

Physicochemical Properties and Antioxidant Activities of Pomegranate Fruit (*Punica granatum*) of Different Cultivars Grown in Iran

Ali Tehranifar*, Mehdi Zarei, Behnam Esfandiyari, and Zahra Nemati

Center of Pomegranate Research, Department of Horticultural Science, Ferdowsi University of Mashhad, Mashhad, Iran

Abstract. The purpose of this research was to analyze and compare the physicochemical properties, along with the antioxidant activity of fifteen different pomegranate cultivars grown in Iran. The fruit weight, fruit length, fruit diameter, skin thickness, skin percentage, aril percentage, and juice percentage were within the range of 204.3-288.5 g, 70.2-81.6 mm, 76.0-84.7 mm, 2.92-6.51 mm, 36.3-75.2%, 26.3-61.9%, and 16.1-44.4%, respectively. Total soluble solid content varied from 11.0 to 15.42°Brix, pH values from 2.87 to 4.36, titratable acidity from 0.38 to 1.52 g/100 g fresh weight, total sugars content from 6.9 to 21.4 g/100 g fresh weight, total anthocyanins content from 5.54 to 26.9 mg/100 g fresh weight, ascorbic acid from 7.19 to 15.5 mg/100 g fresh weight, and total phenolics from 159.8 to 984.2 mg/100 g fresh weight. The antioxidant activity of pomegranate juice, as determined by the 1,1-diphenyl-2-picrylhydrazyl assays, was between 16.0 and 54.4%. In addition, the antioxidant activity was positively correlated with the total phenolics ($r = 0.95$), total anthocyanins ($r = 0.90$), and ascorbic acid ($r = 0.75$). These results demonstrated that the cultivar is the main factor determining the physicochemical properties and antioxidant activities in pomegranates.

Additional key words: anthocyanins, ascorbic acid, nutrition, phenolics

Introduction

Pomegranate (*Punica granatum*) belongs to the Punicaceae family and is one of the commercially important fruit which is extensively cultivated in many tropical and subtropical regions (Tehranifar and Mahmoodi-Tabar, 2009) such as Iran. Iran is one of the major important pomegranate producers and exporters in the world, and its total production was 670,000 tons in 2005 (Iranian Statistical Center, 2005). The fruit is either consumed directly or processed into various products such as juice, jams, syrup, and sauce (Al-Maiman and Ahamed, 2002).

The consumption of pomegranate has been associated with beneficial health effects, such as prevention of oxidation of both low and high density lipoprotein, blood pressure, inflammatory, atherosclerosis, prostate cancer, heart disease, and HIV-1 (Aviram et al., 2000, 2004; Malik et al., 2005; Neurath et al., 2005; Rosenblat et al., 2006). These beneficial effects have been attributed to the high levels of antioxidant activity (Gil et al., 2000) due to the high content of polyphenols such as gallic acid, ellagitannins, gallotannins, chlorogenic acid, caffeic acid, ferulic acid, coumaric acids, and catechin and anthocyanins (Gil et al., 2000; Poyrazoglu et al., 2002; Seeram et al., 2005). Seeram et al. (2008) reported that pomegranate juice has greater antioxidant capacity than other fruit juices and beverages.

Recent studies in pomegranate fruits have shown that cultivar may also substantially influence the antioxidant activity and other physicochemical properties, such as skin and juice percentage, dry matter, pH, total soluble solids (TSS), total sugars,

titratable acidity (TA), total phenolics, and anthocyanins (Al-Siad et al., 2009; Borochov-Neori et al., 2009; Fadavi et al., 2005; Mousavinejad et al., 2009; Ozgen et al., 2008; Ozkan, 2002; Tezcan et al., 2009). These parameters may provide important information to the consumer in terms of recognizing a more nutritional fruit.

Although many pomegranate cultivars have been cultivated in different regions of Iran, only a few studies have been done on physicochemical properties. Therefore, this research is focused on the analysis and comparison of the physicochemical properties and antioxidant activity of fifteen pomegranate cultivars grown in Iran.

