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QUALITY CHARACTERISTICS AND PHENOLIC COMPOUNDS OF EUROPEAN PEAR CULTIVARS

Ahmet Ozturk [1*], Leyla Demirsoy [1], Husnu Demirsoy [1] and Sema Ozturk [2]

[1]Department of Horticulture, Faculty of Agriculture, University of Ondokuz Mayıs, 55139, Samsun- Turkey,
[2]Department of Chemistry, Faculty of Art and Science, University of Ondokuz Mayıs, 55139, Samsun- Turkey,
***correspondence author E-mail:** ozturka@omu.edu.tr

Abstract

Background: Pear fruits are an important source of plant secondary metabolites and one of the major sources of dietary phenolic compounds.
Materials and Methods: The aim of this study was to determine the individual phenolic compounds and some quality characteristics of the flesh and peel of the fruit in four pear cultivars. The phenolic composition of these pear cultivars was determined by high performance liquid chromatography with diode array detection (HPLC-DAD).
Results: The fruit flesh firmness ranged from 35.2 to 85.8 N in the pear cultivars. The soluble solids content was higher in the flesh, while titrate-able acidity, vitamin C, individual phenolic compounds and total phenolics were generally higher in the peel. Arbutin, chlorogenic acid and epicatechin were detected as major phenolic compounds in the peel and flesh of pear fruits. Arbutin, chlorogenic acid and epicatechin of the flesh and peel ranged from 834.8 to 937.9 mg kg^{-1}; from 332.1 to 460.7 mg kg^{-1}; and from 77.2 to 104.0 mg kg^{-1} for 'Seckel' pear fruits, respectively. The highest total phenolics were found to be in the peel and flesh of the 'Flemish Beauty' pear fruits.
Conclusion: Because of the higher level of antioxidant components in the peel of pear fruits (all phenolic compounds and vitamin C) consumption of unpeeled pears, after proper washing, is recommended to maximize the dietary benefit.

Key words: Arbutin, Chlorogenic acid, Flesh and Peel, HPLC, Pear cultivars, Vitamin C

Introduction

The pear (*Pyrus communis* L.) is one of the most important temperate fruits and it is one of the most widely consumed fruits in the world (Bell et al., 1996; Hancock and Lobos, 2008). The fruit is typically eaten fresh and is often found in processed foods such as juice, puree, jam and jellies. They have different dietary phytonutrients such as flavonoids, phenolic compounds, carotenoids and vitamins with strong antioxidant capacities (Barraco et al., 2006; Kevers et al., 2011).

Many plants contain large amounts of antioxidants other than vitamin C, E and carotenoids, which significantly contribute to their total antioxidant capacity (Velioglu et al., 1998). Pear fruits contain a low level of protein and fat, while vitamin C, E and B complex vitamin contents are high. Pears are an extraordinary source of dietary fiber when the skin is eaten along with the flesh (Jackson, 2003; Ozcagiran et al., 2004). Vitamin C is one of the most important nutritional quality factors in many horticultural crops; it has many biological activities in the human body, and plays an important role in protecting plants from oxidative stress (Lee and Kader, 2000; Galvis-Sanchez et al., 2003).

Phenolic compounds are secondary metabolites widely distributed in plants. They are important components of many fruits and vegetables not only for their major influence on sensory qualities of the fruit (color, flavor, taste), but also for their antioxidant, anti-carcinogenic, antimicrobial, anti-allergic, anti-mutagenic and anti-inflammatory properties (Galvis-Sanchez et al., 2003; Tanrıöven and Eksi, 2005). Phenolic compounds are important for plants and humans for several reasons: they protect the plant from biotic and abiotic stressors, they contribute to some organoleptic and quality properties in food and they are considered beneficial for health because of their antioxidant capacity (Ruiz-Garcia and Gomez-Plaza, 2013).

