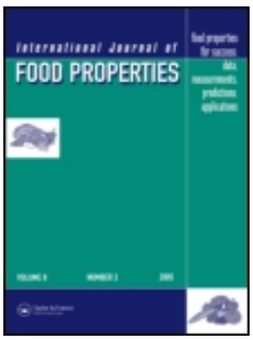

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Phenolic Compounds and Chemical Characteristics of Pears (*Pyrus Communis* L.)

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This study was carried out to determine the phenolic compounds and some chemical characteristics at flesh and peel in some pear cultivars. The fruit weight was varied from 45.9 to 479.9 g and flesh firmness was varied from 29.4 to 89.7 N. Soluble solids content was higher in the flesh than in the peel, while pH, titratable acidity and all phenolic compounds were generally higher in the peel than in the flesh. Quantitative differences were found in the phenolic compounds among the pear cultivars. 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 a minor in the peel and flesh. Catechin ranged from 40.0 to 543.8 mg kg^{-1} in the flesh and 42.4 to 695.2 mg kg^{-1} in the peel. Epicatechin content varied from 11.47 to 243.1 mg kg^{-1} in the flesh and 12.6 to 315.4 mg kg^{-1} in the peel. The ranges of vitamin C content were from 9.1 to 29.7 mg 100 g^{-1} in the flesh and 9.5 to 35.9 mg 100 g^{-1} in the peel. Pear peel indicated higher contents of phenolics than pear flesh, confirming the health benefit of the consumption of pears together with peel.

Keywords: Arbutin, Chlorogenic acid, Firmness, HPLC, Pear cultivar, Vitamin C.

INTRODUCTION

Phenolic compounds are plant secondary metabolites that constitute one of the most common and widespread groups of substances in plants. They give unique stringent taste of fruit and vegetable and they can cause color changes in foods.[1] Phenolics have been shown to have a role in tissue browning, flavor, and color characteristics of fruits and derived products.[2,3] Phenolics have also many roles in plant defense and human health metabolism. They have been shown to have antioxidative,[4] antimutagenic, and anticarcinogenic properties,[5] protective roles against cancer, cardiovascular disease and cataract, antibacterial,[6] antifungal,[7] and enzyme inhibiting effects.[8] The level of phenolic contents in fruits is highly dependent on many factors, such as cultivar, stage of maturity, storage and environmental conditions, genetics, cultivation practices, year, infection with

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pests, and diseases.[2,3,9–15] An understanding of phenolic composition in fresh fruit and the factors that affect phenolics is critical in the design of products and storage conditions.

In pear, the main phenolic compounds are chlorogenic acid and arbutin and epicatechin.[3,16] These phenolic compounds acts as antioxidants[17,18] or as coloring factors in the fruit and their products.[10] Chlorogenic acid is the most important antioxidant-active constituent in pears,[18] as a potential chemopreventive agent, it might promote the prevention of chronic diseases, such as cancer and cardiovascular disease, anticancer activity, immune system enhancement, reduce the toxic effects of chemotherapy drugs.[19,20] Arbutin, another important phenolic compound in pear fruit, acts as an antibiotic substance in fire blight resistance.[21] Different organs and tissues of pear, such as skin, flower bud, leaf bud, young fruit, flesh, and peel of fruit, have different level of phenolic compounds. The skins of pear have much higher and more varied phenolic contents than the flesh of the fruit.[18,22,23]

Vitamin C, E, and B complex vitamin contents are high, although pears are contain low level of protein and fat. They provide a very good source of fiber, copper, and potassium. Pears are an extraordinary source of dietary fiber when the skin is eaten along with the flesh. They are also an excellent source of vitamin C and vitamin E, both powerful antioxidants and essential nutrients.[24] Vitamin C is one of the most important nutritional quality factors in many horticultural crops and has many biological activities in the human body.[25] The aim of this study was to determine the phenolic compounds and selected chemical characteristics in the flesh and peel of some pear cultivars.

MATERIAL AND METHODS

Chemicals and Reagents

Arbutin and (+)-catechin were purchased from Carl Roth (Karlsruhe, Germany). Rutintrihydrate and (−)-epicatechin were purchased from Fluka Chemie GmbH (Buchs, Switzerland). Chlorogenic acid and caffeic acid and rutinhydrate and p-coumaric acid and butylated hydroxytoluene (BHT; 2,6-di-tertbutyl-4-methylphenol), used as an antioxidative agent in the extraction solution, were obtained 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 purchased from Carlo-Erba (Italy), and acetonitrile (an elutant) was from Sigma-Aldrich Chemie GmbH (Steinheim, Germany). In all cases water used was bidistilled, and purified in a Milli-Q water purification system by Millipore (Bedford, MA, USA). Phenolics standards were dissolved and diluted in methanol.