Materials and Methods

Pomegranate cultivars

Fifteen fresh ripe pomegranate cultivars in commercial stage were harvested randomly in September 2009 from different mature trees (14-year-old) to represent the population of the plantation from Agricultural Research Center of Yazd province, Iran. The average temperature, the amount of rainfall, and relative humidity in growing season of 2009 were 28.65°C, 20 mm, and 26%, respectively. Soil characteristics were sand-loam texture, EC = 4.12 (dS·m⁻¹) and soil pH = 7.21. The trees were spaced 6 and 3 m between and along the rows, respectively. Trees were grown under traditional irrigation and routine cultural practices suitable for commercial fruit production. All cultivars were grown under the same geographical conditions and with the same applied agronomic practices. Pomegranate cultivars evaluated were: 'Malase Pust Nazok',

*Corresponding author: Tehranifar2009@yahoo.com

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'Shekarnar Pust Kolof', 'Mohali Parand Gorgan', 'Malase Dane Sefeed Ramhormoz', 'Malase Dane Siah Ramhormoz', 'Garaj Shavar Yazdi', 'Pust Siah Abarndabad', 'Malase Tabas', 'Bazmani Pust Kolof', 'Malase Mamoli Sarjo', 'Malase Porbar Sarvan', 'Mazari Bajestani', 'Lili Pust Nazok', 'Bajestani Pust Nazok', and 'Pust Siah'. Fruits were transported by a ventilated car to the laboratory as soon as harvested, and defective pomegranates (sunburns, cracks, cuts, and bruises in peel) were discarded. Approximately 7 kg of pomegranate fruits were sampled for each cultivar. The fruits were kept at 4°C until analysis. Four replicates were used for each analysis with each replicate indicating five pomegranate fruits. All reagents, solvents, and standards were of analytical reagent grade.

Physical properties

Physical properties were determined on twenty fruits randomly selected from each cultivar. Fruit weight was measured by an electronic balance with an accuracy of 0.001 g. Fruit volume was measured calculated by a liquid displacement method. Fruit density was estimated by employing the method described by Westwood (1993). Fruit length and diameter were measured by using a digital vernier caliper with a sensitivity of 0.01 mm. The measurement of fruit length was made on the polar axis, i.e., between the apex and the end of stem. The maximum width of the fruit, as measured in the direction perpendicular to the polar axis, is defined as the diameter. Arils were manually separated from the fruits, and total arils and peel per fruit were measured as above. The measurements of the peel thickness were made using the digital vernier caliper. Fruit juice content was measured by extracting of total arils per fruit using an electric extractor (model 5020, Toshiba, Tokyo, Japan). The peel, aril, and juice percentage were calculated according to the method described by Zamani (1990). Then the juices were analyzed for major chemical compositions and antioxidant activity.

Chemical composition

The pH was measured with a digital pH meter (model 601, Metrohm, Herisau, Switzerland). TA was determined by titration to pH 8.1 with 0.1 N NaOH and expressed as g of citric acid per 100 g of juice (AOAC, 1984). TSS was determined with a digital refractometer (Erma, Tokyo, Japan). Maturity index was calculated by dividing TSS to TA. Total sugars were estimated according to the method described by Ranganna et al. (2001), and ascorbic acid was determined by employing the method described by Ruck (1963), and results were expressed as mg per 100 g of juice. Total anthocyanins were determined with the pH differential method (Giusti and Wrolstad, 2001) and the results were expressed as mg cyanidin-3-glucoside 100 g of juice. Total phenolics were measured colorimetrically at 760 nm by using the Folin-Ciocalteu reagent (Singleton

and Rossi, 1965). The results were expressed as mg gallic acid equivalent in 100 g of juice.

Antioxidant activity

Antioxidant activity was assessed according to the method of Brand-Williams et al. (1995). Briefly, 100 µL of pomegranate juice diluted in the ratio of 1:100 with methanol:water (6:4, v/v) was mixed with 2 mL of 0.1 mM 1,1-diphenyl-2-pycrylhydrazyl (DPPH) in methanol. The mixtures were shaken vigorously and left to stand for 30 min. Absorbance of the resulting solution was measured at 517 nm by a UV-visible spectrophotometer (model 2010, Cecil Instr. Ltd., Cambridge, UK). The reaction mixture without DPPH was used for the background correction. The antioxidant activity was calculated using the following equation: Antioxidant activity (%) = [1 - (Abs_{sample}/Abs_{control})] × 100.