In a fruit, the range and abundance of phenolic compounds can vary according to the cultivar, skin color, stage of maturity, harvest time, storage and environmental conditions, genetics, cultivation practices, year, infection with pests and diseases (Amiot et al., 1995; Galvis-Sanchez et al., 2003; Tanrıöven and Eksi, 2005; Andreotti et al., 2006; Kevers et al., 2011; Kramer et al., 2012). The chlorogenic acid, arbutin and epicatechin are main phenolic compounds in the pear (Amiot et al., 1995; Schieber et al., 2001). These phenolic compounds act as antioxidants (Galvis-Sanchez et al., 2003; Leontowitcz et al., 2002), coloring factors in the fruit and their products (Amiot et al., 1995).

Different organs and tissues of the pear, such as the skin, flower bud, leaf bud, young fruit, flesh and peel of the fruit have different levels of phenolic compounds. The skin of pear fruits has a much higher and more variable phenolic compound than the pulp and flesh (Kevers et al., 2011; Manzoor et al., 2013). A general recommendation is to consume the peel of pears because of its high level of phenolic compounds, vitamin C and antioxidant capacities (Galvis-Sanchez et al., 2003; Cui et al., 2005; Kevers et al., 2011).

The main aim of this study is to determine the firmness, soluble solids content, titrate-able acidity, vitamin C content and the total phenolic and individual phenolic compounds of the flesh and peel of four European pear cultivars.

Materials and Methods

Plant Material

This research was conducted at the commercial orchard of 'Türel Tobacco, Food and Agricultural Products Industrial Trade Corporation', located 41°18'09'' N and 36°18'05'' E and 20 m above sea level in Samsun, situated in the Central Black Sea Region of Turkey, in 2010 and 2011 years. As the plant material, 20 years old pear (*Pyrus communis* L.) trees cv. 'Seckel', 'Flemish Beauty', 'Grand Champion' and 'Triomphe de Vienne' grafted on a Quince A rootstock were selected. The trees were planted in a 4 x 5 m spacing and trained in the central leader system.

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Thirty fruit samples for each cultivar, randomly selected, were harvested carefully by hand at their commercial maturity stage (85 N-13.5%, 65 N-15.5%, 35 N-15.0% and 55 N-14.5% of flesh firmness and soluble solid content for 'Seckel', 'Flemish Beauty', 'Grand Champion' and 'Triomphe de Vienne', respectively), according to the fruit ripening time (harvest dates are indicated in Table 1). The harvested fruits were transported to the laboratory in plastic bags to reduce water loss during transportation. The fruits were cleaned to remove all foreign materials such as dust, dirt and chaff as well as immature and damaged fruits. Fruit samples were randomly separated into three replicated groups.

Table 1: Fruit weight (g), harvest date and skin color of pear cultivars

Pear cultivars	Fruit weight (g)	Harvest Date		Skin color
		2010	2011	
Seckel	153.6±3.4	1 Sept.	3 Sept.	Greenish-yellow-red blush
Flemish Beauty	173.7±5.9	25 Aug.	23 Aug.	Greenish-yellow-brown russets
Grand Champion	196.7±4.7	30 Aug.	2 Sept.	Greenish-yellow and completely golden russets
Triomphe de Vienne	231.0±5.4	25 Aug.	27 Aug.	Greenish-yellow
Mean	188.7±4.5			
CV (%)	2.38			

Chemicals and Reagents

Arbutin and (+)-catechin were supplied from Carl Roth (Karlsruhe, Germany). Rutintrihydrate and (−)-epicatechin were supplied from Fluka Chemie GmbH (Buchs, Switzerland). Chlorogenic, caffeic, *p*-coumaric acid, rutinhydrate and butylated hydroxytoluene (BHT; *2, 6-di-tertbutyl-4-methylphenol*) used as an anti-oxidative agent in the extraction solution, were purchased from Sigma Chemical Co. (St Louis, MO, USA). Methanol (an extraction solvent for phenolics) was from Sigma Chemical Co. (St Louis, MO, USA), acetic acid (an eluent) was supplied from Carlo-Erba (Italy), and acetonitrile (an elutant) was from Sigma-Aldrich Chemie GmbH (Steinheim, Germany). Folin-Ciocalteu reagent for the total phenolic measurement was supplied from Merck (Darmstadt, Germany). In all cases, the water used was bi-distilled, and purified in a Milli-Q water purification system by Millipore (Bedford, MA, USA). Phenolics standards were dissolved and diluted in methanol.