Plant Material

This research was performed on 13 local and 4 standard pear cultivars grown in Sinop, located between 41° 12′ and 42° 06′ North latitude and 34° 14′ and 35° 26′ East longitude and about 250 m above sea level, situated in the Western Black Sea Region, Turkey, during 2010. For each cultivar, 30 randomly selected fruits were harvested carefully by hand at their commercial maturity stage and they were transported to laboratory in plastic bags to reduce water loss. The fruits were cleaned to remove all foreign materials such as dust, dirt, and chaff as well as immature and damaged fruits.

Extraction of Phenolic Compounds and Quality Indices

Immediately after transport and cleaning, the fruits were peeled and separated peel and flesh and they cut into thin slices and the peel and flesh separately stored in plastic bags at −20°C until preparation of the samples. From 30 harvested fruits, ten samples per treatment (replication), consisting of three representative pear fruits of each cultivar were individually prepared for analyses of phenolics.

The extraction procedure was carried out according to Colaric et al.[26] The pear slices of peel and flesh were homogenized to a puree with a homogenizer (PRO-200, Pro Scientific Inc, Oxford, CT, USA). Bidistilled water (up to a final volume of 50 mL) was added to 10 g of homogenized tissue. To determine of phenolic compounds, 1 g of the homogenized sample was weighed into a test tube and extracted once with 10 mL of methanol containing 1% BHT, prevented oxidation of samples, but did not influence the extraction process and did not interfere with the extracted phenolics in HPLC analysis, in an ultrasonic bath cooled with ice for 45 min. The extracted samples were centrifuged (12,000 × *g*, 10 min, 10°C) and the supernatant was used for HPLC analyses of phenolic compounds after filtration through a 0.45 μm Chromafil polyamide filter (Millipore Corp., Bedford, USA).

Chemical Characteristics

Immediately after transport to laboratory, fruit weight, fruit firmness, skin color, titratable acidity (TA), pH, soluble solids content (SSC) and vitamin C content were evaluated as quality characteristics in peel and flesh. Fruit weight was measured by using a digital balance (Precisa BJ 6100D, Dietikon, Switzerland) with a sensitivity of 0.01 g. Flesh firmness was tested on two sides of each fruit by a penetrometer with a 7.8 mm plunger after removal of the peel and it was read in kilograms, and then converted to Newton (N).[27] The skin color was classified as "green," "green-yellow," "yellow," and "red."[28] SSC was measured with a Carl-Zeiss Abbe refractometer (Atago ATC-1, Tokyo, Japan) in 25°C temperature. For TA, a 5 ml sample of juice was diluted with 45 ml of distilled water and then titrated with 0.1 N NaOH. TA was expressed as equivalent of malic acid 100 g^{-1}).[29] pH was measured by pH meter (PHSJ-4A, Shanghai, China). Vitamin C content was based on spectrophotometric procedure.[29] Mature fruit samples were stored in a deep-freeze at –20°C until analyzed for Vitamin C. Fruit samples were waited at room temperature until thawed and were transformed into fruit peel and flesh of pulp by crushing between the fingers. Five grams of pulp was added to 50 ml with 0.4% oxalic acid solution. Spectrophotometric readings were made at 520 nm. The results were expressed as mg kg^{-1}.

Analyses of Phenolic Compounds

HPLC method[26,30] was used to determine the phenolic compounds (arbutin, chlorogenic acid, (−)-epicatechin, (+) catechin, caffeic acid, *p*-coumaric acid, caffeic acid, rutinhydrate, and rutintrihydrate). The separation of the phenolic compounds was performed on a HPLC system (Shimadzu, Kyoto, Japan), with a degasser DGU-20A_5, a gradient pump LC-20AT, an autosampler SIL-20A, column oven CTO-10ASVP and diode array detection (DAD) system SPD-M20A. The column was used Luna 5μ C_{18} 100A (250 × 4.6 mm) from Phenomenex (Torrance, CA, USA). Column temperature was maintained at 25°C. The chromatographic conditions were similar to those previously described by Schieber et al.[30] with minor modifications. The mobile phase A was 2% (v/v) acetic acid prepared in bidistilled water; eluent B was 0.5% acetic acid in bidistilled water and acetonitrile (50:50, v/v). The gradient was as follows: 90 to 55% of A within 40 min, 55 to 0% of A within 5 min, and returning to the initial 90% of A within 5 min. the among of 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 50 min.

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 rutinhydrate and rutintrihydrate. Quantification was achieved according to the concentrations of a corresponding

external standard. Concentrations of analysed compounds are expressed in mg kg^{-1}. Data are presented as mean ± standard error (SE) for each treatment.