Statistical analysis

Data were analyzed by Statistical Analysis System (SAS) software Ver. 9.1 using analysis of variance (ANOVA) and the differences among means were determined for significance at $P < 0.05$ using Tukey's test.

Results and Discussion

Physical properties

Significant differences ($P < 0.05$) were detected in all measured factors except the fruit density and length/diameter ratio (Tables 1, 2). The fruit weight ranged between 204.3 ('Bazmani Pust Kolof') and 288.5 g ('Malase Dane Siah Ramhormoz'). Similarly, the lowest (223.4 cm³) and the highest (309.9 cm³) fruit volume were observed in 'Bazmani Pust Kolof' and 'Malase Dane Siah Ramhrmoz', respectively (Table 1). Thus, there was a close relationship between the fruit weight and volume. The fruit length values were 70.2 ('Garaj Shavar Yazdi') and 81.6 ('Malase Dane Siah Ramhormoz'), fruit diameter 76.0 ('Bajestani Pust Nazok') and 84.7 ('Pust Siah'), calyx length 16.7 ('Malase Dane Sefeed Ramhormoz') and 23.6 ('Garaj Shavar Yazdi'), and calyx diameter 14.9 ('Pust Siah Abarndabad') and 24.2 mm ('Pust Siah') (Table 1). These values were near to the values reported by Sarkhosh et al. (2009).

The fruit skin thickness varied from 2.92 ('Bazmani Pust Kolof') to 6.51 mm ('Pust Siah') (Table 2). Our results were higher than the values reported by Sarkhosh et al. (2009). Because of the highest skin thickness, 'Bazmani Pust Kolof' was suitable for transport to far markets. A large variation in percentage of skin (36.3-75.2%), aril (26.3-61.9%), juice (16.1-44.4%), and seed (9.9-20.6%) were observed among the cultivars (Table 2). 'Malase Tabas' having a low skin percentage (36.3%), had a high percentage of aril (61.9%) and juice (44.4%) correspondingly. The skin percentage was found

Table 1. Fruit weight (FW), fruit volume (FV), fruit density (FDe), fruit length (FL), fruit diameter (FD), fruit length/diameter (F l/d), calyx length (CL), calyx diameter (CD), and calyx length/diameter (C l/d) of fifteen Iranian pomegranate cultivars.

Cultivar ^z	FW (g)	FV (cm ³)	FDe	FL (mm)	FD (mm)	F l/d (mm)	CL (mm)	CD (mm)	C l/d (mm)
MPN	279.3 ab ^y	298.6 ab	0.93 a	76.1 abc	81.2 ab	0.93 a	17.6 b	15.6 bc	1.13 abc
SPK	259.6 abcd	279.7 abcd	0.93 a	77.9 abc	81.0 ab	0.96 a	18.5 ab	18.9 abc	0.99 abc
MPG	256.0 abcd	271.4 abcd	0.96 a	79.1 abc	78.7 ab	1.00 a	18.2 ab	16. bc	1.14 abc
MDSiR	288.5 a	309.9 a	0.93 a	81.6 a	84.6 a	0.96 a	21.6 ab	19.7 abc	1.10 abc
MDSR	236.5 abcd	260.3 abcd	0.91 a	74.7 abc	77.9 ab	0.96 a	16.7 b	20.5 ab	0.81 c
GSY	213.1 bcd	232.6 cd	0.92 a	70.2 c	76.2 b	0.92 a	23.6 a	18.2 bc	1.28 a
PSA	252.1 abcd	270.5 abcd	0.93 a	80.3 ab	79.7 ab	1.00 a	17.3 b	14.9 c	1.16 abc
MT	260.8 abcd	270.5 abcd	0.94 a	77.0 abc	78.5 ab	0.98 a	17.2 b	15.3 bc	1.13 abc
BPK	204.3 d	223.4 d	0.91 a	73.8 abc	76.0 b	0.97 a	19.6 ab	15.9 bc	1.24 ab
MMS	271.9 abc	295.8 abc	0.92 a	81.3 a	82.2 ab	0.99 a	18.6 ab	16.5 bc	1.13 abc
MPS	223.7 abcd	242.0 bcd	0.92 a	71.1 bc	79.1 ab	0.90 a	20.1 ab	20.4 abc	0.99 abc
MB	217.3 bcd	240.0 bcd	0.90 a	72.6 abc	76.7 b	0.94 a	21.2 ab	17.3 bc	1.24 ab
LPN	206.5 cd	230.1 d	0.90 a	73.2 abc	77.2 ab	0.95 a	20.0 ab	15.5 bc	1.31 a
BPN	243.1 abcd	264.2 abcd	0.93 a	76.5 abc	80.9 ab	0.95 a	20.5 ab	17.7 bc	1.18 abc
PS	246.0 abcd	285.1 abcd	0.86 a	80.0 ab	84.7 a	0.94 a	20.8 ab	24.2 a	0.86 bc

