Scientia Horticulturae 126 (2010) 180–185

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Investigation of physico-chemical properties and antioxidant activity of twenty Iranian pomegranate (*Punica granatum* L.) cultivars

Ali Tehranifar[a,*], Mehdi Zarei[a], Zahra Nemati[a], Behnam Esfandiyari[a], Mohamad Reza Vazifeshenas[b]

[a] *Center of Pomegranate Research, Department of Horticultural Science, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran*
[b] *Agricultural Research Center of Yazd, Yazd, Iran*

ARTICLE INFO

Article history:
Received 15 February 2010
Received in revised form 26 June 2010
Accepted 1 July 2010

Keywords:
Pomegranate
Cultivar
Physico-chemical
Total phenolics
Antioxidant activity

ABSTRACT

Pomegranate is one of the native fruits of Iran which contains high genetic resources, but there are insufficient information regarding properties of the fruit. The objective of the present study was to investigate the physcio-chemical characteristics and antioxidant activity of twenty pomegranate cultivars grown in Iran. This study showed that there were significant differences among the cultivars in all measured factors except the length/diameter ratio of fruit. The fruit weight, skin percentage, aril percentage and juice percentage were within the range of 196.89–315.28 g, 32.28–59.82%, 37.59–65% and 26.95–46.55%, respectively. The total soluble solids content varied from 11.37 (°Brix) to 15.07 (°Brix), pH values from 3.16 to 4.09, titratable acidity content from 0.33 g 100 g^{-1} to 2.44 g 100 g^{-1} and total sugars content from 13.23 g 100 g^{-1} to 21.72 g 100 g^{-1}. The results also showed that the values of ascorbic acid ranged from 9.91 mg 100 g^{-1} to 20.92 mg 100 g^{-1}. The total anthocyanins content was observed in pomegranate cultivars between 5.56 mg 100 g^{-1} and 30.11 mg 100 g^{-1}. The level of total phenolics was varied from 295.79 mg 100 g^{-1} to 985.37 mg 100 g^{-1}. The antioxidant activity of pomegranate cultivars was found between 15.59 and 40.72%. These data demonstrated that the cultivar was the main parameter which influences the physico-chemical properties and antioxidant activity in pomegranates.

1. Introduction

Pomegranate (*Punica granatum* L.) is an important commercial fruit crop that is extensively cultivated in parts of Asia, North Africa, the Mediterranean and the Middle East (Sarkhosh et al., 2006). Iran is one of the most important pomegranate producers and exporters in the world, and its total production in 2005 was 670,000 tons (Anonymous, 2005). Pomegranate fruits are widely consumed fresh or processed into juice, jams, syrup and sauce. The edible portion (aril) of fruit is about 55–60% of the total fruit weight and consists of about 75–85% juice and 15–25% seeds (Al-Maiman and Ahmad, 2002).

Recently, the high antioxidant activity of the extracts from different part of pomegranate fruit such as peel, juice and seeds have been reported (Gil et al., 2000; Aviram et al., 2000; Singh et al., 2002). The antioxidant capacity of pomegranate juice is greater than other fruit juices and beverages (Seeram et al., 2008). This antioxidant activity has been attributed to the high level of phenolic compounds (Gil et al., 2000). Pomegranate is known to contain considerable of phenolic compounds, including anthocyanins (3-glucosides and 3,5-diglucosides of delphinidin, cyanidin, and pelargonidin), ellagic acid, punicalin, punicalagin, pedunculagin and different flavanols (Gonzalez-Molina et al., 2009).

The pomegranate has been of recent interest for its nutritional and antioxidant activity. Al-Maiman and Ahmad (2002) also have analyzed changes in physical and chemical properties during pomegranate fruit maturation. Ozgen et al. (2008) evaluated the chemical and antioxidant properties of pomegranate cultivars grown in the Mediterranean region of Turkey. The composition of pomegranate fruit is strongly dependent on the cultivar type, growing region, climate, maturity and cultural practice (Holcroft et al., 1998; Melgarejo and Artes, 2000; Heshi et al., 2001; Ozkan, 2002). In addition, various reports have shown significant variations in organic acids, phenolic compounds, sugars and water-soluble vitamins composition of pomegranates during the years (Melgarejo and Artes, 2000; Poyrazoglu et al., 2002; Al-Maiman and Ahmad, 2002; Kulkarni and Aradhya, 2005; Ozgen et al., 2008; Tezcan et al., 2009). These parameters may supply important information to the consumer in terms of recognizing a more nutritional fruit.