Statistical Analysis

Data were analyzed using Statistical Analysis Software procedures and software (SAS, Cary, NC, USA). Means and standard deviations were calculated. Calculations of analysis of variance tables were not statistically valid as the pear cultivars were not sampled from a common environment with an experimental design. To evaluate variation between cultivars for variables tests, coefficient of variations (C.V.) were calculated and expressed as percentages. C.V. were calculated, dividing relevant standard deviations by means and multiplying by 100.

RESULTS AND DISCUSSION

Chemical Characteristics

The harvest date was varied from 13 July to 10 October, fruit weight varied from 45.9 g to 479.9 g in examined pear cultivars. Fruit firmness varied from 29.4 N to 89.7 N among to pear cultivars (Table 1). Fruit weight, SSC, TA, and skin color of fruit can be used in order to determine the best time of harvest of pears and they are the most important indicators for both quality and maturity of pears.[31,32] SSC varied from 6.5 to 16.2% in the flesh and peel of pear cultivars. "Kara" had the

TABLE 1
Harvest date, skin color of fruit, fruit weight (g), fruit firmness (*N*), and soluble solid content (%) of pear cultivars

Cultivars	*Harvest date*	*Skin color of fruit*	*Fruit weight*[x] *(g)*	*Fruit firmness*[x] *(N)*	*Soluble solids content*[y] *(%)*	
					Flesh	*Peel*
Istanbul	13 July	Yellow and red blush	45.9 ± 1.9	66.9 ± 4.3	9.2 ± 0.1	7.7 ± 0.6
Seker	13 July	Greenish-yellow red blush	56.5 ± 2.2	29.4 ± 3.6	9.7 ± 0.3	8.6 ± 0.5
Kıs	10 Oct.	Greenish-yellow	339.1 ± 9.6	69.1 ± 3.3	11.6 ± 0.2	9.5 ± 0.8
Bardak	04 Aug.	Greenish-yellow	170.3 ± 5.5	40.9 ± 3.4	8.9 ± 0.2	6.5 ± 0.4
Fırıncık	23 Aug.	Greenish-yellow	68.1 ± 3.1	64.8 ± 4.4	10.2 ± 0.5	7.0 ± 0.8
Esek	02 Sept.	Greenish-yellow	200.8 ± 7.6	74.3 ± 5.1	12.9 ± 0.3	11.3 ± 0.4
Pazar	04 Aug.	Greenish-yellow	81.9 ± 2.3	70.4 ± 5.8	12.6 ± 0.2	12.2 ± 1.0
Yaz Ziraati	04 Aug.	Greenish-yellow	192.5 ± 6.6	81.8 ± 6.6	8.8 ± 0.4	6.8 ± 0.5
Karpuz	13 July	Greenish-yellow red blush	100.7 ± 3.8	42.7 ± 3.3	7.4 ± 0.1	7.0 ± 0.2
Sarıkum	04 Aug.	Yellow- red blush	90.7 ± 3.5	61.5 ± 4.4	12.90 ± 0.3	10.0 ± 1.1
Kara	02 Sep.	Greenish-yellow-red blush	129.2 ± 5.1	56.9 ± 4.7	16.2 ± 0.5	15.5 ± 0.8
Rıza	02 Sep.	Yellow	134.0 ± 3.4	67.9 ± 5.6	13.8 ± 0.5	12.3 ± 0.5
Dalkıran	10 Oct.	Greenish-yellow- red blush	479.9 ± 9.9	89.7 ± 8.2	15.0 ± 0.6	14.2 ± 0.8
Deveci*	01 Oct.	Greenish-yellow	219.5 ± 7.7	89.3 ± 9.1	14.0 ± 0.8	13.4 ± 0.5
Williams*	05 Sep.	Greenish-yellow	182.7 ± 5.8	72.9 ± 7.2	13.0 ± 0.2	12.7 ± 0.3
Abbe Fetel*	05 Sep.	Yellow-rusty	222.2 ± 12.4	72.9 ± 7.4	14.6 ± 0.4	14.4 ± 0.5
Santa Maria*	23 July	Yellow and red blush	200.2 ± 9.6	66.7 ± 6.6	9.4 ± 0.1	9.3 ± 0.5
Mean			171.4 ± 5.8	64.9 ± 5.5	11.7 ± 0.3	10.4 ± 0.6
C.V. (%)			3.43	8.47	2.84	5.71

*: Standard pear cultivars;
x: $n = 30$ (3 replications × 10 different measurements for each replicate);
y: $n = 9$ (3 replications × 3 different measurements for each replicate).

