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Organic acid, phenolic profile and antioxidant capacities of pomegranate (*Punica granatum* L.) cultivars and selected genotypes

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ABSTRACT

In this study, organic acid and phenolic compound contents and antioxidant capacities of some standard Turkish pomegranates and formerly selected 5 promising local pomegranate genotypes in Pervari region of Siirt Province (Gündoğdu, 2006) were determined. With respect to antioxidant capacities, the highest value (14.67 mmol TE L^{-1}) was determined in Silifke aşısı pomegranate fruits among all examined cultivars and genotypes. Considering the organic acid contents of pomegranate juices, citric acid was identified to be the predominant organic acid and the highest value (2.1823 g L^{-1}) was identified in 56PER19 genotype. No acetic acid content was identified in the examined cultivars and genotypes. In terms of phenolic compound contents, the highest value of gallic acid (6.361 g L^{-1}) was identified in Çevlik pomegranate cultivar. The findings of study indicated that pomegranate cultivars and genotypes have important phytonutrients. Rather than the content of energy; the rich content of minerals, vitamins, organic acids and phenolic compounds make pomegranate an important source material for fruit processing industry.

1. Introduction

Pomegranate is considered as a tropic and subtropic climate fruit. Despite its production and consumption at lower amounts compared to other fruits, Pomegranate (*Punica granatum* L.) has been produced for thousands of years in its motherlands of South and Southwest Asia, the neighbor regions around South Caucasus, Iran, Afghanistan, South Asia, West Asia, Anatolia and Mediterranean. It is also cultivated in Mediterranean coastal parts of Europe and Africa, China, India, Afghanistan, Iran, Arabia, Chili, Argentina, California and Arizona states of USA as well as North Mexico (Özbek, 1977; Dokuzoğuz and Mendilcioğlu, 1978; Onur, 1983).

Organic acid contents of pomegranate fruits depend on the cultivar. Organic acid content is a determinant of taste depending on acid–sugar balance. Organic acids in fruits and vegetables mostly occur in free form or combined as salt, ester or glycosides (Cemeroğlu and Acar, 1986; Savran, 1999). As the acids in fruits are rapidly oxidized in metabolism, they do not have negative effects on human body. Since the salts have alkalic effects, they are important in nutrition (Schobinger, 1988; Savran, 1999). Organic acids form complexes with heavy metal ions and prevent them from catalyzing oxidation (Balcı, 1996; Savran, 1999). The proportion of total acid content to sugar content is a determinant of fruit maturity. Since acids decrease sweetness and increase sourness, they have a determinant role on taste. Type and amount of acidity is a criterion of food decay. Some of the acids increase mold growth in fruits. Organic acids are also important in purity control (Özkaya, 1988; Savran, 1999).

Despite their low content in fruits and vegetables, phenolic compounds result many problems in product processing (particularly juice industry). They affect the taste of products and generate sourish taste. Anthocyanins, as one of the phenolic compounds, provide the particular colors to the fruits and vegetables. Additionally, catalyzing effects of polyphenol oxidase (PPO) enzymes cause browning reaction in fruits and vegetables. Phenolic compounds also result blurring and sedimentation in drinks such as fruit juices and wines. Phenolic compounds are present in almost all fruits and vegetables at varying contents. Enzymatic browning does not occur in intact plant cells since phenolic compounds in cell vacuoles are separated from the PPO enzyme in the cytoplasm. Once tissue is damaged by slicing, cutting or pulping, brown pigments are generated due to reaction of phenolic compounds and PPO enzyme. For example, some fruits and vegetables such as apple, banana and potato get immediately brown after slicing (Cemeroğlu et al., 2004; Gündogdu et al., 2011).

The pomegranate cultivars examined in the study are widely cultivated in Turkey and are valuable in European markets. These cultivars, which are widely utilized in fruit juice processing industry and fresh market use, are among the mostly exported cultivars.

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Hence, the determination of organic acid and phenolic compound contents and antioxidant capacities of these particular cultivars is an important research topic.

2. Materials and methods

2.1. Plant materials

A total of 11 standard pomegranate cultivars including worldwide recognized ones (Hicaznar, Silifke aşısı, Katırbaşı, Çevlik, Fellahyemez, 33N34, İzmir 26, İzmir 23, İzmir 1513, Beynarı, Kuşnarı) grown in Alata Horticultural Research Institute (Mersin Province) and formerly selected best 5 local pomegranate genotypes (56PER021, 56PER022, 56PER020, 56PER019, 56PER003) in Pervari region of Siirt Province (Gündoğdu, 2006) were used in the study. About 30 fruits were homogeneously collected from each selected pomegranate tree during the harvest period of September–October. The samples were placed in cloth bags and then transferred to laboratory for analyses.