Extraction of Phenolic Compounds

Immediately after transporting and cleaning, the fruits were peeled with the peel and flesh separated and then cut into thin slices. The peel and flesh were stored in separated plastic bags at -20^{o}C until preparation of the samples. Ten samples per treatment consisting of three representative pear fruits for each cultivar were individually prepared for analysis of their phenolic. The extraction procedure was carried out according to Colaric et al. (2006). The pear slices of peel and flesh were homogenized to a puree with a homogenizer (PRO-200, Pro Scientific Inc, Oxford, USA). Bi-distilled water (up to a final volume of 50 mL) was added to 10 g of homogenized tissue. To determine the phenolic compounds, 1 g of the homogenized sample was weighed in a test tube and extracted once with 10 mL of methanol containing 1% BHT. BHT prevented oxidation of the samples, but had no effect on the extraction process and did not interfere with the extracted phenolic in the HPLC analysis which was carried out in an ultrasonic bath cooled with ice for 45min. The extracted samples were centrifuged (12.000×*g*, 10 min, 10^{o}C) and the supernatant was used for the HPLC analyses of the phenolic compounds after filtration through a 0.45 µm Millex syringe filter (Millipore, Billerica, USA).

Fruit Quality Characteristics

Fruit weight, skin color, titrate-able acidity (TA), soluble solids content (SSC) and vitamin C content were evaluated as quality characteristics. Immediately after transporting to the laboratory, fruit weight, flesh firmness, titrate-able acidity (TA) and the soluble solids content (SSC) were determined in the peel and flesh. Fruit weight was measured by using a digital balance with a sensitivity of 0.01g (Precisa BJ 6100D, Dietikon, Switzerland). Flesh firmness was determined according to method reported by Dumanoglu et al. (2006) and then converted to Newton (N). The skin color was classified as "green", "green-yellow", "yellow" or "red" (IBPGR, 1983). Immediately, fruits after transport to the laboratory, titrate-able acidity (TA) and the soluble solids content (SSC) were determined in the peel and flesh. The soluble solids content was measured with a digital refractometer at a temperature of 25^{o}C and expressed as a percentage. The titrate-able acidity was determined according to Demirsoy and Demirsoy (2003) and expressed as g of malic acid per 100 mL^{-1}. Mature fruit samples were stored in a deep-freeze at -20^{o}C until analyzed for vitamin C. Vitamin C content was based on the spectrophotometric procedure described by Kilic et al. (1991) and expressed as mg 100 g^{-1}.

Analyses of Individual Phenolic Compounds

The HPLC method (Schieber et al., 2001; Colaric et al., 2006) was used to determine the phenolic compounds (arbutin, chlorogenic acid, (-)-epicatechin, (+) catechin, caffeic acid, *p*-coumaric acid, caffeic acid, rutin-hydrate and rutin-tri-hydrate). The separation of the phenolic compounds was performed using the HPLC system (Shimadzu, Kyoto, Japan), with a DGU-20A$_5$ degasser, a gradient pump LC-20AT, an auto-sampler SIL-20A, a column oven CTO-10ASVP and a diode array detection (DAD) system SPD-M20A. The column used was the Luna 5µ C$_{18}$ 100A (250x4,6 mm) from Phenomenex (Torrance, CA, USA). The column temperature was maintained at 25^{o}C. The chromatographic conditions were similar to those previously described by Schieber et al. (2001) with minor modifications. The mobile phase A contained 2% (v/v) acetic acid prepared in bidistilled water; the eluent B consisted of 0.5% acetic acid in bi-distilled water and acetonitrile (50:50, v/v). The gradient was as follows: 90 to55% of A within 40min, 55 to 0% of A within 5 min, and returning to the initial 90% of A within 5 min. Between each analysis 15 min of equilibration treatment (90% of A) was performed. The flow rate was 1 mL min^{-1} and the injection volume was 20 µL. The total run time was 45 min.