highest SSC in the peel and the flesh. In the pear cultivars, SSC was always higher in the flesh than in the peel (Table 1). These results were similar to previously reported values in the pear.[1,18,33,34] TA varied from 0.11 to 0.67%, "Kıs" had the highest TA in the flesh and the peel (Table 2). TA content was very close to that shown by Galvis-Sanchez et al.,[18] who reported that pear fruits contained 0.06–0.23 g 100mL^{-1}, Ozturk et al.[34] determined that pear contained 0.48–0.60% of TA. The pH was ranged from 3.43 to 4.87 in the flesh and from 3.63 to 5.31 in the peel of pear cultivars. The pH value was highest in "Fırıncık" in the flesh, "Seker" in the peel (Table 2). The pH was generally higher in the peel than in the flesh. Generally, the pH values of pear was very similar to that shown by Galvis-Sanches et al.[18] who reported that pH content was varied from 4.31–5.26 in the unpeeled pear fruit, Ozturk et al.[34] reported that pear contained 3.94–4.24 of pH. In this study SSC, TA, and pH values was differed among the cultivars. The variation of SSC, TA, and pH in pear fruits could be result of cultivar differences.[34]

Large differences were not found in the content of vitamin C between flesh and peel. However, vitamin C content was slightly higher in the peel than in the flesh. Vitamin C content varied from 9.1–29.7 mg 100 g^{-1} in the flesh, 9.5–35.9 mg 100 g^{-1} in the peel. "Karpuz" and "Deveci" (in the flesh) and "Sarıkum" (in the peel) had the lowest vitamin C content; "Dalkıran," "Seker," and "Kıs" (in the peel) had the highest vitamin C content (Table 2). Previous studies have shown lower vitamin C content than these found in the present study.[13,18,34] Vitamin C content is associated with the enzymatic browning of fruits, such as pear, apple, and quince.[13,18] Browning is initiated in a cultivar dependent manner when a certain threshold of vitamin C is passed.[13] Lee and Kader[25] cited that vitamin C is the most important vitamin for the human nutrition and its acts as an antioxidant, required for the prevention of chronic diseases, scurvy, and maintenance of healthy skin. The

TABLE 2
Titratable acidity (%), pH, and vitamin C content (mg 100 g^{-1}) in peel and flesh of pear cultivars

	Titratable acidity^x (g malic acid 100 g^{-1})		*pH^x*		*Vitamin C^x (mg 100 g^{-1})*	
Cultivars	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*
Istanbul	0.11 ± 0.4	0.13 ± 0.3	4.22 ± 0.1	4.60 ± 0.1	13.8 ± 0.1	11.9 ± 0.3
Seker	0.16 ± 0.2	0.15 ± 0.1	4.50 ± 0.8	5.31 ± 0.8	15.4 ± 0.3	35.5 ± 0.3
Kıs	0.67 ± 0.2	0.43 ± 0.2	3.43 ± 0.2	4.18 ± 0.5	29.6 ± 0.4	33.9 ± 0.8
Bardak	0.30 ± 0.2	0.24 ± 0.3	3.90 ± 0.4	4.30 ± 0.5	28.0 ± 0.2	17.8 ± 0.3
Fırıncık	0.12 ± 0.1	0.11 ± 0.1	4.87 ± 0.1	5.22 ± 0.3	22.5 ± 0.3	26.1 ± 0.6
Esek	0.48 ± 0.3	0.38 ± 0.2	3.92 ± 0.2	4.16 ± 0.1	29.7 ± 0.1	9.6 ± 0.1
Pazar	0.30 ± 0.1	0.19 ± 0.3	3.52 ± 0.2	3.63 ± 0.3	23.2 ± 0.2	28.6 ± 0.5
Yaz Ziraati	0.51 ± 0.3	0.20 ± 0.1	3.39 ± 0.2	4.21 ± 0.3	17.5 ± 0.1	15.5 ± 0.4
Karpuz	0.19 ± 0.1	0.17 ± 0.2	4.41 ± 0.2	4.82 ± 0.4	9.1 ± 0.1	11.7 ± 0.1
Sarıkum	0.20 ± 0.1	0.21 ± 0.1	3.83 ± 0.3	4.20 ± 0.6	10.9 ± 0.3	9.5 ± 0.1
Kara	0.30 ± 0.1	0.32 ± 0.2	4.48 ± 0.1	4.55 ± 0.5	24.2 ± 0.5	14.8 ± 0.3
Rıza	0.62 ± 0.2	0.40 ± 0.4	3.70 ± 0.4	4.20 ± 0.1	18.8 ± 0.4	26.1 ± 0.4
Dalkıran	0.24 ± 0.1	0.28 ± 0.3	4.29 ± 0.3	4.79 ± 0.9	11.6 ± 0.2	35.9 ± 0.4
Deveci*	0.34 ± 0.1	0.40 ± 0.1	4.10 ± 0.3	4.55 ± 0.3	9.1 ± 0.1	24.1 ± 0.3
Williams*	0.38 ± 0.2	0.34 ± 0.3	4.09 ± 0.4	4.05 ± 0.9	21.3 ± 0.3	13.6 ± 0.2
Abbe Fetel*	0.34 ± 0.3	0.32 ± 0.2	4.16 ± 0.5	4.25 ± 0.4	22.9 ± 0.5	25.2 ± 0.5
Santa Maria*	0.39 ± 0.1	0.20 ± 0.2	3.75 ± 0.2	4.80 ± 0.1	21.9 ± 0.4	18.5 ± 0.4
Mean	0.33 ± 0.2	0.26 ± 0.2	4.03 ± 0.3	4.46 ± 0.4	19.3 ± 0.3	21.1 ± 0.4
C.V. (%)	5.52	8.14	7.44	9.36	1.43	1.89