2.2. Chemicals

In the present study, chemicals with analytical purity were used. Organic acid standards (citric acid, tartaric acid, malic acid, succinic acid, lactic acid, fumaric acid, and acetic acid), phenolic acid standards (gallic acid, catechin, caffeic, chlorogenic acid, *o*-coumaric acid, *p*-coumaric acid, ferulic acid, syringic, vanillic, phlorodizin, quercetin, rutin, and pyrocatechin) were obtained from Sigma–Aldrich (St. Louis, MO, USA). The other chemicals were obtained from Merck (Darmstadt, Germany).

2.3. Extraction and determination of organic acids

Pomegranates were stripped from the skin and the membranes and then granulated. The granules were pressed manually in a cheesecloth for juice extraction. The juices were then stored at freezer (−20 °C) until analysis. In the study, contents of succinic acid, oxalic acid, citric acid, malic acid, fumaric acid, tartaric acid, acetic acid and lactic acid were determined in the fruit juices.

The method of Bevilacqua and Califano (1989) was modified and used to extract organic acids. Mixtures containing 5 mL pomegranate juice and 20 mL 0.009 N H_2SO_4 homogenized (Heidolph Silent Crusher M, Germany). The mixtures were blended by a shaker (Heidolph Unimax 1010, Germany) for 1 h and then were centrifuged for 15 min at 15,000 rpm. The supernatants were filtered first through filter paper and then twice through a 0.45 μm membrane filter (Millipore Millex-HV Hydrophilic PVDF, Millipore, USA) before being passed through a SEP-PAK C_{18} cartridge. An Aminex column (HPX-87 H, 300 mm × 7.8 mm, Bio-Rad Laboratories, Richmond, CA, USA) was used in the HPLC system, and the instrument was controlled by a PC with Agilent software. The DAD detector in the system (Agilent, USA) was set at wavelengths of 214 and 280 nm. The mobile phase was 0.009 N H_2SO_4 that had been filtered through a 0.45 μm membrane filter.

2.4. Extraction and determination of phenolic compounds

Phenolic compounds were separated by HPLC using the method described by Rodriguez-Delgado et al. (2001). The pomegranate juices were diluted 1:1 with distilled water and centrifuged for 15 min at 15,000 rpm. The supernatant was passed through 0.45 μm membrane filter (Millipore Millex-HV Hydrophilic PVDF, Millipore, USA), then injected into HPLC system (gradient). The chromatographic separation in Agilent 1100 series HPLC took place in DAD detector (Agilent, USA) with 250 mm × 4.6 mm, 4 μm ODS column (HiChrom, USA). The following solvents in water with a flow rate of 1 mL/min and 20 μL injection volume were used for spectral measurements at 254, and 280 nm: as mobile phase solvent A, methanol–acetic acid–water (10:2:88) and Solvent B, methanol–acetic acid–water (90:2:8).

2.5. Extraction and determination of total antioxidant activity

For a standard TEAC measurement, the ABTS reagent was dissolved in acetate buffer and prepared with potassium persulfate (Özgen et al., 2006). For preserving stability, ABTS was diluted in an acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700 ± 0.01 at 734 nm. For spectrophotometric measurements, 3 mL $ABTS^+$ solution was mixed with 20 μL fruit extract, incubated for 10 min and absorbance values were measured at 734 nm.

2.6. Statistical analysis

Descriptive statistics were expressed as average and standard error. 2-Factor Factorial Analysis of Variance was used for the comparing cultivar averages in terms of examined parameters. Subsequent to variance analysis, Duncan's Multiple Range Test was used to determine the different cultivars (Zar, 1999). Statistical Significance Level of 5% was applied in the calculations which were executed with SPSS (ver: 13) statistical package.

3. Results and discussion

3.1. Organic acid content

In the study, oxalic acid contents ranged between 0.0313 and 1.0167 g L^{-1}, malic acid contents between 0.1175 and 2.2302 g L^{-1}, citric acid contents between 0.6130 and 2.1823 g L^{-1}, succinic acid contents between 0.0390 and 0.3293 g L^{-1}, lactic acid contents between 4.516 and 33.115 mg L^{-1}, fumaric acid contents between 0.0119 and 0.2990 mg L^{-1} and tartaric acid contents between 0.0330 and 0.1266 g L^{-1} (Tables 1 and 2). In their study, Poyrazoglu et al. (2002) reported that citric acid contents in pomegranate juices ranged between 0.33 and 8.96 g L^{-1}, L-malic acid contents between 0.56 and 6.86 g L^{-1}, tartaric acid contents between 0.28 and 2.83 g L^{-1}, oxalic acid contents between 0.02 and 6.72 g L^{-1} and succinic acid contents between 0.00 and 1.54 g L^{-1}. Our findings are in agreement with those of Poyrazoglu et al. (2002). In a similar study of Melgarejo et al. (2000), average oxalic acid content was 0.037 g 100 g^{-1} in sweet cultivars; 0.015 g 100 g^{-1} in sourish cultivars and 0.017 g 100 g^{-1} in sour cultivars. Average citric acid content was 0.142 g 100 g^{-1} in sweet cultivars; 0.566 g 100 g^{-1} in sourish cultivars and 2.317 g 100 g^{-1} in sour cultivars. According to the findings of the same study, average malic acid content was 0.135 g 100 g^{-1} in sweet cultivars; 0.160 g 100 g^{-1} in sourish cultivars and 0.176 g 100 g^{-1} in sour cultivars. Oxalic acid, citric acid and malic acid values in our study are lower. Özgen et al. (2008) reported that citric acid content ranged between 3.20 and 0.20 g 100 mL^{-1} and malic acid content ranged between 0.09 and 0.15 g 100 mL^{-1}. Our findings are in agreement with the findings of Özgen et al. (2006).