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Analyzed compounds were identified by addition of standard solutions in combination with retention times as well as by comparing their spectra with those of corresponding standards. Absorbance monitoring of eluted phenolic compounds was done at 280 nm for arbutin, catechin, epicatechin, chlorogenic acid and at 320 nm for caffeic acid, *p*-coumaric acid and at 370 nm for rutin-hydrate and rutin-tri-hydrate. Quantification was achieved by comparing to the concentrations with a corresponding external standard. Concentrations of analyzed compounds are expressed in mg per kg.

Determination of Total Phenolic Content

Prior to analysis, 100 g samples of pear peel and flesh were homogenized in a stainless steel blender. Total phenolic content was measured according to the Singleton and Rossi (1965) procedure and the results are expressed as mg garlic acid equivalent (GAE) per kg fresh weight (FW).

Statistical Analysis

The normality of the data was confirmed by the Kolmogorov-Smirnov test and the homogeneity of variances by the Levene's test. The data sets were analyzed with two-way ANOVA using SAS Version 9.3 (SAS Institute Inc., Cary, NC, USA) software; the means were compared with the 'Duncan Multiple Tests' and the level of significance was determined at 5% ($p < 0.05$). The data presented in tables and figures are based on averages of two years (2010 and 2011).

Results and Discussion

Fruit Quality Characteristics

Significant differences were found in terms of fruit flesh firmness among the pear cultivars. The fruit flesh firmness was found to increase from 35.2 N to 85.8 N, in the following order: 'Seckel' < 'Flemish Beauty' < 'Triomphe de Vienne' < 'Grand Champion' (Fig 1). Mean fruit weight varied from 153.6 g to 231.0 g (Table 1). Flesh firmness, fruit weight, soluble solids content, titrate-able acidity and the skin color of the fruit can be used to determine the best time to harvest the pears and they are the most important indicators for both the quality and maturity of the pears (Karacali, 1990; Kawamura, 2000). Significant differences for the soluble solids content were observed in the flesh of the pear cultivars, but not observed in the peel. The soluble solids content varied from 13.6% to 15.3% in the flesh and from 13.4% to 14.6% in the peel. 'Flemish Beauty' had the highest SSC content in the peel and the flesh, while 'Seckel' had the lowest. In the pear cultivars, SSC was always higher in the flesh than in the peel (Table 2). These results were similar to previously reported values by several authors (Galvis-Sanchez et al., 2003; Tanrıöven and Eksi, 2005; Ozturk et al., 2009; Hussain et al., 2013). The titrate-able acidity ranged from 0.40 to 0.51 g malic acid 100 mL^{-1} in the flesh and was from 0.42 to 0.58 g malic acid 100 mL^{-1} in the peel, with significant differences among the pear cultivars. 'Flemish Beauty' had the highest TA in the peel, whereas 'Grand Champion' had the highest in the flesh (Table 2). TA content was very close to that shown by Galvis-Sanchez et al. (2003), who reported that pear fruits contained 0.06-0.23g 100 mL^{-1}, Ozturk et al. (2009) who determined that the pear contained 0.48-0.60 % of TA, Hussain et al. (2013), who cited that pear fruits contained 0.12-0.26% of TA.