In spite of various pomegranate cultivars grown in different regions of the Iran, few published results on the properties of the cultivars in the literature are available (Mousavinejad et al., 2009). Such data will assist in the cultivar selection for commercial production to meet market demand. Therefore, the aim of the present study was to analyse and compare the physico-chemical character-

* Corresponding author. Tel.: +98 915 1107389; fax: +98 511 8787430.
E-mail addresses: tehranifar2009@yahoo.com, tehranifar@um.ac.ir (A. Tehranifar).

0304-4238/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.scienta.2010.07.001

istics and antioxidant activity of 20 pomegranate cultivars grown in Iran.

2. Materials and methods

2.1. Pomegranate cultivars

Twenty pomegranate cultivars were studied: 'Agha Mandali Save' (AMS), 'Alak Shirin Save' (ASS), 'Bazmani Pust Nazok' (BPN), 'Dom Ambaroti' (DA), 'Khazar Bajestani' (KB), 'Lili Post Koloft' (LPK), 'Malas Pust Sorkh' (MPS), 'Malas Save' (MS), 'Malas Yazdi' (MY), 'Pust Sefeed Dezfol' (PSD), 'Save Pust Ghermez' (SPGh), 'Save Pust Sefeed' (SPSe), 'Shirin Dane Ghermez Ferdows' (SDGF), 'Shirin Dane Sefeed Ferdows' (SDSF), 'Shirin Pust Ghermez' (SPG), 'Shirin Pust Sefeed' (SPS), 'Shishe Kap' (SK), 'Torsh Shahvar Ferdows' (TSF), 'Torsh Shahvar Kashmar' (TSK), 'Zagh Yazdi' (ZY). Commercially ripe fresh fruits were harvested in september 2009 from different mature trees (14-year-old) randomly selected to represent the population of the plantation from the Agricultural Research Center of the 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 texture being sandy-loam, 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. Fruits were transported by a ventilated car to the laboratory soon after harvest, where pomegranates with defects (sunburns, cracks, cuts and bruises in peel) were discarded. Approximately 7 kg of pomegranate fruit was sampled for each cultivar. The fruits were kept at 4 °C until analysis. Four replicates were maintained for each analysis and each replicate indicating five pomegranate fruits. All reagents, solvents and standards were of analytical reagent grade.

2.2. Physical properties

Twenty fruits of each cultivar were individually analyzed for physical characteristics. Fruits were weighted in the air on a balance of accuracy of 0.001 g. Fruit volume was calculated by a liquid displacement method. The weight density of the fruit was obtained by the ratio of weight to volume. The length and diameter of the fruit and calyx were measured with a digital vernier caliper. 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. After measuring the whole fruit size, the 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 calliper. Then the juices were analyzed for major chemical composition and antioxidant activity.

2.3. Titrable acidity, pH, total soluble solids and maturity index

The titrable acidity (TA) was determined by titration to pH 8.1 with 0.1 M NaOH solution and expressed as g of citric acid per 100 g of juice (AOAC, 1984). The pH measurements were performed using a digital pH meter (Metrohm 601) at 21 °C. The total soluble solids (TSS) were determined with a digital refractrometer (Erma, Tokyo, calibrated using distilled water). Results were reported as °Brix at 21 °C. Maturity index was calculated by dividing total soluble solids to titrable acidity.

2.4. Total sugars and ascorbic acid

The total sugars were estimated according to the method described by Ranganna (2001). Results were expressed as g per 100 g of juice. Ascorbic acid was determined by employing the method described by Ruck (1963). Results were expressed as mg per 100 g of juice.

2.5. Total anthocyanins

The total anthocyanins were estimated by pH differential method using two buffer systems: potassium chloride buffer, pH 1.0 (25 mM) and sodium acetate buffer, pH 4.5 (0.4 M) (Giusti and Wrolstad, 2001). The samples were diluted by a potassium chloride buffer until the absorbance of the sample at 510 nm wavelength was within the linear range of the spectrophotometer (Cecil 2010 UV–visible). This dilution factor was later used to dilute the sample with the sodium acetate buffer. The wavelength reading was performed after 15 min of incubation, four times per sample, diluted in the two different buffers and at two wavelengths of 510 nm and 700 nm. The total anthocyanins content was calculated as follows: total anthocyanins = $[(A \times MW \times DF \times 100)/MA]$, where $A = (A_{510} - A_{700})\ pH_{1.0} - (A_{510} - A_{700})\ pH_{4.5}$; MW: molecular weight (449.2); DF: dilution factor; MA: molar absorptive coefficient of cyaniding-3-glucosid (26.900). Results were expressed as mg cyaniding-3-glucoside 100 g^{-1} of juice.