The findings of former studies also reveal the lack of acetic acid content in pomegranate samples (Melgarejo et al., 2000). Despite the minimization of organic acid loss during harvest, storage and analysis, complete prevention of loss not possible. Therefore, changes and reactions in fruit physiology affect organic acid content. Furthermore, cultivar-specific characteristics and environmental factors also affect the organic acid content (Poyrazoglu et al., 2002).

Table 1
Organic acid concentrations of juice from Turkey pomegranate cultivars and genotypes.

Cultivars and genotypes	Oxalic acid (g L^{-1})	Malic acid (g L^{-1})	Citric acid (g L^{-1})	Succinic acid (g L^{-1})
Katırbaşı	0.1319 ± 0.0027 cde*	1.2698 ± 0.0025 f*	1.3274 ± 0.0182 e	0.1417 ± 0.0038 cde
İzmir 1513	0.0619 ± 0.0013 e	1.4427 ± 0.0122 d	1.5329 ± 0.0177 d	0.0444 ± 0.0020 f
Kuşnarı	0.0994 ± 0.0029 cde	0.8924 ± 0.0027 g	1.7697 ± 0.0156 c	0.0390 ± 0.0036 f
İzmir 23	0.2226 ± 0.006 cde	0.3514 ± 0.0035 j	1.0492 ± 0.0063 g	0.0580 ± 0.0011 f
Hicaznar	0.1712 ± 0.0011 cde	0.5005 ± 0.0015 i	0.6743 ± 0.0059 i	0.0654 ± 0.0095 ef
33N34	0.0313 ± 0.0012 e	0.7683 ± 0.0103 h	1.5402 ± 0.0097 d	0.2041 ± 0.0066 bc
Çevlik	0.5413 ± 0.0080 b	0.3386 ± 0.0068 j	0.8091 ± 0.0047 h	0.3293 ± 0.0012 a
Silifke aşısı	0.0664 ± 0.0032 e	1.4231 ± 0.0150 d	0.6578 ± 0.0037 i	0.1601 ± 0.0048 bcd
İzmir 26	0.3109 ± 0.0014 c	0.1572 ± 0.0075 l	0.6538 ± 0.0067 i	0.2186 ± 0.0050 bc
Fellahyemez	0.2392 ± 0.0079 cde	0.1175 ± 0.0012 l	0.6560 ± 0.0038 i	0.1529 ± 0.0051 bcd
Beynarı	1.0167 ± 0.0027 a	0.2702 ± 0.0076 k	0.7969 ± 0.0098 h	0.1816 ± 0.0013 bc
56 PER 03	0.1365 ± 0.0047 cde	2.2302 ± 0.0134 a	1.1772 ± 0.0076 f	0.2327 ± 0.0021 b
56 PER 19	0.0718 ± 0.0014 de	1.5505 ± 0.0066 c	2.1823 ± 0.0132 a	0.1490 ± 0.0027 bcd
56 PER 20	0.2876 ± 0.0113 cd	1.7926 ± 0.0117 b	0.6130 ± 0.0054 i	0.1607 ± 0.0007 bcd
56 PER 21	0.1042 ± 0.0080 cde	1.3516 ± 0.0049 e	1.3316 ± 0.0101 e	0.1906 ± 0.0029 bc
56 PER 22	0.1641 ± 0.0123 cde	1.3485 ± 0.0176 e	1.8485 ± 0.0118 b	0.0783 ± 0.0019 def

* Different letters in columns indicate significantly different values at $p \leq 0.05$.