^zMPN, 'Malase Pust Nazok'; SPK, 'Shekarnar Pust Koloft'; MPG, 'Mohali Parand Gorgan'; MDSiR, 'Malase Dane Siah Ramhormoz'; MDSR, 'Malase Dane Sefeed Ramhormoz'; GSY, 'Garaj Shavar Yazdi'; PSA, 'Pust Siah Abarndabad'; MT, 'Malase Tabas'; BPK, 'Bazmani Pust Koloft'; MMS, 'Malase Mamoli Sarjo'; MPS, 'Malase Porbar Sarvan'; MB, 'Mazari Bajestani', LPN, 'Lili Pust Nazok'; BPN, 'Bajestani Pust Nazok'; PS, 'Pust Siah'

^yMean separation within columns by Tukey's test at $P < 0.05$.

Table 2. Skin thickness (ST), skin weight (SkW), skin percentage (SkP), aril weight (AW), aril percentage (AP), juice weight (JW), juice percentage (JP), seed weight (SW), and seed percentage (SP) of fifteen Iranian pomegranate cultivars.

Cultivar ^z	ST (mm)	SkW (g)	SkP (%)	AW (g)	AP (%)	JW (g)	JP (%)	SW (g)	SP (%)
MPN	3.82 bcde ^y	112.3 bcde	40.3 de	163.7 a	58.6 ab	117.7 a	42.2 ab	32.5 bcde	11.6 defg
SPK	4.08 bcde	113.0 bcde	43.6 cde	141.6 ab	54.4 abc	102.8 ab	39.5 ab	31.2 bcde	12.0 defg
MPG	4.20 bcde	117.6 bcde	46.4 cde	136.5 abc	52.9 abc	98.1 abc	38.0 ab	33.7 bcde	13.1 cdefg
MDSiR	3.69 bcde	115.9 bcde	40.4 de	166.2 a	57.4 ab	105.5 ab	36.2 abc	59.6 a	20.6 a
MDSR	4.71 bcd	128.8 bc	54.4 bc	105.1 bcd	44.6 cd	76.2 abcd	32.3 abc	23.3 e	9.9 g
GSY	3.68 bcde	107.1 bcde	50.3 bcd	105.9 bcd	49.7 bcd	76.8 abcd	36.0 abc	23.5 e	11.1 efg
PSA	3.91 bcde	123.1 bcd	48.9 bcde	127.5 abc	50.6 abcd	82.7 abcd	32.7 abc	42.1 bc	16.7 bc
MT	3.35 de	92.1 de	36.3 e	157.6 ab	61.9 a	112.9 ab	44.4 a	39.3 bcd	15.4 bcd
BPK	2.92 e	84.5 e	41.6 cde	116.5 abcd	57.1 ab	76.9 abcd	37.5 abc	29.2 cde	14.2 cde
MMS	4.64 bcd	133.7 b	49.1 bcde	137.0 ab	50.5 abcd	98.6 abc	36.3 abc	32.6 bcde	12.0 defg
MPS	5.07 b	113.7 bcde	51.1 bcd	106.0 bcd	47.1 bcd	70.2 bcd	31.1 bc	32.7 bcde	14.6 bcd
MB	4.85 bc	130.9 bc	60.2 b	83.9 cd	38.7 d	54.3 cd	25.0 cd	25.0 de	11.5 efg
LPN	3.50 cde	97.7 cde	47.5 bcde	104.9 bcd	50.8 abc	71.2 bcd	34.5 abc	28.9 cde	13.9 cdef
BPN	3.38 de	114.6 bcde	47.9 bcde	125.0 abc	50.7 abcd	77.4 abcd	31.3 bc	44.2 b	18.2 ab
PS	6.51 a	185.1 a	75.2 a	64.5 d	26.3 e	39.3 d	16.1 d	25.2 de	10.3 fg