2.6. Total phenolics

The total phenolics were determined by using Folin–Ciocalteu method (Singleton and Rossi, 1965). 300 μl of diluted pomegranate juice in the ratio of 1:100 with methanol:water (6:4) was mixed with 1.5 ml of 10-fold-diluted Folin–Ciocalteu reagent and 1.2 ml of 7.5% sodium carbonate. The mixture was allowed to stand for 90 min at room temperature before the absorbance was measured by a Cecil 2010 UV–visible spectrophotometer at 760 nm. Gallic acid was used as a standard. The results were expressed as mg gallic acid equivalent in 100 g of fruit juice (mg GAE/100 g of juice).

2.7. 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) was mixed with 2 ml of 0.1 mM 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 Cecil 2010 UV–visible spectrophotometer. The reaction mixture without DPPH was used for the background correction. The antioxidant activity was calculated using the following equation: antioxidant activity (%) = [1 − (sample 517 nm/control 517 nm)] × 100.

2.8. Statistical analysis

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

3. Results and discussion

3.1. Physical properties

The physical characteristics of twenty pomegranate cultivars analyzed are described in Tables 1 and 2. Significant differences

Table 1
Fruit weight (FW), fruit volume (FV), fruit densities (FDs), 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 twenty Iranian pomegranate cultivars.