3.2. Phenolic profile and trolox equivalent antioxidant capacity (TEAC)

Phenolic compound contents in pomegranate juices were determined by HPLC. 13 phenolic compounds were examined in the pomegranate juice samples in the study. Among these, gallic acid contents ranged between 0.190 and 6.361 g L^{-1}, catechin contents between 0.533 and 3.176 g L^{-1}, chlorogenic acid contents between 0.0375 and 0.5473 g L^{-1}, caffeic acid contents between 0.0162 and 0.0960 g L^{-1}, syringic acid contents between 0.0214 and 0.0609 g L^{-1}, *p*-coumaric acid contents between 0.0200 and 0.2456 g L^{-1}, ferulic acid contents between 0.0446 and 0.2326 g L^{-1}, *o*-coumaric acid contents between 0.0325 and 0.5514 g L^{-1}, phloridzin contents between 0.0414 and 1.2155 g L^{-1}, protocatechuic acid contents between 0.0169 and 0.4489 g L^{-1}, vanilic acid contents between 0.0061 and 0.1708 g L^{-1}, rutin contents between 0.1306 and 1.3283 g L^{-1} and quercetin contents between 0.1928 and 1.2473 g L^{-1} (Tables 3–6). Gallic acid was the predominant phenolic compound in Çevlik, Hicaz and İzmir 26 cultivars. Catechin was the predominant phenolic compound in Katırbaşı, İzmir 1513, İzmir 23, Silifke aşısı, Beynarı cultivars and 56 PER 03, 56 PER 19, 56 PER 21, 56 PER 22 genotypes. Quercetin was the predominant phenolic compound in 33N34, Fellahyemez cultivars and 56 PER 20 genotype. In Kuşnarı cultivar, phloridzin was the "predominant phenolic compound". Significant differences were determined among the cultivars with respect to phenolic compound distribution. These differences are possibly attributed to cultivar-specific characteristics, cultural practices (fertilization, pruning, spraying, etc.) as well as regional climate and soil characteristics. In their study, Poyrazoglu et al. (2002) reported gallic acid contents between 0.03 and 30.86 g L^{-1}, protocatechuic acid contents between 0.12 and 2.09 g L^{-1}, catechin contents between 0.13 and 8.44 g L^{-1}, chlorogenic acid contents between 0.00 and 4.72 g L^{-1}, caffeic acid contents between 0.08 and 2.89 g L^{-1}, *p*-coumaric acid contents between 0.02 and 0.21 g L^{-1}, ferulic acid contents between 0.01 and 0.06 g L^{-1}, *o*-coumaric acid contents between 0.03 and 0.30 g L^{-1}, phloridzin contents between 0.03 and 4.93 g L^{-1} and quercetin contents between 0.23 and 5.30 g L^{-1} (Poyrazoglu et al., 2002). In the study of Amakura et al. (2000), chlorogenic acid content in pomegranate fruits was reported as 16.6 μg g^{-1}. Gallic acid, catechin, chlorogenic acid, *p*-coumaric acid, quercetin and *o*-coumaric acid contents found in our study are similar to those reported by Amakura et al. (2000), but caffeic acid, phloridzin and protocatechuic acid contents are lower and ferulic acid contents are higher in our study. In the study of Gözlekçi et al. (2011), total phenolic content of pomegranate juice and seed extract were reported between 784.4–1551.5 mg GAE/L and 117.0–177.4 mg GAE/L, respectively.

Flavonol glycosides, which are one of the phenolic compounds, are in light yellow color and exist in almost all plants. As light is required for their synthesis in plants, they are more abundantly present in the skins of fruits. Since they effect color formation, climatic factors of temperature and light are particularly important determinants (Cemeroğlu et al., 2004). Additionally, phenolic

Table 2
Organic acid concentrations of juice from Turkey pomegranate cultivars and genotypes.

Cultivars and genotypes	Tartaric acid (g L^{-1})	Lactic acid (mg L^{-1})	Fumaric acid (mg L^{-1})
Katırbaşı	0.0366 ± 0.0047 g*	11.001 ± 0.058 j	0.0119 ± 0.0051 l
İzmir 1513	0.0583 ± 0.0061 de	16.559 ± 0.022 h	0.0148 ± 0.0013 kl
Kuşnarı	0.0353 ± 0.0049 g	31.882 ± 0.048 b	0.0167 ± 0.0005 kl
İzmir 23	0.0640 ± 0.0036 cd	27.006 ± 0.008 d	0.0578 ± 0.0037 h
Hicaznar	0.0833 ± 0.0051 b	4.516 ± 0.055 l	0.1266 ± 0.0047 f
33N34	0.0446 ± 0.0015 f	9.239 ± 0.051 k	0.2152 ± 0.0028 c
Çevlik	0.0690 ± 0.0072 c	33.115 ± 0.065 a	0.2263 ± 0.0116 b
Silifke aşısı	0.0533 ± 0.0060 e	14.287 ± 0.040 i	0.0270 ± 0.0057 j
İzmir 26	0.0783 ± 0.0016 b	21.296 ± 0.02 f	0.2990 ± 0.0026 a
Fellahyemez	0.0863 ± 0.0070 b	10.631 ± 0.042 j	0.2026 ± 0.0046 d
Beynarı	0.0543 ± 0.0025 e	22.906 ± 0.050 e	0.1528 ± 0.0072 e
56 PER 03	0.0330 ± 0.0040 g	29.608 ± 0.086 c	0.0739 ± 0.0052 g
56 PER 19	0.1266 ± 0.0047 a	15.604 ± 0.180 h	0.0139 ± 0.0041 kl
56 PER 20	0.1196 ± 0.0029 a	19.576 ± 0.034 g	0.0301 ± 0.0012 j
56 PER 21	0.0806 ± 0.0038 b	11.085 ± 0.012 j	0.0238 ± 0.009 jk
56 PER 22	0.0826 ± 0.0045 b	14.453 ± 0.034 i	0.0426 ± 0.0036 i