In this study, SSC and TA values varied from cultivar to cultivar. The variation of SSC and TA in pear fruits could be the result of cultivar differences (Ozturk et al., 2009). Significant differences were observed in the vitamin C content among the pear cultivars, being slightly higher in the peel than in the flesh. The vitamin C content ranged from 8.3 to 14.5 mg $100g^{-1}$ in the flesh and from 12.7 to 23.6 mg $100g^{-1}$ in the peel. 'Seckel' had the highest vitamin C content in the flesh and peel. The lowest vitamin C content was in the flesh of 'Flemish Beauty' and in the peel of 'Triomphe de Vienne'. 'Flemish Beauty' and 'Grand Champion' had similarly low vitamin C content in the peel (Table 2). This result is in accordance with previous studies showing similar vitamin C contents (Galvis-Sanchez et al., 2003; Ozturk et al., 2009). Also, Lee and Kader (2000) cited that the vitamin C content of fruits can vary according to the cultivar and tissue. Skin tissues have a generally higher vitamin C content to protect the fruit from outside stress caused by light and oxidation. The same authors reported that vitamin C plays a major role in the defense against free radicals inducing peroxidation in stressed plants. Additionally, vitamin C is one of the most important vitamins for human nutrition and it acts as an antioxidant, required for the prevention of chronic diseases, scurvy and the maintenance of healthy skin (Lee and Kader, 2000). The concentration of vitamin C can be influenced by various factors such as genotypic differences, cultivar, maturity, harvest practices, postharvest handling procedures, climatic and storage conditions (Lee and Kader, 2000; Ozturk et al., 2009). This finding in the present study could be related to the browning susceptibility of some cultivars and the capacity to avoid browning during postharvest storage (Galvis-Sanchez et al., 2003).

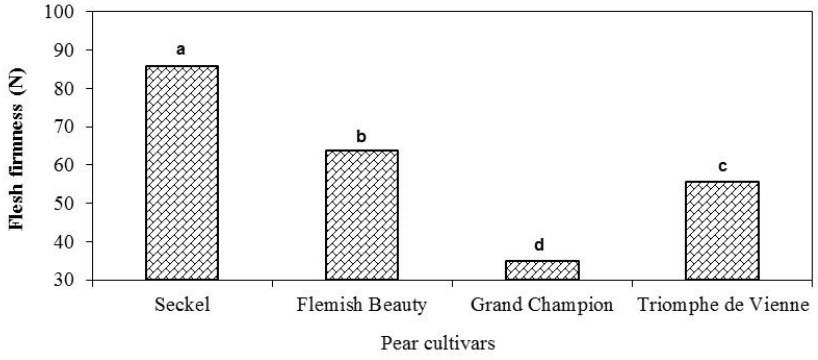

Figure 1: Flesh firmness of pear cultivars [(n= 60 for flesh firmness (10 fruits x 3 replications x 2 years). The difference between mean values shown with the same letter is not significant (P<0.05)].

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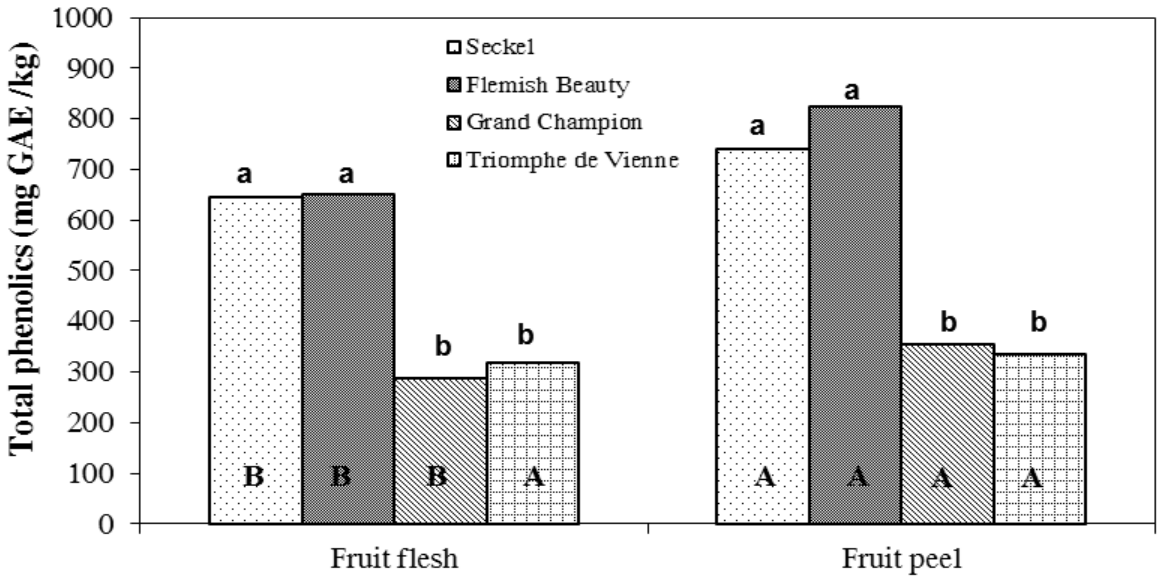