*: Standard pear cultivars;
x: $n = 9$ (3 replications × 3 different measurements for each replicate)

content of vitamin C in fruits and vegetables can be influenced by various factors such as genotypic differences, preharvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures.[25,34]

Phenolic Content in Pear Flesh and Peel

Arbutin and chlorogenic acid were detected as the major phenolic compounds in the peel and flesh of pear. Arbutin and chlorogenic acid are main phenolic compound in the peel of pear.[23] Chlorogenic acid was ranged from 15.8 to 891.9 mg kg^{-1} in the flesh and 21.0 to 1348.4 mg kg^{-1} in the peel. "Sarıkum" had the highest chlorogenic acid content in flesh and peel than the others (Table 3). Chlorogenic acid was detected as the secondary major phenolic compound in the peel and flesh in pear. Its content was always higher in the peel than in the flesh. The contents of chlorogenic acid in this study are in accordance with Galvis-Sanches et al.,[18] who reported that chlorogenic acid content consistently higher in the peel than in the flesh. These findings were similar to previously reported by Amiot et al.,[10] Carbonora and Mattera,[14] and Colaric et al.[26]

Caffeic acid was higher in the peel than in the flesh, except for "Santa Maria." "Istanbul" had the lowest caffeic acid, while "Rıza," "Kara," and "Pazar" had higher caffeic acid values in both the flesh and the peel than the others (Table 3). The present result is in concordance with previously reported by Leontowitcz et al.[17] and Tanrıöven and Ekşi.[1] Leontowitcz et al.[17] reported that much higher caffeic acid content was obtained from pulps of "Blanquilla" pear cultivar (701 mg kg^{-1}). The present study showed that local pear cultivars were an even better source of caffeic acid than the standard cultivars.

TABLE 3
Hydroxycinnamic acid derivates (chlorogenic, caffeic, and *p*-coumaric acid) content (mg kg^{-1}) in peel and flesh of pear cultivars

	Chlorogenic acid[x]		*Caffeic acid*[x]		p-*coumaric acid*[x]	
Cultivars	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*
Istanbul	164.8 ± 8.1	320.7 ± 17.9	4.5 ± 0.9	8.8 ± 1.2	3.8 ± 0.7	3.9 ± 0.4
Seker	223.1 ± 9.8	342.4 ± 18.1	24.9 ± 1.1	29.5 ± 2.9	3.7 ± 0.6	3.9 ± 0.2
Kıs	46.0 ± 5.8	69.3 ± 7.5	12.1 ± 1.1	12.7 ± 1.2	3.9 ± 0.5	4.2 ± 0.8
Bardak	47.6 ± 4.9	69.4 ± 7.6	12.1 ± 1.2	12.7 ± 1.2	3.4 ± 0.4	3.9 ± 0.3
Fırıncık	164.9 ± 5.4	225.9 ± 13.9	15.3 ± 2.1	18.7 ± 1.8	1.9 ± 0.5	1.9 ± 0.5
Esek	61.6 ± 5.2	78.2 ± 8.5	77.7 ± 3.5	88.5 ± 8.8	0.3 ± 0.1	0.3 ± 0.2
Pazar	164.8 ± 9.8	375.7 ± 11.9	176.8 ± 9.8	238.4 ± 12.6	0.2 ± 0.2	0.2 ± 0.4
Yaz Ziraati	320.9 ± 8.8	344.9 ± 15.9	12.5 ± 1.3	17.3 ± 1.2	2.2 ± 0.3	2.5 ± 0.3
Karpuz	46.0 ± 6.2	76.4 ± 9.7	12.2 ± 1.2	14.2 ± 1.3	2.4 ± 0.4	2.2 ± 0.4
Sarıkum	891.9 ± 31.2	1348.4 ± 32.8	54.6 ± 3.2	128.7 ± 9.6	0.3 ± 0.1	0.4 ± 0.1
Kara	15.8 ± 3.1	67.6 ± 8.5	180.7 ± 9.9	199.3 ± 8.9	1.9 ± 0.1	2.7 ± 0.1
Rıza	17.8 ± 3.8	58.7 ± 5.2	258.3 ± 10.1	317.6 ± 19.2	0.8 ± 0.1	0.9 ± 0.1
Dalkıran	100.6 ± 7.5	300.5 ± 9.8	72.1 ± 2.6	103.5 ± 9.6	0.4 ± 0.2	0.5 ± 0.1
Deveci*	47.5 ± 6.1	36.8 ± 3.2	10.3 ± 1.1	18.9 ± 1.9	1.7 ± 0.3	1.8 ± 0.3
Williams*	18.0 ± 2.9	21.0 ± 2.9	9.1 ± 0.9	10.3 ± 0.8	1.3 ± 0.1	1.3 ± 0.4
Abbe Fetel*	424.6 ± 28.2	457.7 ± 21.2	4.9 ± 0.5	14.4 ± 1.8	0.3 ± 0.1	0.4 ± 0.1
Santa Maria*	242.6 ± 19.1	459.8 ± 25.4	16.5 ± 1.2	15.8 ± 1.3	0.4 ± 0.1	0.4 ± 0.1
Mean	176.4 ± 9.8	273.7 ± 12.9	56.2 ± 3.0	73.5 ± 5.0	1.7 ± 0.3	1.8 ± 0.3
C.V (%)	5.55	4.71	5.33	6.82	17.6	16.7

