as 13.1 mmol Fe^{2+} kg^{-1}, 2.1 mmol trolox kg^{-1} and 2.7 mmol trolox kg^{-1} by using the fluorescence recovery after photobleaching (FRAP), total radical-trapping antioxidant parameter (TRAP) and trolox-equivalent antioxidant capacity (TEAC) assays, respectively. Gelmez (2008) tested ultrasound assisted supercritical carbon dioxide ($SC\text{-}CO_2$) extraction method for antioxidant extraction from roasted wheat germ. In the results, amount of the total phenolics and tocopherols and total antioxidant activity were found to be 3-7 mg GAE g^{-1} extract, 0.31 mg tocopherol g^{-1} and 40-165 mg DPPH scavenger g^{-1} germ, respectively. As can be seen in the previous studies, different solvents and extraction methods for extraction of bioactive compounds from different food matrixes were investigated (Tsao & Deng 2004; Huang et al 2005). Phenolics were reported to be the most significant compounds with strong antioxidant activity in wheat (Andlauer & Fürst 1998; Anıl 2006; Doğan & Meral 2006; Dykes & Rooney 2007). In this respect, the results of this study were in accordance with those of the previous findings.

Similarly, Jiang & Niu (2011) reported that total phenolic content of the wheat germ oil obtained by $SC\text{-}CO_2$ and solvent extraction methods were found to be 8.64 µg GAE mL^{-1} and 4.02 µg GAE mL^{-1}, respectively. King (1962) reported the phenolic content in wheat germ as 3.49 mg ferrulic acid equivalent g^{-1}. Melikoglu (2005) noted that phenolic content of the ethanolic extracts of roasted and unroasted wheat germs were 1.7 mg GAE g^{-1} and as 2 mg GAE g^{-1}, respectively. In another study, total phenolic content of wheat was reported as 150 mg GAE 100 g^{-1} (Adom & Liu 2002).

Tocopherols constitute approximately 18% of the unsaponifiable fractions of wheat germ oil (Dunford 2008). Several different methods were used for the determination of the α-tocopherol content of wheat germ oil samples. In the previous studies, α-tocopherol contents were reported as 1300-2700 mg kg^{-1} (Wang & Johnson 2001), 1660 mg kg^{-1} (Arshad et al 2008), 1390 mg kg^{-1} (hexane extraction), 2560 mg kg^{-1} ($SC\text{-}CO_2$ extraction; Eisenmenger 2003), 1510 mg kg^{-1} (hexane extraction), 2560 mg kg^{-1} ($SC\text{-}CO_2$ extraction; Eisenmenger & Dunford 2008), 1640 mg kg^{-1} (hexane extraction) and 1665 mg kg^{-1} (chloroform/methanol extraction) (El-Shami et al 2011).

It is clear from the results of the previous studies that oil extraction method had aconsiderable effect on the α-tocopherol content of foods. The α-tocopherol content of the wheat germ oil obtained by $SC\text{-}CO_2$ extraction was reported to be higher than that of the oil obtained by hexane extraction in various studies (Eisenmenger 2003; Eisenmenger & Dunford 2008; El-Shami et al 2011). In the present study, the α-tocopherol contents of the samples B and E were higher than the previously reported values in spite of the employment of hexane extraction, whereas the α-tocopherol content of the sample C was similar to the previously reported values.

4. Conclusions

Several chemical properties of germ and germ oil samples obtained from different species of wheat were investigated in the present study and the results were compared based on the wheat variety. Investigation of the nutritional factors of wheat germ samples including oil, protein and ash indicated that the bread wheat germ (B, E) samples exhibited higher nutritional value than the durum wheat sample (C). Wheat germ is rich in protein content especially in comparison to other vegetable sources and it would be considered as a nutritional supplement owing to its highly nutritious content.

The wheat germ oil samples were shown to be considerably rich in unsaturated fatty acids, specifically polyunsaturated fatty acids. In addition, essential fatty acids such as linoleic acid and linolenic acid, which are not synthesized in the metabolism but rather need to be supplemented, were present in wheat germ oil at high levels. The quantity of some of the most significant functional compounds with favourable effects (apart from its nutritional value) on human health in wheat germ oil such as antioxidants, phenolic compounds and α-tocopherol were also determined. The antioxidant activity of the samples was almost similar. The phenolic contents were shown to vary even though it was the highest in the durum wheat germ oil sample (C). The α-tocopherol contents of the bread wheat germ oil samples (B, E) were considerably higher than that of the durum wheat germ oil sample. Approximately 5 g of wheat germ oil would be sufficient to meet the daily adult requirement which is 7-10 mg α-tocopherol. Wheat germ oil samples exhibited high contents of unsaturated fatty acids, essential fatty acids, antioxidant compounds and α-tocopherol which are eminently important bioactive compounds for human health. With this purpose in mind, wheat germ and wheat germ oil would be suggested as a supplement to enrich food products.

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