* Different letters in columns indicate significantly different values at $p \leq 0.05$.

Table 3
Phenolic acid concentrations of juice from Turkey pomegranate cultivar and genotypes.

Cultivars and genotypes	Gallic acid (g L^{-1})	Catechin (g L^{-1})	Chlorogenic acid (g L^{-1})	Caffeic acid (g L^{-1})
Katırbaşı	0.351 ± 0.032 hi*	0.820 ± 0.008 k	0.1037 ± 0.0020 gh	0.0919 ± 0.0014 b
İzmir 1513	1.700 ± 0.025 d	2.070 ± 0.010 e	0.4042 ± 0.0038 b	0.0376 ± 0.0009 g
Kuşnarı	0.743 ± 0.006 f	0.865 ± 0.003 j	0.0375 ± 0.0027 k	0.0247 ± 0.0005 i
İzmir 23	0.967 ± 0.021 e	2.310 ± 0.005 c	0.0839 ± 0.0094 i	0.0162 ± 0.0004 j
Hicaznar	2.672 ± 0.164 c	1.161 ± 0.003 i	0.0927 ± 0.0032 hi	0.0176 ± 0.0004 j
33N34	0.510 ± 0.012 g	0.533 ± 0.001 n	0.1959 ± 0.0018 f	0.0294 ± 0.0013 h
Çevlik	6.361 ± 0.016 a	1.521 ± 0.010 h	0.1823 ± 0.0024 f	0.0659 ± 0.0010 d
Silifke aşısı	0.190 ± 0.002 j	0.885 ± 0.002 j	0.0508 ± 0.0013 jk	0.0496 ± 0.0012 f
İzmir 26	3.500 ± 0.046 b	2.368 ± 0.009 b	0.0485 ± 0.0011 jk	0.0743 ± 0.0017 c
Fellahyemez	0.265 ± 0.002 ij	0.841 ± 0.006 k	0.0556 ± 0.0014 j	0.0476 ± 0.0009 f
Beynarı	0.384 ± 0.003 ghi	1.676 ± 0.008 g	0.2196 ± 0.0093 e	0.0495 ± 0.0009 f
56 PER 03	0.440 ± 0.002 gh	1.930 ± 0.020 f	0.1818 ± 0.0045 f	0.0567 ± 0.0016 e
56 PER 19	0.356 ± 0.001 hi	2.255 ± 0.004 d	0.5473 ± 0.0033 a	0.0960 ± 0.0021 a
56 PER 20	0.381 ± 0.003 ghi	0.770 ± 0.002 l	0.3602 ± 0.0054 c	0.0349 ± 0.0011 g
56 PER 21	0.445 ± 0.011 gh	0.594 ± 0.001 m	0.3211 ± 0.0071 d	0.0566 ± 0.0005 e
56 PER 22	0.460 ± 0.007 gh	3.176 ± 0.012 a	0.1165 ± 0.0035 g	0.0740 ± 0.0005 c

* Different letters in columns indicate significantly different values at $p \leq 0.05$.

Table 4
Phenolic acid concentrations of juice from Turkey pomegranate cultivar and genotypes.