*: Standard pear cultivars;
x: $n = 6$ (3 replications × 2 different measurements for each replicate).

P-coumaric acid content ranged from 0.2 to 3.9 mg kg^{-1} in the flesh and from 0.2 to 4.2 mg kg^{-1} in the peel. "Kıs" had the highest *p*-coumaric acid content in the flesh and peel of pear. "Pazar" had the lowest *p*-coumaric acid content in the flesh and peel. Except for "Karpuz," *p*-coumaric acid was higher in the peel than in the flesh (Table 3). The *p*-coumaric acid content in this study was very similar to previously reported by Tanrıöven and Ekşi,[1] who reported that pear juice of "Ankara" and "Starkrimson" cultivars contained 0.46–3.0 mg L^{-1} of *p*-coumaric acid.

Arbutin content was higher than the chlorogenic acid in the peel and flesh. Arbutin content was varied from 3067.7 to 15412.0 mg kg^{-1} in the flesh and from 4890.0 to 67446.3 mg kg^{-1} in the peel among the cultivars (Table 4). "Deveci" had the highest arbutin content in the flesh; "Sarıkum" had the highest arbutin content in the peel. Except for "Deveci" and "Dalkıran" and "Santa Maria" and "Rıza," arbutin content was generally higher in the peel than in the flesh (Table 3). This result was confirmed to findings of Galvis-Sanchez et al.[18] and Cui et al.[22] In present study, the arbutin contents were higher than those previously reported by Schieber et al.[30]

In this study, arbutin and chlorogenic acid contents were generally higher in the cultivars with greenish-yellow and red blush skin color. Arbutin and chlorogenic acid have a role as coloring factor in the fruit.[10,22] Additionally, Galvis-Sanches et al.[18] cited that red and green pears have higher antioxidant components 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.

Catechin was higher in the peel than in the flesh, except for "Esek" and "Dalkıran" pear. In the flesh and peel, "Pazar" had the highest catechin, whereas the level of catechin was the lowest in "Yaz Ziraati" (Table 4). Catechin contents found in this study were quite higher than those previously reported by Amiot et al.[10] and Tsanova-Savova et al.,[35] but were slightly higher values of Colaric

TABLE 4
Arbutin, flavan-3-ol (catechin and epicatechin) content (mg kg^{-1}) in peel and flesh of pear cultivars