Figure 2: Total phenolics in the fruit flesh and peel of each pear cultivar [n= 30 for total phenolics (2 years x 3 replications x 5 different measurements for each replications). The difference between mean values shown with the same letter on the histograms is not significant. Values followed by different capital letters for each pear cultivar indicate significant differences among flesh and peel of fruit ($p<0.05$)].

Table 2: Soluble solids content (SSC), titratable acidity (TA) and vitamin C content of pear cultivars

Quality Characteristics	Fruit Tissue	Pear cultivars				Mean
		Seckel	Flemish Beauty	Grand Champion	Triomphe de Vienne	
SSC	*Flesh*	13.6 b	15.3 a	14.8 ab	14.6 ab	14.6 A
	Peel	13.4 a	14.6 a	14.6 a	14.2 a	14.2 A
TA	*Flesh*	0.43 bc	0.48 ab	0.51 a	0.40 c	0.46 A
	Peel	0.45 bc	0.58 a	0.52 b	0.42 c	0.49 A
Vitamin C	*Flesh*	14.5 a	8.3 c	10.9 b	11.9 b	11.4 A
	Peel	23.6 a	13.5 b	13.3 b	12.7 b	15.8 B

n= 18 for SSC, TA and vitamin C (2 years x 3 replications x 3 different measurements for each replicate). The difference between mean values shown on the same line with the same letter is not significant. For each quality characteristic, the difference between mean values shown on the same column with the same capital letter is not significant ($P<0.05$).

Phenolic Contents in Pear Flesh and Peel

Significant differences in arbutin content were observed among the pear cultivars. In the flesh and peel, 'Seckel' had the highest arbutin content, while 'Triomphe de Vienne' had the lowest (Table 3). Arbutin and chlorogenic acid were detected as the major phenolic compounds in the peel and flesh of the pear. Lin and Harnly (2008) reported that arbutin and chlorogenic acid are the main phenolic compounds in the peel of the pear. Arbutin content was higher than the chlorogenic acid content in the peel and flesh. Arbutin content varied from 362.3 to 834.8 mg kg^{-1} in the flesh and from 583.0 to 937.9 mg kg^{-1} in the peel among the cultivars. Arbutin content was always higher in the peel than in the flesh (Table 3). This result confirmed findings of Galvis-Sanchez et al. (2003) and Cui et al. (2005). In the present study, the arbutin contents were considerably higher than those previously reported by Schieber et al. (2001) (0.4-1.0 mg kg^{-1} FW) and Salta et al. (2010) (2.6-22.5 mg 100^{-1} FW).

Statistical differences were observed in terms of the chlorogenic acid contents in the pear cultivars. The fruit flesh of 'Flemish Beauty' had higher chlorogenic acid contents, whereas the levels were lowest in the 'Grand Champion' (Table 3). The contents of chlorogenic acid in this study are in accordance with Galvis-Sanches et al. (2003), who reported that chlorogenic acid content is always higher in the peel than in the flesh. These findings were similar to those previously reported by Amiot et al. (1995) and Colaric et al. (2006; 2007) and were quite a bit higher than those reported by Salta et al. (2010), who cited that chlorogenic acid content ranged from 2.6 to 5.6 mg $100g^{-1}$ FW in the 'General Leclerc', 'Comice', 'Abate' and 'Passe Crassane' pear cultivars. Arbutin and chlorogenic acid have a role as coloring factors in the fruit and they have an important role in plant defense metabolism (Amiot et al., 1995; Cui et al., 2005). Chlorogenic acid is the most important antioxidant-active constituent in pears and as a potential chemo-preventive agent; it may promote the prevention of chronic diseases (Galvis-Sanchez et al., 2003). Additionally, Galvis-Sanches et al. (2003) cited that red and green pears have higher antioxidant components (phenolic, vitamin C and antioxidant capacity) than the others. However, enzymatic browning of pears has been associated with the presence of chlorogenic acid in the fruit, even though the extent of browning seems to be mostly dependent upon the level of maturity.