Cultivars and genotypes	Syringic acid (g L^{-1})	*p*-Coumaric acid (g L^{-1})	Ferulic acid (g L^{-1})	*o*-Coumaric acid (g L^{-1})
Katırbaşı	0.0242 ± 0.0007 h*	0.0639 ± 0.0017 g	0.1299 ± 0.0035 d	0.1265 ± 0.0039 ef
İzmir 1513	0.0372 ± 0.0005 fg	0.1783 ± 0.0019 b	0.1767 ± 0.0038 b	0.1456 ± 0.0051 c
Kuşnarı	0.0379 ± 0.0016 fg	0.0311 ± 0.0022 j	0.2326 ± 0.0030 a	0.1217 ± 0.0022 f
İzmir 23	0.0440 ± 0.0011 de	0.0626 ± 0.0003 g	0.1561 ± 0.0032 c	0.0792 ± 0.0026 h
Hicaznar	0.0433 ± 0.0012 e	0.0671 ± 0.0013 g	0.1132 ± 0.0034 e	0.1360 ± 0.0025 cde
33N34	0.0335 ± 0.0002 g	0.0510 ± 0.0019 h	0.1008 ± 0.0022 f	0.1306 ± 0.0038 def
Çevlik	0.0482 ± 0.0015 cd	0.0567 ± 0.0011 h	0.1801 ± 0.0040 b	0.5514 ± 0.0039 a
Silifke aşısı	0.0431 ± 0.0013 e	0.0848 ± 0.0019 e	0.1001 ± 0.0039 f	0.0467 ± 0.0007 i
İzmir 26	0.0371 ± 0.0013 fg	0.0979 ± 0.0022 d	0.2304 ± 0.0046 a	0.2076 ± 0.0045 b
Fellahyemez	0.0214 ± 0.0003 h	0.0200 ± 0.0011 k	0.0869 ± 0.0036 g	0.0909 ± 0.0026 g
Beynarı	0.0481 ± 0.0006 cd	0.0334 ± 0.0021 j	0.0689 ± 0.0019 h	0.0325 ± 0.0043 j
56 PER 03	0.0562 ± 0.0015 b	0.1231 ± 0.0017 c	0.1496 ± 0.0023 c	0.0967 ± 0.0027 g
56 PER 19	0.0398 ± 0.0013 ef	0.2456 ± 0.0025 a	0.1192 ± 0.0037 e	0.0386 ± 0.0036 ij
56 PER 20	0.0398 ± 0.0017 ef	0.0420 ± 0.0036 i	0.0446 ± 0.0021 i	0.0403 ± 0.0020 ij
56 PER 21	0.0502 ± 0.0023 c	0.0421 ± 0.0027 i	0.1172 ± 0.0035 e	0.1398 ± 0.0011 cd
56 PER 22	0.0609 ± 0.0030 a	0.0747 ± 0.0011 f	0.1308 ± 0.0011 d	0.0448 ± 0.0025 i

* Different letters in columns indicate significantly different values at $p \leq 0.05$.

compounds also generate sourish taste in fruit products and blurred appearance in fruit juices (Cemeroğlu et al., 2004). Hence, phenolic compounds are highly important in fruit juice processing industry.

The antioxidant capacities of the examined cultivars and genotypes were determined by TEAC method in our study. The findings indicated that Silifke aşısı cultivar has the highest antioxidant capacity (14.67 mmol TE L^{-1}) among the cultivars and genotypes. On the other land, 56 PER 03 genotype has the lowest antioxidant capacity (6.45 mmol TE L^{-1}). Except 33N34 and Fellahymez cultivars, the antioxidant capacities of other standard cultivars were higher than those of the genotypes. Mousavinejad et al. (2009) explored the antioxidant capacities of 8 pomegranate cultivars grown in Iran. In their study, antioxidant capacities were reported between 18.6 and 42.8 mM based on TEAC method. In a similar study of Özgen et al. (2008), antioxidant capacities were

Table 5
Phenolic acid concentrations of juice from Turkey pomegranate cultivar and genotypes.

Cultivars and genotypes	Phloridzin (g L^{-1})	Protocatechuic acid (g L^{-1})	Vanillic acid (g L^{-1})
Katırbaşı	0.3339 ± 0.0050 e*	0.4489 ± 0.0035 a	0.0154 ± 0.0003 e
İzmir 1513	0.1435 ± 0.0046 i	0.0461 ± 0.0034 g	0.0442 ± 0.0006 b
Kuşnarı	1.2155 ± 0.0017 a	0.0213 ± 0.0006 i	0.0143 ± 0.0003 ef
İzmir 23	0.2678 ± 0.0031 f	0.0676 ± 0.0010 de	0.0061 ± 0.0001 g
Hicaznar	0.1619 ± 0.0019 h	0.0323 ± 0.0067 h	0.0138 ± 0.0006 f
33N34	0.0556 ± 0.0033 k	0.1096 ± 0.0051 c	0.0350 ± 0.0003 c
Çevlik	0.0735 ± 0.0024 j	0.1327 ± 0.0016 b	0.0246 ± 0.0022 d
Silifke aşısı	0.1553 ± 0.0023 h	0.0675 ± 0.0010 de	0.0366 ± 0.0008 c
İzmir 26	0.4597 ± 0.0007 c	0.0750 ± 0.0020 d	0.1708 ± 0.0029 a
Fellahyemez	0.3875 ± 0.0013 d	0.0169 ± 0.0009 i	0.0149 ± 0.0005 e
Beynarı	0.9083 ± 0.0045 b	0.0333 ± 0.0005 h	0.0259 ± 0.0015 d
56 PER 03	0.0414 ± 0.0013 l	0.0730 ± 0.0017 d	0.0243 ± 0.0019 d
56 PER 19	0.0659 ± 0.0038 j	0.0583 ± 0.0003 f	0.0240 ± 0.0006 d
56 PER 20	0.0442 ± 0.0025 l	0.0551 ± 0.0008 f	0.0106 ± 0.0007 f
56 PER 21	0.2315 ± 0.0039 g	0.0587 ± 0.0013 f	0.0261 ± 0.0005 d
56 PER 22	0.0421 ± 0.0021 l	0.0597 ± 0.0024 ef	0.0234 ± 0.0011 d

* Different letters in columns indicate significantly different values at $p \leq 0.05$.