^zMPN, 'Malase Pust Nazok'; SPK, 'Shekarnar Pust Koloft'; MPG, 'Mohali Parand Gorgan'; MDSiR, 'Malase Dane Siah Ramhormoz'; MDSR, 'Malase Dane Sefeed Ramhormoz'; GSY, 'Garaj Shavar Yazdi'; PSA, 'Pust Siah Abarndabad'; MT, 'Malase Tabas'; BPK, 'Bazmani Pust Koloft'; MMS, 'Malase Mamoli Sarjo'; MPS, 'Malase Porbar Sarvan'; MB, 'Mazari Bajestani', LPN, 'Lili Pust Nazok'; BPN, 'Bajestani Pust Nazok'; PS, 'Pust Siah'

^yMean separation within columns by Tukey's test at $P < 0.05$.

to be inversely correlated to aril percentage.

Among all the pomegranate cultivars, 'Malase Dane Siah Ramhrmoz' showed the highest fruit weight. It is commonly accepted that the fruit size affects consumer appeal and attrac-

tiveness; hence, because of its bigger size, 'Malase Dane Siah Ramhrmoz' is mostly preferred for fresh consumption. On the other hand, 'Malase Tabas' seems the most promising, combined least skin percentage and higher percentage of aril and

juice which is a highly desirable property in the food processing and industry. ‘Malase Dane Siah Ramhrmoz’ and ‘Malase Tabas’ cultivars may be useful especially in developing cultivars with the greater agronomic potential.

Chemical composition

Significant differences ($P < 0.05$) were revealed among the pomegranate cultivars for TSS, pH, TA, total sugars, maturity index, total anthocyanins, ascorbic acid, and total phenolics (Tables 3 and 4).

The TSS content ranged between 11 (‘Mohali Parande Gorgan’) and 15.42°Brix (‘Pust Siah Abarndabad’) (Table 3), which is in agreement with the results of Fadavi et al. (2005), but disagrees with the results of Poyrazoglu et al. (2002). For the production of pomegranate juice concentrates of good quality, ‘Pust Siah Abarndabad’, ‘Bazmani Pust Koloft’, ‘Lili Pust Nazok’, and ‘Malase Tabas’ are ideal cultivars because they have a relatively high TSS contents. The pH values varied from 2.87 (‘Mohali Parande Gorgan’) to 4.36 (‘Pust Siah Abarndabad’) (Table 3). Our results were higher than the values observed (2.82-3.81) by Cam et al. (2009a) on pomegranate cultivars grown in Turkey. The TA was between 0.38 (‘Pust Siah Abarndabad’) and 1.52 g/100 g (‘Mohali Parande Gorgan’) (Table 3). Fadavi et al. (2005) reported that TA values of some pomegranate cultivars in Iran were between 0.40 and 2.45 g/100 g.