Cultivars	Parameter								
	FW (g)	FV (cm^3)	FDs	FL (mm)	FD (mm)	F l/d (mm)	CL (mm)	CD (mm)	C l/d (mm)
SPG	196.89 ± 9.43^{d}	204.24 ± 12.25^{d}	0.96 ± 0.03^{ab}	72.84 ± 3.20^{ab}	74.71 ± 2.69^{ab}	0.97 ± 0.04^{a}	18.39 ± 3.06^{defgh}	14.66 ± 1.56^{fgh}	1.27 ± 0.26^{cd}
SPS	315.28 ± 21.17^{a}	341.35 ± 32.57^{a}	0.92 ± 0.02^{abc}	81.42 ± 2.72^{a}	86.88 ± 1.77^{a}	0.93 ± 0.01^{a}	23.00 ± 2.42^{ab}	19.23 ± 1.51^{bcde}	1.20 ± 0.25^{cdef}
AMS	219.84 ± 17.99^{bcd}	251.37 ± 14.37^{bcd}	0.87 ± 0.04^{c}	74.54 ± 3.33^{ab}	80.56 ± 2.30^{ab}	0.92 ± 0.03^{a}	13.45 ± 1.36^{i}	12.52 ± 1.77^{h}	1.07 ± 0.04^{defgh}
ASS	293.96 ± 65.84^{ab}	301.57 ± 69.72^{abc}	0.97 ± 0.01^{a}	74.82 ± 4.75^{ab}	84.69 ± 4.30^{a}	0.88 ± 0.04^{a}	19.46 ± 3.03^{cdef}	21.21 ± 3.17^{ab}	0.94 ± 0.12^{gh}
MS	251.54 ± 15.27^{abcd}	270.58 ± 15.11^{abcd}	0.92 ± 0.02^{abc}	79.79 ± 3.32^{ab}	79.42 ± 2.32^{ab}	1.00 ± 0.03^{a}	20.65 ± 1.01^{abcd}	20.69 ± 2.66^{abc}	1.01 ± 0.13^{fgh}
MPS	288.52 ± 35.29^{abc}	309.93 ± 29.89^{ab}	0.93 ± 0.03^{abc}	81.56 ± 1.84^{a}	84.63 ± 1.99^{a}	0.96 ± 0.01^{a}	20.96 ± 2.84^{abcd}	19.68 ± 2.10^{bcde}	1.07 ± 0.20^{defgh}
SDGF	264.19 ± 28.78^{abcd}	279.11 ± 24.90^{abcd}	0.94 ± 0.03^{abc}	77.55 ± 2.29^{ab}	64.98 ± 2.44^{b}	1.61 ± 0.05^{a}	21.15 ± 1.47^{abcd}	17.15 ± 1.04^{defg}	1.23 ± 0.09^{cde}
SDSF	260.79 ± 27.12^{abcd}	291.00 ± 36.87^{abc}	0.89 ± 0.04^{bc}	80.43 ± 3.83^{a}	83.12 ± 2.65^{ab}	0.96 ± 0.05^{a}	22.91 ± 2.22^{abc}	14.96 ± 1.60^{fgh}	1.53 ± 0.06^{ab}
PSD	228.92 ± 23.99^{bcd}	241.33 ± 26.29^{bcd}	0.94 ± 0.07^{abc}	73.83 ± 2.02^{ab}	77.90 ± 2.72^{ab}	0.94 ± 0.02^{a}	21.21 ± 1.57^{abcd}	15.09 ± 1.97^{fgh}	1.42 ± 0.18^{bc}
ZY	217.08 ± 24.17^{bcd}	227.46 ± 33.49^{bcd}	0.95 ± 0.07^{ab}	75.80 ± 3.69^{ab}	75.22 ± 3.33^{ab}	1.00 ± 0.06^{a}	21.38 ± 1.42^{abcd}	19.38 ± 1.42^{bcde}	1.10 ± 0.00^{defgh}
MY	220.43 ± 12.44^{bcd}	233.41 ± 15.91^{bcd}	0.94 ± 0.01^{abc}	69.49 ± 4.19^{b}	72.96 ± 6.32^{ab}	0.95 ± 0.09^{a}	20.01 ± 1.69^{bcde}	19.23 ± 1.65^{bcde}	1.04 ± 0.12^{efgh}
SPSe	243.79 ± 29.54^{abcd}	258.30 ± 36.55^{bcd}	0.94 ± 0.0.2^{abc}	79.86 ± 4.94^{ab}	78.80 ± 3.98^{ab}	1.01 ± 0.04^{a}	15.25 ± 3.79^{hi}	14.71 ± 1.56^{fgh}	1.03 ± 0.25^{efgh}
SPGh	230.57 ± 21.83^{bcd}	239.25 ± 20.36^{bcd}	0.96 ± 0.03^{ab}	73.58 ± 1.77^{ab}	77.29 ± 2.23^{ab}	0.95 ± 0.01^{a}	15.74 ± 1.66^{ghi}	14.67 ± 1.21^{fgh}	1.07 ± 0.12^{defgh}
BPN	254.15 ± 37.40^{abcd}	264.16 ± 37.24^{abcd}	0.96 ± 0.01^{ab}	77.04 ± 2.64^{ab}	78.54 ± 3.64^{ab}	0.98 ± 0.02^{a}	16.30 ± 2.38^{fghi}	15.34 ± 1.57^{fgh}	1.07 ± 0.22^{defgh}
TSK	228.53 ± 28.68^{bcd}	245.14 ± 32.39^{bcd}	0.93 ± 0.02^{abc}	73.13 ± 2.26^{ab}	78.99 ± 4.78^{ab}	0.92 ± 0.05^{a}	18.93 ± 1.27^{defg}	16.16 ± 2.00^{efg}	1.18 ± 0.12^{def}
DA	230.36 ± 37.19^{bcd}	245.05 ± 32.75^{bcd}	0.93 ± 0.04^{abc}	74.38 ± 4.19^{ab}	78.19 ± 3.89^{ab}	0.95 ± 0.01^{a}	19.02 ± 3.50^{defg}	17.20 ± 2.38^{cdefg}	1.10 ± 0.14^{defg}
SK	274.59 ± 25.32^{abcd}	296.16 ± 29.33^{abc}	0.92 ± 0.05^{abc}	78.94 ± 2.18^{ab}	81.35 ± 3.47^{ab}	0.97 ± 0.05^{a}	24.00 ± 1.83^{a}	13.95 ± 1.61^{gh}	1.71 ± 0.09^{a}
TSF	214.38 ± 25.50^{cd}	223.84 ± 18.56^{cd}	0.95 ± 0.08^{ab}	72.93 ± 2.94^{ab}	76.69 ± 3.08^{ab}	0.95 ± 0.01^{a}	16.78 ± 2.36^{efghi}	17.85 ± 2.17^{bcdef}	0.93 ± 0.04^{gh}
LPK	257.31 ± 34.72^{abcd}	275.96 ± 37.65^{abcd}	0.93 ± 0.02^{abc}	73.37 ± 2.49^{ab}	79.82 ± 4.24^{ab}	0.92 ± 0.05^{a}	20.00 ± 2.44^{efghi}	20.67 ± 3.53^{abcd}	0.99 ± 0.17^{fgh}
KB	219.08 ± 32.29^{bcd}	238.04 ± 33.80^{bcd}	0.92 ± 0.01^{abc}	73.51 ± 4.80^{ab}	77.39 ± 3.36^{ab}	0.94 ± 0.02^{a}	21.04 ± 2.16^{abcd}	23.96 ± 2.33^{a}	0.88 ± 0.09^{h}