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Table 3: Phenolic compounds of pear cultivars

Individual phenolics (mg kg^{-1})	Tissue Types	Pear cultivars				Mean
		Seckel	Flemish Beauty	Grand Champion	Triomphe de Vienne	
Arbutin	*Fruit flesh*	834.8 a*	700.9 b	802.0 a	362.3 c	675.0 B
	Fruit peel	937.9 a	855.6 b	926.2 a	583.0 c	825.7 A
Chlorogenic acid	*Fruit flesh*	332.1 b	380.2 a	72.1 d	94.1 c	219.6 B
	Fruit peel	460.7 b	528.4 a	124.2 c	107.6 d	305.2 A
Caffeic acid	*Fruit flesh*	4.5 d	15.6 b	8.5 c	32.9 a	15.4 B
	Fruit peel	6.1 d	20.5 b	13.5 c	35.2 a	18.8 A
Catechin	*Fruit flesh*	48.7 a	22.4 c	34.4 b	32.2 b	34.4 B
	Fruit peel	64.1 a	46.1 c	36.9 d	55.8 b	50.7 A
Epicatechin	*Fruit flesh*	77.2 a	44.3 d	63.5 b	49.8 c	58.7 B
	Fruit peel	104.0 a	62.0 c	66.3 c	84.3 b	79.1 A
p-coumaric acid	*Fruit flesh*	0.75 c	1.64 a	0.95 b	0.20 d	0.88 B
	Fruit peel	0.78 c	1.69 a	0.98 b	0.30 d	0.94 A
Rutinhydrate	*Fruit flesh*	0.76 b	1.00 a	0.84 b	0.79 b	0.83 B
	Fruit peel	0.77 c	1.02 a	0.94 ab	0.88 b	0.90 A
Rutintrihydrate	*Fruit flesh*	0.33 a	0.02 b	0.01 b	0.02 b	0.09 A
	Fruit peel	0.34 a	0.03 b	0.02 b	0.03 b	0.10 A

*n= 18 for phenolic compounds (2 years x 3 replications x 3 different measurements for each replicate). The difference between mean values shown on the same line with the same letter is not significant. For each phenolic compound, the difference between mean values shown with the same capital letter on the same column is not significant between flesh and peel tissue ($P<0.05$).

The caffeic acid content ranged from 4.5 mg kg^{-1} to 32.9 mg kg^{-1} in the flesh and from 6.1 mg kg^{-1} to 35.2 mg kg^{-1} in the peel, with significant differences among to the pear cultivars. Caffeic acid content was always higher in the peel than in the flesh (Table 3). The caffeic acid contents found in this study were considerably higher than those reported by Colaric et al. (2006), but were in agreement with the values of Tanrıöven and Eksi (2005) and Salta et al. (2010).

p-Coumaric acid was detected as the minor hydroxycinnamic derivative. Its content varied from 0.20 to 1.64 mg kg^{-1} in the flesh and from 0.30 to 1.69 mg kg^{-1} in the peel of the cultivars, in the following decreasing order: 'Flemish Beauty' > 'Grand Champion' > 'Seckel' > 'Triomphe de Vienne' (Table 3). This finding is in accordance with Tanrıöven and Eksi (2005) and Salta et al. (2010).

The 'Seckel' had the highest epicatechin content in the flesh and peel (77.2 and 104.0 mg kg^{-1} respectively) and 'Flemish Beauty' had the lowest (44.3 and 62.0 mg kg^{-1} respectively). Epicatechin was always higher in the peel than in the flesh (Table 3). Epicatechin contents found in this study were similar to those previously reported (Tanrıöven and Eksi, 2005; Salta et al., 2010).