The maturity index (TSS/TA) is one of the important factors influencing the taste and flavor of pomegranate, which some

researcher used to classify the pomegranate cultivars (Cam et al., 2009b; Martinez et al., 2006; Melgarejo et al., 2000). This classification has been optimized for Spanish cultivars: maturity index (MI) = 5-7 for sour, MI = 17-24 for sour-sweet, and MI = 31-98 for sweet cultivars (Martinez et al., 2006). The maturity index values varied from 7.24 to 40.4 (Table 3). According to Martinez et al. (2006), cultivars classified: ‘Pust Siah Abarndabad’ as sweet, ‘Lili Pust Nazok’, ‘Bazmani Pust Koloft’, ‘Pust Siah’, ‘Shekarnar Pust Koloft’, ‘Bajestani Pust Nazok’, ‘Garaj Shavar Yazdi’, ‘Malase Pust Nazok’, ‘Malase Tabas’, ‘Malase Mamoli Sarjo’, ‘Mazari Bajestani’, ‘Malase Porbar Sarvan’, ‘Malase Dane Sefeed Ramhormoz’, and ‘Malase Dane Siah Ramhormoz’ as sour-sweet, and ‘Mohali Parand Gorgan’ as sour. It was noteworthy that ‘Pust Siah Abarndabad’ had the highest soluble solids but the lowest acid content, the maturity index of 40.4, and is an appropriate cultivar for fresh eating. The results also showed that the sweet cultivar has higher TSS and pH values than sour-sweet and the sour cultivars, while TA was higher in sour cultivar than in the other cultivars.

The level of total sugars of fifteen pomegranate cultivars was within 6.9-21.4 mg/100 g and ‘Mazari Bajestani’ had the highest amount of total sugars than the other cultivars (Table 4). In another study, the total sugar’s values of some pomegranate cultivars growing in Turkey were between 13.9 and 16.1 g/100 g (Poyrazoglu et al., 2002). The red, blue, or purple color of many fruits such as pomegranate juice are caused by anthocyanins which are a type of phenolics compounds and

Table 3. pH, TSS, TA, maturity index (MI), and description of juice from fifteen Iranian pomegranate cultivars.

Cultivar ^z	pH	TSS (°Brix)	TA (g/100 g)	MI	Description
MPN	3.37 e ^y	11.6 c	0.58 cde	19.9 cdef	Sour-sweet
SPK	4.14 abcd	14.8 a	0.61 cd	24.2 bcd	Sour-sweet
MPG	2.87 f	11.0 c	1.52 a	7.2 g	Sour
MDSiR	3.31 e	13.4 abc	0.91 b	14.6 fg	Sour-sweet
MDSR	3.21 e	13.1 abc	0.91 b	15.0 fg	Sour-sweet
GSY	4.04 bcd	14.6 ab	0.66 cd	21.9 bcdef	Sour-sweet
PSA	4.36 a	15.42 a	0.38 e	40.4 a	Sweet
MT	3.92 cd	15.3 a	0.79 bc	19.4 cdef	Sour-sweet
BPK	4.26 ab	15.4 a	0.63 cd	23.2 bcde	Sour-sweet
MMS	3.42 e	13.1 abc	0.73 bc	18.1 def	Sour-sweet
MPS	3.27 e	13.2 abc	0.93 b	14.1 fg	Sour-sweet
MB	3.20 e	12.1 bc	0.78 bc	15.7 ef	Sour-sweet
LPN	4.20 abc	15.4 a	0.57 cde	26.9 bc	Sour-sweet
BPN	4.15 abc	15.0 a	0.63 cd	23.2 bcde	Sour-sweet
PS	3.85 d	13.2 abc	0.48 de	27.8 b	Sour-sweet

^zMPN, ‘Malase Pust Nazok’; SPK, ‘Shekarnar Pust Koloft’; MPG, ‘Mohali Parand Gorgan’; MDSiR, ‘Malase Dane Siah Ramhormoz’; MDSR, ‘Malase Dane Sefeed Ramhormoz’; GSY, ‘Garaj Shavar Yazdi’; PSA, ‘Pust Siah Abarndabad’; MT, ‘Malase Tabas’; BPK, ‘Bazmani Pust Koloft’; MMS, ‘Malase Mamoli Sarjo’; MPS, ‘Malase Porbar Sarvan’; MB, ‘Mazari Bajestani’; LPN, ‘Lili Pust Nazok’; BPN, ‘Bajestani Pust Nazok’; PS, ‘Pust Siah’

^yMean separation within columns by Tukey’s test at $P < 0.05$.

Table 4. Total sugars (TS), total anthocyanins (TAs), ascorbic acid (A), total phenolics (TPs), and antioxidant activity (AA) of juice from fifteen Iranian pomegranate cultivars.