Means of 20 fruits in each column followed by different letters are significantly different ($P < 0.05$); ±, standard deviation.

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 twenty Iranian pomegranate cultivars.

Cultivars	Parameter								
	ST (mm)	SkW (g)	SkP (%)	AW (g)	AP (%)	JW (g)	JP (%)	SW (g)	SP (%)
SPG	3.13 ± 0.37^{h}	63.61 ± 6.37^{l}	32.28 ± 2.35^{h}	127.89 ± 6.23^{bcdef}	65.00 ± 2.89^{a}	91.62 ± 4.14^{abcde}	46.55 ± 1.49^{a}	30.29 ± 2.27^{defgh}	15.40 ± 1.30^{bcd}
SPS	4.93 ± 0.24^{abc}	166.59 ± 17.24^{a}	52.77 ± 2.99^{abc}	140.58 ± 12.33^{abcde}	44.72 ± 4.58^{hij}	91.06 ± 12.55^{abcde}	28.94 ± 4.00^{gh}	45.39 ± 1.36^{b}	14.43 ± 0.85^{cde}
AMS	4.01 ± 0.38^{defg}	117.36 ± 23.16^{bcdef}	53.11 ± 7.28^{abc}	99.65 ± 12.08^{fgh}	45.53 ± 6.12^{hij}	65.53 ± 13.88^{fg}	30.01 ± 6.86^{gh}	29.99 ± 2.55^{efgh}	13.65 ± 0.71^{defg}
ASS	5.36 ± 0.58^{a}	140.87 ± 36.17^{b}	48.12 ± 6.85^{cde}	151.05 ± 42.48^{abc}	51.13 ± 7.68^{defgh}	99.90 ± 27.54^{abc}	34.15 ± 7.08^{defgh}	42.23 ± 16.78^{bc}	13.97 ± 2.41^{def}
MS	4.16 ± 0.41^{def}	129.40 ± 7.82^{bcde}	51.46 ± 1.72^{bcd}	118.15 ± 8.74^{defg}	46.96 ± 1.61^{fghi}	72.09 ± 13.46^{defg}	28.53 ± 3.79^{h}	41.92 ± 6.76^{bc}	16.78 ± 3.29^{b}
MPS	3.68 ± 0.22^{efgh}	114.02 ± 5.35^{cdefg}	40.00 ± 5.77^{fgh}	170.43 ± 35.85^{a}	58.58 ± 5.61^{abcd}	105.50 ± 25.36^{abc}	36.17 ± 4.32^{cdefg}	59.58 ± 11.50^{a}	20.55 ± 2.32^{a}
SDGF	4.62 ± 0.57^{bcd}	131.57 ± 8.12^{bcd}	50.07 ± 3.89^{bcd}	130.36 ± 23.37^{bcdef}	49.08 ± 3.77^{efgh}	82.49 ± 16.03^{cdefg}	31.05 ± 3.22^{efgh}	43.71 ± 4.89^{bc}	16.58 ± 1.26^{bc}
SDSF	3.37 ± 0.3^{1gh}	106.74 ± 21.05^{efghi}	40.84 ± 5.86^{efg}	150.36 ± 20.46^{abcd}	57.75 ± 5.98^{abcd}	97.98 ± 11.13^{abc}	37.79 ± 4.76^{bcdef}	43.60 ± 6.70^{bc}	16.67 ± 1.19^{bc}
PSD	3.58 ± 0.10^{efgh}	102.16 ± 7.94^{fghij}	44.84 ± 4.05^{def}	123.07 ± 20.59^{cdefg}	53.54 ± 3.66^{cdefgh}	88.37 ± 21.02^{abcdef}	38.25 ± 4.92^{bcde}	31.72 ± 2.14^{defg}	13.98 ± 1.87^{def}
ZY	3.20 ± 0.60^{h}	80.20 ± 23.59^{jkl}	37.08 ± 10.96^{fgh}	133.55 ± 29.52^{bcde}	61.40 ± 10.56^{abc}	96.61 ± 24.36^{abcd}	44.42 ± 9.40^{ab}	32.49 ± 4.49^{defg}	14.95 ± 0.95^{bcde}