Table 6
Phenolic acid and TEAC concentrations of juice from Turkey pomegranate cultivar and genotypes.

Cultivars and genotypes	Rutin ($g\,L^{-1}$)	Quercetin ($g\,L^{-1}$)	TEAC ($mmol\,TE\,L^{-1}$)
Katırbaşı	0.6372 ± 0.0026 d*	0.4337 ± 0.0026 h	13.41 ± 0.194 bc
İzmir 1513	0.3096 ± 0.0039 h	0.6712 ± 0.0010 e	11.36 ± 0.292 ef
Kuşnarı	0.7840 ± 0.0011 c	0.3177 ± 0.0336 jk	14.57 ± 0.206 a
İzmir 23	0.4212 ± 0.0033 f	0.2907 ± 0.0043 kl	14.32 ± 0.098 ab
Hicaznar	0.2773 ± 0.0020 i	0.2515 ± 0.0008 m	12.57 ± 0.231 cd
33N34	0.2785 ± 0.0037 i	0.7415 ± 0.0058 d	10.47 ± 0.102 fg
Çevlik	0.8419 ± 0.0024 b	0.6182 ± 0.0016 f	11.69 ± 0.193 de
Silifke aşısı	0.5152 ± 0.0025 e	0.2763 ± 0.0045 lm	14.67 ± 0.199 a
İzmir 26	1.3283 ± 0.0055 a	0.1928 ± 0.0025 n	12.58 ± 0.103 cd
Fellahyemez	0.3684 ± 0.0007 g	1.1292 ± 0.0045 b	10.56 ± 0.211 fg
Beynarı	0.1306 ± 0.0024 k	0.9652 ± 0.0199 c	11.34 ± 0.165 ef
56 PER 03	0.2486 ± 0.0046 j	0.2687 ± 0.0020 lm	6.45 ± 0.117 h
56 PER 19	0.2329 ± 0.0169 j	0.3637 ± 0.0014 i	10.73 ± 0.339 efg
56 PER 20	0.2482 ± 0.0199 j	1.2473 ± 0.0166 a	9.66 ± 0.092 g
56 PER 21	0.3171 ± 0.0152 h	0.5062 ± 0.0053 g	10.55 ± 0.248 fg
56 PER 22	0.3206 ± 0.0038 h	0.3422 ± 0.0012 ij	10.28 ± 0.079 fg

* Different letters in columns indicate significantly different values at $p \leq 0.05$.

4.38 $mmol\,TE\,L^{-1}$ and 7.70 $mmol\,TE\,L^{-1}$ in Katırbaşı and Kan cultivars, respectively. The antioxidant capacity in Katırbaşı cultivar was higher (13.41 $mmol\,TE\,L^{-1}$ in our study compared to the findings of Özgen et al., 2008). This is possibly attributed to external factors (cultural practices, climate, soil, etc.) (Çam et al., 2009).

4. Conclusion

In general, citric acid was the predominant organic acid in the examined pomegranate juices. However, malic acid was the predominant one in Silifke aşısı cultivar, 56 PER 03, 56 PER 20 and 56 PER 21 genotypes. This is attributed to the formation of ester upon the reaction of predominant citric acid with some juice compounds (Savran, 1999). Low oxalic acid contents were identified in the examined pomegranate juices, while it was the predominant organic acid in Beynarı cultivar. Lactic acid, foumaric acid and tartaric acid – the predominant organic acid in grape – contents were also low and no acetic acid content was determined. Phenolic compounds are responsible for many physiological events in fruits. They affect the taste of products and generate sourish taste. Anthocyanins, as one of the phenolic compounds, provide colors of the fruits and vegetables. Additionally, catalyzing effects of polyphenol oxidase (PPO) enzymes cause browning reaction in fruits and vegetables. Phenolic compounds also result to blurring and sedimentation in drinks such as fruit juices and wines (Cemeroğlu et al., 2004). The importance of pomegranate in human health has been further enhanced by the recent studies. Particularly, due to its strong antioxidant effects, the utilization of pomegranate in treatment of fatal diseases such as cancer, has increased the popularity of the fruit (Beşikci and Arıoğlu, 2010).