Cultivar ^z	TS (g/100 g)	TAs (mg/100 g)	A (mg/100 g)	TPs (mg/100g)	AA (%)
MPN	16.9 fg ^y	10.4 de	11.8 bc	283.8 f	28.6 e
SPK	16.7 fg	5.6 g	7.2 e	159.8 k	16.0 i
MPG	16.6 g	10.6 de	14.4 ab	283.0 fg	28.5 e
MDSiR	17.5 ef	12.6 cd	14.4 ab	539.0 c	41.9 b
MDSR	19.6 bcd	8.72 ef	10.4 cde	281.8 g	28.1 ef
GSY	18.0 e	5.54 g	8.0 de	207.4 j	21.2 h
PSA	19.8 bcd	7.07 fg	10.0 cde	248.3 i	24.4 g
MT	20.2 bc	7.41 fg	10.7 cd	272.2 h	27.2 ef
BPK	6.9h	13.8 bc	15.5 a	541.1 c	42.4 b
MMS	20.4 b	11.3 cde	11.5 bc	335.3 d	36.5 c
MPS	19.0 d	13.2 cde	9.8 cde	205.8 j	20.1 h
MB	21.4 a	5.78 g	14.4 ab	301.3 e	31.3 d
LPN	19.7 bcd	15.9 b	14.6 ab	555.3 b	43.5 b
BPN	19.6 cd	5.74 g	9.7 cde	246.9 i	24.2 g
PS	16.6 g	26.9 a	15.1 a	984.2 a	54.4 a

^zMPN, 'Malase Pust Nazok'; SPK, 'Shekarnar Pust Koloft'; MPG, 'Mohali Parand Gorgan'; MDSiR, 'Malase Dane Siah Ramhormoz'; MDSR, 'Malase Dane Sefeed Ramhormoz'; GSY, 'Garaj Shavar Yazdi'; PSA, 'Pust Siah Abarndabad'; MT, 'Malase Tabas'; BPK, 'Bazmani Pust Koloft'; MMS, 'Malase Mamoli Sarjo'; MPS, 'Malase Porbar Sarvan'; MB, 'Mazari Bajestani', LPN, 'Lili Pust Nazok'; BPN, 'Bajestani Pust Nazok'; PS, 'Pust Siah'

^yMean separation within columns by Tukey's test at $P < 0.05$.

are well-known for their antioxidant activity. The variation in terms of total anthocyanins content (5.54-26.9 mg/100 g) was observed among the pomegranate cultivars (Table 4). Our results showed the lower total anthocyanins values than the results (8.1-36.9 mg/100 g) reported by Cam et al. (2009b). Ascorbic acid, which is abundant and has many biological functions in fruits, plays important roles in many aspects of redox control and antioxidant activity, for instance preventing from the browning of tissues (Kulkarni and Aradhya, 2005). The ascorbic acid content ranged between 7.2 ('Shekarnar Pust Koloft') and 15.5 (mg/100 g) ('Bazmani Pust Koloft') (Table 4). The values of ascorbic acid obtained in the current study are higher than pomegranate juice from 'Ganesh' (>10 mg/100 g) reported by Kulkarni and Aradhya (2005).

The content of total phenolics is one of the most important parameters for appraising the characterization of pomegranate cultivars, with respect to their nutritional value and potential use for different products. The total phenolics content ranged from 159.8 to 984.2 mg/100 g in 'Shekarnar Pust Koloft' and 'Pust Siah', respectively (Table 4). The total phenolics content has been reported for eight pomegranate juices from Iran 23.7-930.4 mg/100 g (Mousavinejad et al., 2009) and seven commercial pomegranate juices from Turkey 14.4-1008.6 mg/100 g (Tezcan et al., 2009). According to the results, as being a good source of total phenolics, pomegranate can be considered as an important nutrient for human health.