MY	3.64 ± 0.36^{efgh}	92.67 ± 3.70^{ghijk}	42.15 ± 3.15^{efg}	125.27 ± 13.33^{bcdef}	56.72 ± 2.88^{bcde}	85.00 ± 9.54^{bcdefg}	38.48 ± 2.23^{bcd}	36.68 ± 5.42^{bcde}	16.60 ± 1.88^{bc}
SPSe	4.27 ± 0.68^{cde}	126.87 ± 29.81^{bcde}	51.69 ± 7.48^{bcd}	112.85 ± 16.04^{efgh}	46.67 ± 8.11^{ghi}	81.29 ± 11.25^{cdefg}	33.69 ± 6.18^{defgh}	24.10 ± 4.40^{gh}	9.90 ± 1.67^{hi}
SPGh	3.18 ± 0.14^{h}	89.16 ± 8.96^{ijk}	38.68 ± 1.62^{fgh}	138.74 ± 14.53^{abcde}	60.14 ± 1.69^{abc}	90.09 ± 11.39^{abcdef}	39.04 ± 2.74^{bcd}	45.24 ± 5.21^{b}	19.61 ± 0.94^{a}
BPN	3.35 ± 0.48^{gh}	89.54 ± 11.52^{hijk}	35.30 ± 1.14^{gh}	157.55 ± 26.57^{ab}	61.88 ± 2.23^{ab}	112.92 ± 19.33^{a}	44.36 ± 2.58^{ab}	39.25 ± 8.28^{bcd}	15.35 ± 1.13^{bcd}
TSK	4.67 ± 0.60^{abcd}	136.59 ± 16.08^{bc}	59.82 ± 2.57^{a}	85.24 ± 6.64^{h}	37.59 ± 4.07^{j}	61.65 ± 9.63^{g}	26.95 ± 2.16^{h}	26.21 ± 4.64^{gh}	11.44 ± 1.02^{ghi}
DA	3.57 ± 0.27^{fgh}	92.59 ± 11.19^{ghijk}	40.53 ± 3.93^{efg}	128.26 ± 28.04^{bcdef}	55.30 ± 3.77^{bcde}	94.46 ± 21.29^{abcd}	40.70 ± 3.13^{abcd}	27.45 ± 5.75^{fgh}	11.84 ± 0.65^{efg}
SK	3.72 ± 0.20^{efgh}	113.37 ± 10.47^{cdefgh}	41.31 ± 1.84^{efg}	142.72 ± 14.77^{abc}	55.64 ± 2.64^{bcde}	107.73 ± 6.7^{ab}	39.37 ± 2.82^{abcd}	35.75 ± 4.01^{cdef}	13.01 ± 0.84^{efg}
TSF	3.66 ± 0.80^{efgh}	77.90 ± 15.05^{kl}	37.00 ± 10.47^{fgh}	130.77 ± 33.98^{bcdef}	60.34 ± 10.57^{abc}	95.85 ± 32.78^{abcd}	43.95 ± 11.65^{ab}	31.79 ± 1.64^{defg}	14.94 ± 1.43^{bcde}
LPK	3.73 ± 0.68^{efgh}	108.41 ± 20.62^{defghi}	42.02 ± 4.96^{efg}	140.44 ± 19.86^{abcde}	54.66 ± 4.18^{bcdef}	107.91 ± 3.78^{ab}	42.33 ± 3.92^{abc}	27.45 ± 2.68^{fgh}	10.73 ± 0.97^{hi}
KB	5.25 ± 0.83^{ab}	125.02 ± 6.46^{bcdef}	57.63 ± 7.25^{ab}	91.85 ± 26.55^{gh}	41.10 ± 6.79^{ij}	67.82 ± 18.71^{efg}	30.40 ± 5.06^{fgh}	21.22 ± 7.51^{h}	9.44 ± 2.15^{i}

Means of 20 fruits in each column followed by different letters are significantly different ($P < 0.05$); ±, standard deviation.

($P < 0.05$) were detected in all measured parameters except the length/diameter ratio of fruit.