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References

Amakura, Y., Okada, M., Tsuji, S., Tonogai, Y., 2000. Determination of phenolic acids in fruit juices by isocratic column liquid chromatography. J. Chromotogr. A 891, 183–188.
Balcı, N., 1996. Meyve Sularında Organik Asit Dağılımı. Yüksek Lisans Semineri. Ankara Üniversitesi, Ankara.
Beşikci, A.O., Arıoğlu, E., 2010. Nar (*Punica granatum* L.) Suyunun Kardiyovasküler Etkileri. Modern Fitofarmakoterapi ve Doğal Farmasötikler 1 (3), 26–31.
Bevilacqua, A.E., Califano, A.N., 1989. Determination of organic acids in dairy products by high performance liquid chromatography. J. Food Sci. 54, 1076–1079.
Cemeroğlu, B., Acar, J., 1986. Meyve ve Sebze İşleme Teknolojisi. Gıda Teknolojisi Derneği 6, 29–30.
Cemeroğlu, B., Yemenicioğlu, A., Özkan, M., 2004. Meyve ve Sebzelerin Bileşimi. In: B. Cemeroğlu (Eds.), 1. Meyve ve Sebze İşleme Teknolojisi, 2. Başkent Klişe Matbaacılık, vol. 1, Ankara, p. 670.
Çam, M., Hışıl, Y., Durmaz, G., 2009. Classification of eight pomegranate juices based on antioxidant capacity measured by four methods. Food Chem. 112 (3), 721–726.
Dokuzoğuz, M., Mendilcioğlu, K., 1978. Ege Bölgesi Nar Çeşitleri Üzerinde Pomolojik Çalışmalar. Ege Üniversitesi Ziraat Fakültesi Dergisi 15 (12), 133–159.
Gözlekçi, Ş., Saraçoğlu, O., Onursal, E., Özgen, M., 2011. Total phenolic distribution of juice, peel, and seed extracts of four pomegranate cultivars. Pharma. Mag. 7 (26), 161–164.
Gündogdu, M., Muradoglu, F., Gazioglu Sensoy, R.İ., Yilmaz, H., 2011. Determination of fruit chemical properties of *Morus nigra* L. *Morus alba* L. and *Morus rubra* L. by HPLC. Sci. Hortic. 132, 37–41.
Gündoğdu, M., 2006. Pervari (Siirt) Yöresi Nar (*Punica granatum* L.) Populasyonlarında Mahalli Tiplerin seleksiyonu (Yüksek Lisans Tezi). YYÜ, Fen Bilimleri Enstitüsü, Van.
Melgarejo, P., Salazar, D.M., Artes, F., 2000. Organic acids and sugars composition of harvested pomegranate fruits. Eur. Food Res. Technol. 211, 185–190.
Mousavinejad, G., Djomeh, Z.E., Rezaei, K., Khodaparast, M.H.H., 2009. Identification end quantification of phenolic compounds and their effects on antioxidant activity in pomegranate juices of eight Iranian cultivars. Food Chem. 115, 1274–1278.
Onur, C., 1983. Akdeniz Bölgesi narlarının seleksiyonu (Doktora). Alata Bahçe Kültürleri Araştırma Eğitim Merkezi Yayın No.: 46, Mersin.
Özgen, M., Durgaç, C., Serçe, S., Kaya, C., 2008. Chemical and antioxidant properties of pomegranate cultivars grown in the Mediterranean region of Turkey. Food Chem. 111, 703–706.
Özgen, M., Reese, R.N., Tulio, A.Z., Scheerens, J.C., Miller, A.R., 2006. Modified 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) method to measure antioxidant capacity of selected small fruits and a comparison to ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhdrazyl (DPPH) methods. J. Agric. Food Chem. 54, 1151–1157.
Özbek, S., 1977. Genel Meyvecilik. Ç.Ü.Z.F. Yayınları, p. 111.
Özkaya, H., 1988. Analitik Gıda Kalite Kontrolü, vol. 1086. Ankara Üniversitesi Ziraat Fakültesi, Yayın, pp. 43–46.
Poyrazoglu, E., Gokmen, V., Artik, N., 2002. Organic acids and phenolic compounds in pomegranates (*Punica granatum* L.) grown in Turkey. J. Food Compos. Anal. 15, 567–575.
Rodriguez-Delgado, M.A., Malovana, S., Perez, J.P., Borges, T., Garcia-Montelongo, F.J., 2001. Separation pf phenolic compounds by high-performance liquid chromatography with absorbance and fluorimetric detection. J. Chromatogr. 912, 249–257.
Savran, H.S., 1999. Nar Suyunda Organik Ait Dağılımı (yüksek lisans tezi). AÜ, Fen Bilimleri Enstitüsü, Ankara.
Schobinger, U., 1988. Meyve ve Sebze Üretim Teknolojisi. Çeviren. J. Acar. H.Ü. Basımevi, Ankara, pp. 63–64.
Zar, J.H., 1999. Biostatistical Analysis, fourth ed. Prentice-Hall, Upper Saddle River, NJ, p. 663.