Generally, these results indicate that the fifteen cultivars

are different in terms of their TSS, pH, TA, maturity index, total sugars, total anthocyanins, ascorbic acid, and total phenolics. The chemical composition of pomegranate juice is markedly influenced by many factors such as cultivar type, environmental conditions, nutrition, and other agricultural practices. Since all fifteen pomegranate cultivars used in this study were grown in the same location using similar agronomic practices, the differences in measured parameters above showed that there was a high genetic heterogeneity within the studied cultivars and also cultivar type which plays an important role in factors.

Antioxidant activity

The DPPH radical scavenging assay is commonly employed to evaluate the ability of antioxidant to scavenge free radicals. The use of the DPPH free radical is advantageous in evaluating antioxidant effectiveness because it is more stable than the hydroxyl and superoxide radicals. The degree of discoloration indicates the scavenging potentials of the antioxidant extract. A significant variation in antioxidant activity was found among the fifteen cultivars of pomegranate studied and the values ranged from 16.0 to 54.4% (Table 4). The highest level of antioxidant activity was observed in 'Pust Siah' and the lowest one in 'Shekarnar Pust Koloft'. The antioxidant activities for pomegranate fruits were found to be 10.4 and 67.5% by Tezcan et al. (2009) and 18.6 and 42.8% by Mousavinejad et al. (2009).

Table 5. Correlation coefficients (*r*) of pH, TSS, TA, maturity index (MI), total sugars (TS), ascorbic acid (A), total anthocyanins (TAs), total phenolics (TPs), and antioxidant activity (AA) of juice from fifteen Iranian pomegranate cultivars.

Variable	pH	TSS	TA	MI	TS	A	TAs	TPs
TSS	0.766**							
TA	-0.727**	-0.487*						
MI	0.798**	0.679*	-0.844**					
TS	-0.242 ^{NS}	-0.132 ^{NS}	0.032 ^{NS}	-0.071 ^{NS}				
A	-0.208 ^{NS}	-0.274 ^{NS}	0.164 ^{NS}	-0.170 ^{NS}	-0.313 ^{NS}			
Tas	0.053 ^{NS}	-0.041 ^{NS}	-0.170 ^{NS}	0.178 ^{NS}	-0.312 ^{NS}	0.622*		
TPs	0.115 ^{NS}	0.006 ^{NS}	-0.238 ^{NS}	0.207 ^{NS}	-0.283 ^{NS}	0.655*	0.942**	
AA	0.050 ^{NS}	-0.033 ^{NS}	-0.186 ^{NS}	0.150 ^{NS}	-0.318 ^{NS}	0.753**	0.894**	0.951**

NS, *, **Nonsignificant or significant at *P* = 0.05 or 0.01, respectively.

Correlation analysis

Antioxidant activity was positively correlated with the total phenolics (*r* = 0.95), total anthocyanins (*r* = 0.89), and ascorbic acid (*r* = 0.75) (Table 5). These data demonstrate that these components are primarily responsible for the antioxidant activity in all pomegranate cultivars. Similar correlations have been reported by Serrano et al. (2005). In addition, Feryal et al. (2005) reported a positive correlation between antioxidant activity and total phenolics (*r* = 0.93) in fruits grown in Turkey. A high and significant correlation between total anthocyanins and total phenolic content was determined (*r* = 0.94). Similar findings have been reported by Ozgen et al. (2008). The maturity index was positively correlated with pH (*r* = 0.80) and TSS (*r* = 0.68), while there was a significant negative correlation between maturity index and TA (*r* = -0.84) (Table 5). Thus, maturity index in this study could serve as a valid estimate for PH, TSS, and TA when comparing the different pomegranate cultivars.

Conclusion

In this study, fifteen pomegranate cultivars were analyzed for various physicochemical properties and antioxidant activity. The results showed that there were significant differences between pomegranate cultivars investigated in parameters measured except the fruit density and length/diameter ratio. This indicates that there is a high genetic heterogeneity within the studied cultivars and also cultivar type plays an important role in measured factors. In addition, the results provide important information of the physicochemical properties of pomegranate cultivars which can be useful for developing fruit processing industry, selecting superior desirable pomegranate genotypes to bring to commercial cultivation and possibly helping pomegranate breeders to establish and manage germplasm collections. Since Iran has a high genetic variation, however, more studies of physical and chemical properties of pomegranate are required.

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