Average fruit weight of pomegranate cultivars ranged between 196.89 g ('Shirin Pust Ghermez') and 315.28 g ('Shirin Pust Sefeed') (Table 1). Shulman et al. (1984) reported that variation of fruit weight depend on the cultivar and ecological condition. Similarly, the lowest (204.24 cm^3) and the highest (341.35 cm^3) fruit volume were observed in 'Shirin Pust Ghermez' and 'Shirin Pust Sefeed', respectively (Table 1). Thus, one can say that there is a close relation between fruit weight and fruit volume. The fruit length values were 69.49 mm ('Malas Yazdi') and 81.56 mm ('Malas Pust Sorkh'), fruit diameter 64.98 mm ('Shirin Dane Ghermez Ferdows') and 86.88 mm ('Shirin Pust Sefeed'), calyx length 13.45 mm ('Agha Mandali Save') and 24 mm ('Shishh Kab'), calyx diameter 12.52 mm ('Agha Mandali Save') and 23.96 mm ('Khazar Bajestani') (Table 1). It was previously showed that the fruit weight, fruit length, fruit diameter, calyx length and calyx diameter of pomegranate fruits grown in Iran are between 164.89 g and 375.76 g; 64–137.4 mm; 68–86.9 mm; 16.7–29.9 mm and 13.9–25 mm (Sarkhosh et al., 2009). Our results in general were close to these studies. Valero and Ruiz-Altisent (2000) have reported this knowledge is particularly relevant in the design or selection of appropriate packaging for fruit handling and storage.

The variation in fruit skin thickness was observed among the studied cultivars (3.13 and 5.36 mm) (Table 2). These values were higher than values reported by Sarkhosh et al. (2009). As shown in Table 2, there are wide variations in percentage of skin (32.28–59.82%), aril (37.59–65%) and seed (9.44–20.55%) among the pomegranate cultivars. The highest aril percentage (65%) and the lowest skin percentage (32.28%) were recorded in 'Shirin Pust Ghermez'. According to the current study, the aril percentage was inversely correlated to skin percentage. One of the most important parameters from an industrial point of view is the juice content of the aril. The juice percentage (of whole fruit) of the studied pomegranate cultivars varied from 26.95% ('Torsh Shahvar Kashmar') to 46.55% ('Shirin Pust Ghermez'), which agree with the results reported by Fadavi et al. (2005).

The results for the physical properties of the pomegranate cultivars in this research demonstrated that twenty cultivars are different in all measured parameters except the length/diameter ratio of fruit. 'Shirin Pust Ghermez' cultivar seems the most promising, combined more percentage of aril and juice and least skin percentage that was a highly desirable property in the food processing and beverage industry. The other promising cultivars were 'Shirin Dane Ghermez' for its bigger fruits. Both of the cultivars may be useful especially in developing cultivars with the greater agronomic potential.

3.2. Total soluble solids, pH, titrable acidity, total sugars and maturity index

The results for total soluble solids, pH, titrable acidity, total sugars and maturity index of the pomegranate from the different cultivars are given in Table 3. Significant differences ($P < 0.05$) were revealed among the pomegranate cultivars for total soluble solids, pH, titrable acidity, total sugars and maturity index.

As shown in Table 3, the highest total soluble solids content was in 'Torsh Shavar Ferdows' (15.07 °Brix) and the lowest was in 'Agha Mandali Save' (11.37 °Brix). Our results were lower than values observed (16–19 °Brix) by Poyrazoglu et al. (2002), while our results were in agreement with values (10–16.5 °Brix) reported by Fadavi et al. (2005). The pH values ranged between 3.16 ('Khazar Bajestani') and 4.09 ('Agha Mandali Save') (Table 3). The pH values obtained in the current study are greater than those reported by Cam et al. (2009a) on pomegranate cultivars grown in Turkey. The titrable acidity content varied from 0.33 ('Shirin Dane Ghermez Fer-

Table 3
pH, total soluble solids (TSS), titrable acidity (TA), maturity index (MI), total sugars (TS), total anthocyanins (TAs), ascorbic acid (A), total phenolics (TPs) and antioxidant activity (AA) of twenty Iranian pomegranate juice cultivars.