	Arbutin[x]		*Catechin*[x]		*Epicatechin*[x]	
Cultivars	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*
Istanbul	12803.1 ± 27.9	17422.9 ± 83.1	248.1 ± 12.1	306.2 ± 12.3	140.6 ± 5.2	145.9 ± 4.9
Seker	13153.7 ± 31.9	14637.4 ± 77.2	462.8 ± 23.6	502.0 ± 23.6	86.5 ± 2.9	97.5 ± 3.2
Kıs	10952.6 ± 34.3	14919.2 ± 89.8	115.9 ± 7.6	123.5 ± 6.5	98.8 ± 2.8	116.2 ± 3.1
Bardak	6023.2 ± 28.2	13853.4 ± 77.6	88.9 ± 4.6	102.3 ± 2.3	35.1 ± 1.2	32.4 ± 0.9
Fırıncık	13270.8 ± 22.7	15565.8 ± 83.2	174.4 ± 6.1	186.3 ± 6.5	69.4 ± 2.3	78.0 ± 2.1
Esek	9431.9 ± 25.3	14875.4 ± 61.4	139.4 ± 6.5	128.1 ± 5.6	57.5 ± 2.5	61.3 ± 2.6
Pazar	6182.6 ± 22.4	15175.3 ± 77.6	543.8 ± 25.3	695.2 ± 26.5	41.5 ± 3.1	43.8 ± 1.9
Yaz Ziraati	8464.7 ± 29.8	15199.8 ± 81.0	39.3 ± 3.1	42.4 ± 2.1	69.1 ± 5.4	86.8 ± 2.0
Karpuz	11036.1 ± 35.3	15565.9 ± 72.5	157.5 ± 9.6	166.2 ± 4.9	78.9 ± 5.2	86.0 ± 3.1
Sarıkum	3779.1 ± 26.7	67446.3 ± 93.7	56.3 ± 2.6	75.2 ± 3.8	114.7 ± 5.9	315.4 ± 15.9
Kara	5669.5 ± 21.2	22403.1 ± 51.6	63.2 ± 2.8	85.0 ± 6.5	119.6 ± 8.7	261.2 ± 6.5
Rıza	11602.8 ± 39.4	10433.0 ± 89.6	40.0 ± 2.1	265.8 ± 11.2	11.4 ± 0.1	12.6 ± 0.2
Dalkıran	14175.7 ± 37.5	14171.8 ± 86.4	174.1 ± 12.1	147.9 ± 14.2	174.7 ± 6.2	191.1 ± 3.5
Deveci*	15412.0 ± 45.9	13049.6 ± 87.5	55.9 ± 2.5	61.7 ± 6.1	243.1 ± 8.1	227.2 ± 7.9
Williams*	3195.0 ± 20.2	4890.0 ± 59.5	45.4 ± 1.2	48.5 ± 3.5	47.8 ± 3.6	59.4 ± 3.6
Abbe Fetel*	3067.7 ± 19.1	16031.2 ± 38.6	107.3 ± 6.4	117.0 ± 8.7	15.5 ± 0.5	19.6 ± 0.8
Santa Maria*	15209.9 ± 44.1	13270.0 ± 48.4	364.9 ± 10.1	374.8 ± 12.7	108.5 ± 4.2	118.1 ± 4.1
Mean	9613.5 ± 30.1	17582.9 ± 74.0	166.3 ± 8.1	201.7 ± 9.2	88.9 ± 4.0	114.8 ± 3.9
C.V (%)	0.31	0.42	4.87	4.56	4.49	3.39

*: Standard pear cultivars;
x: $n = 6$ (3 replications × 2 different measurements for each replicate).

et al.[26] Karacali,[31] reported that catechin content in peel of pear fruit was three times higher than in the flesh.

Except for the "Bardak" and "Deveci," epicatechin was generally higher in the peel than in the flesh. "Sarıkum" had the highest epicatechin content in the peel, while "Deveci" had the highest epicatechin in the flesh (Table 4). In this study, epicatechin contents of some standard pear cultivars were similar or higher than reported by Tanrıöven and Ekşi,[1] Tsanova-Savova et al.[35] and Colaric et al.[26] they reported that epicatechin content ranged from 11.9 to 83.09 mg kg^{-1} in pear fruits. Lower epicatechin content of pear was reported by Schieber et al.[30] (up to 6.0 mg kg^{-1}) and Galvis-Sanchez et al.[18] (up to 1.4–22.4 mg kg^{-1}). Additionally, epicatechin was slightly lower than catechin in the pear. This result is inconsistent with reported by Colaric et al.[26] who reported that epicatechin content was slightly higher than catechin content in the pear.

From the flavonol glycoside derivates, rutinhydrate (Quercetin-3-rutinoside-hydrate) and rutin-tri-hydrate (Quercetin-3-rutinoside-trihydrate) were detected as the minor phenolic compounds in the flesh and peel. Large differences were found in the flavonol derivates among the flesh and peel of pear cultivars. "Santa Maria" had the highest, while "Abbe Fetel" had the lowest rutinhydrate content in the flesh and peel. "Istanbul" and "Yaz Ziraati" had the lowest rutin-tri-hydrate in the flesh (0.004 mg kg^{-1}), while "Bardak" had the highest rutin-tri-hydrate in the flesh and peel (respectively, 0.418 mg kg^{-1} and 0.848 mg kg^{-1}) (Table 5). From the flavonol glycoside derivates, rutinhydrate was slightly higher than rutin-tri-hydrate in the pear. Macheix et al.[2] cited that flavonols were located especially in the peel. The flavanol glycoside content examined in this study were quite similar to previously reported by Schieber et al.[30] who reported that pear fruits contained 0.2–0.5 mg kg^{-1} of rutinhydrate (quercetin-3-rutinoside hydrate) and Galvis-Sanchez et al.[18] also cited similar values of quercetin-3-O-rutinoside (0.11–1.42 mg kg^{-1}).