The catechin values were about one half of those for epicatechin in all cultivars. Catechin was always higher in the peel than in the flesh (Table 3). Catechin contents found in this study were quite a bit higher than those previously reported (Amiot et al., 1995; Colaric et al., 2006), but were in accordance with the values of Salta et al. (2010). Catechin content in the peel of the pear is higher than in the flesh (Colaric et al., 2006; Karacali, 1990).

Rutin-hydrate and rutin-tri-hydrate were detected as the minor phenolic compounds in the flesh and peel. Significant differences were found in the flavonol derivates among the cultivars (Table 3). Rutin-hydrate was slightly higher than rutin-tri-hydrate in the pear. This result was quite similar to those previously reported by Schieber et al. (2001). The flavonols are located mainly in the peel (Macheix et al., 1990).

The total phenolic content of pear cultivars varied from 286.5 to 649.5 mg GAE kg^{-1} in the flesh and from 334.6 to 824.8 mg GAE kg^{-1} in the peel. In the flesh, 'Flemish Beauty' and 'Seckel' had the highest total phenolic content, while 'Triomphe de Vienne' and 'Grand Champion' had the lowest. In the peel, 'Flemish Beauty' and 'Seckel' had the highest total phenolic content, while 'Grand Champion' and 'Triomphe de Vienne' had the lowest (Fig 2). In the present study, the total phenolic content was very close to that shown by Tanrıöven and Eksi (2005), who reported that pear juice contained 196-457 mg L^{-1} and Manzoor et al. (2013), who noted that pear pulp contained 333.90-355.80 mg GAE $100g^{-1}$ DW (dry weight) and pear peel contained 601.50-619.80 mg GAE $100g^{-1}$ DW of total phenolic contents in two local pear cultivars. These values were slightly higher than those reported by Salta et al. (2010) (164.3 mg 100 g^{-1} FW in Rocha pear) and Kevers et al. (2011) and considerably higher than those reported by Galvis-Sanchez et al. (2003) in the other pear cultivars. The pear fruits have the highest percentage rate of total flavonoids and total phenolics compared to any other fruits (Marinova et al., 2005). Moreover, the same authors reported that unpeeled pear fruits showed a significantly higher content of total phenolics and flavonoids than peeled pear fruits.

In this study, except for SSC in the peel of the pear cultivars, significant differences existed in all of the examined characteristics among the cultivars. Soluble solids content was higher in the flesh than in the peel, while titrate-able acidity, vitamin C, all phenolic compounds and total phenolic were higher in the peel than in the flesh. The main reason for these differences is probably that the phenolic content in the pear is specifically affected by the fruit variety not by the stage of maturity (Amiot et al., 1995). Additionally, the level of phenolic compounds in fruits is strongly highly dependent upon many external and internal factors, such as stage of maturity, variety, storage and environmental or genetic factors (Macheix et al., 1990; Amiot et al., 1995; Tanrıöven and Eksi, 2005; Andreotti et al., 2006; Ozturk et al., 2009; Kramer et al.,

2012). According to the results of this study, arbutin and chlorogenic acid were detected as major phenolic compounds in the peel and flesh, while rutin-hydrate and rutin-tri-hydrate were detected as minor ones in the examined pear cultivars. This result is in accordance with previously reported studies (Galvis-Sanchez et al., 2003; Cui et al., 2005; Lin and Harnly, 2008; Salta et al., 2010).

Conclusions

Phenolic compounds are commonly found in fruits and vegetables which are considered important sources of dietary phenols. Fruits are one of the most important sources of phenolic compounds for human health. In this study, the quantity of phenolic compounds was found to be higher in the peel than in the flesh in pear fruits. If the pear is eaten with its peel, it is a good source of dietary fibre. From the nutritional point of view, due to the higher levels of antioxidant components in the peel of pear fruits (all phenolic compounds and vitamin C), consumption of unpeeled pears, after proper washing, is recommended to maximize the dietary benefit.

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