TABLE 5
Flavonol glycoside (rutinhydrate and rutin-tri-hydrate) and content (mg kg^{-1}) in peel and flesh of pear cultivars

	Rutinhydrate[x]		*Rutin-tri-hydrate*[x]	
Cultivars	*Flesh*	*Peel*	*Flesh*	*Peel*
Istanbul	0.29 ± 0.1	0.30 ± 0.1	0.004 ± 0.01	0.742 ± 0.04
Seker	0.28 ± 0.1	0.29 ± 0.1	0.053 ± 0.01	0.054 ± 0.02
Kıs	0.40 ± 0.1	0.59 ± 0.2	0.005 ± 0.01	0.323 ± 0.04
Bardak	1.19 ± 0.2	1.27 ± 0.2	0.418 ± 0.02	0.848 ± 0.04
Fırıncık	0.28 ± 0.1	0.29 ± 0.1	0.006 ± 0.01	0.006 ± 0.02
Esek	0.66 ± 0.3	0.78 ± 0.2	0.022 ± 0.01	0.022 ± 0.01
Pazar	0.43 ± 0.2	0.50 ± 0.1	0.005 ± 0.01	0.110 ± 0.01
Yaz Ziraati	0.40 ± 0.1	0.47 ± 0.2	0.004 ± 0.01	0.365 ± 0.02
Karpuz	0.34 ± 0.2	0.39 ± 0.1	0.324 ± 0.02	0.364 ± 0.02
Sarıkum	1.31 ± 0.2	1.38 ± 0.2	0.046 ± 0.03	0.055 ± 0.01
Kara	0.53 ± 0.1	0.59 ± 0.1	0.073 ± 0.01	0.075 ± 0.02
Rıza	0.89 ± 0.2	0.98 ± 0.2	0.075 ± 0.01	0.082 ± 0.03
Dalkıran	0.75 ± 0.1	0.82 ± 0.1	0.036 ± 0.01	0.041 ± 0.01
Deveci*	0.88 ± 0.1	1.00 ± 0.2	0.169 ± 0.03	0.181 ± 0.01
Williams*	0.14 ± 0.1	0.15 ± 0.1	0.061 ± 0.02	0.056 ± 0.02
Abbe Fetel*	0.03 ± 0.1	0.04 ± 0.1	0.007 ± 0.01	0.006 ± 0.01
Santa Maria*	1.34 ± 0.2	1.48 ± 0.2	0.087 ± 0.01	0.080 ± 0.03
Mean	0.59 ± 0.14	0.66 ± 0.16	0.13 ± 0.014	0.20 ± 0.021
C.V (%)	24.92	24.95	10.76	10.5

*: Standard pear cultivars;
x: $n = 6$ (3 replications × 2 different measurements for each replicate).

In the present study, SSC was higher in the flesh than in the peel, while pH, TA, and all phenolic compounds were generally higher in the peel than in the flesh. The main reason for these differences is probably that the phenolic content in pear is specifically affected by the fruit variety than by the maturity stage.[10] Additionally, the level of phenolic compounds in fruits is highly depending on many external and internal factors, such as stage of maturity, variety, storage, and environmental or genetic factors.[3,9,10,15,34] According to the results obtained in 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 in the examined pear cultivars. This result is in accordance with previously reported studies.[18,22,23,36]

CONCLUSIONS

This research demonstrated that phenolic compounds were found richer in the local pear cultivars than the standard pear cultivars. Especially, "Bardak," "Dalkıran," "Kara," "Pazar," and "Seker" pear genotypes, due to the higher contents of phenolic compounds, these local pear cultivars should be considered in terms of pear growing. Examined phenolic compounds were found higher in the peel than in the flesh in fruits of pear. In terms of the human and plant health, especially, arbutin, acts as an antibiotic substances in fire blight resistance and a specific marker of pear products for the evaluation of product authenticity, and chlorogenic acid, acts as an antioxidants to promote the prevention of cancer, cardiovascular disease, and immune system enhancement, were detected as a major phenolic compounds in the peel of pear cultivars. From the nutritional point of view, since the phenolics were higher located in the peel, the consumption of unpeeled pears, after properly sluiced whole fruit, is recommended to maximize the dietary intake of requirements.

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