Cultivars	Parameter								
	pH	TSS (°Brix)	TA (g 100 g^{-1})	MI	TS(g 100 g^{-1})	TAs (mg 100 g^{-1})	A (mg 100 g^{-1})	TPs (mg 100 g^{-1})	AA (%)
SPG	3.46 ± 0.03^{gh}	14.22 ± 1.70^{abc}	0.49 ± 0.54^{fg}	30.67 ± 2.02^{ab}	18.21 ± 0.49^{fg}	9.56 ± 0.12^{cdef}	17.62 ± 0.71^{abc}	377.62 ± 32.09^{ghi}	23.16 ± 1.19^{ghi}
SPS	4.02 ± 0.05^{ab}	14.35 ± 1.03^{ab}	0.40 ± 0.08^{g}	37.18 ± 7.11^{a}	19.18 ± 0.25^{de}	6.37 ± 0.23^{lmn}	13.43 ± 0.84^{efgh}	622.21 ± 26.79^{d}	29.83 ± 1.04^{cd}
AMS	4.09 ± 0.21^{a}	11.37 ± 1.10^{e}	0.56 ± 0.03^{fg}	20.02 ± 3.98^{bc}	13.23 ± 0.38^{j}	6.23 ± 0.15^{lmn}	16.96 ± 1.95^{bcd}	309.03 ± 13.02^{ij}	18.16 ± 2.06^{jkl}
ASS	3.37 ± 0.08^{hi}	14.95 ± 0.12^{a}	0.36 ± 0.12^{g}	46.31 ± 1.15^{a}	19.17 ± 0.30^{de}	8.57 ± 0.12^{fghi}	14.09 ± 2.59^{defg}	540.99 ± 21.39^{e}	27.39 ± 1.18^{cdefg}
MS	3.43 ± 0.07^{gh}	13.37 ± 0.46^{bc}	1.67 ± 0.12^{b}	8.02 ± 2.20^{c}	17.55 ± 0.12^{gh}	6.90 ± 0.23^{jklm}	9.91 ± 0.84^{i}	710.74 ± 11.68^{c}	29.87 ± 1.77^{cd}
MPS	3.56 ± 0.03^{efgh}	14.35 ± 0.92^{ab}	1.51 ± 0.07^{bc}	9.45 ± 1.18^{c}	20.89 ± 0.97^{ab}	8.72 ± 0.14^{efgh}	16.74 ± 2.27^{bcde}	985.37 ± 9.02^{a}	40.72 ± 0.45^{a}
SDGF	3.99 ± 0.13^{ab}	13.85 ± 1.74^{abc}	0.33 ± 0.06^{g}	42.55 ± 8.20^{a}	17.24 ± 0.22^{h}	8.09 ± 0.40^{ghij}	17.84 ± 1.50^{ab}	332.07 ± 20.71^{hij}	17.45 ± 2.38^{kl}
SDSF	3.91 ± 0.13^{abc}	13.70 ± 0.98^{abc}	0.70 ± 0.05^{f}	19.75 ± 2.99^{bc}	16.15 ± 0.22^{i}	9.87 ± 0.66^{cde}	13.21 ± 3.13^{fghi}	522.08 ± 21.69^{ef}	28.37 ± 1.87^{cdef}
PSD	3.78 ± 0.37^{bcde}	14.07 ± 1.16^{abc}	0.78 ± 0.07^{de}	17.95 ± 1.93^{cd}	17.27 ± 0.36^{h}	8.99 ± 0.49^{defg}	15.20 ± 1.95^{bcdef}	306.3 ± 30.83^{ij}	22.41 ± 1.82^{hij}
ZY	3.56 ± 0.25^{efgh}	14.22 ± 1.17^{abc}	1.07 ± 0.15^{de}	13.39 ± 2.60^{c}	20.19 ± 0.13^{bc}	9.05 ± 0.37^{defg}	14.76 ± 0.84^{bcefg}	409.49 ± 25.11^{g}	21.64 ± 2.5 6^{hijk}
MY	3.52 ± 0.12^{fgh}	14.02 ± 0.74^{abc}	1.70 ± 0.09^{b}	8.27 ± 3.56^{c}	19.4 ± 0.20^{cd}	30.11 ± 3.63^{a}	20.92 ± 2.00^{a}	916.03 ± 22.10^{b}	35.60 ± 1.37^{b}
SPSe	3.65 ± 0.07^{defg}	14.37 ± 1.26^{ab}	0.79 ± 0.05^{de}	13.24 ± 2.10^{c}	21.72 ± 0.16^{a}	11.85 ± 0.35^{b}	16.96 ± 0.84^{bcd}	540.28 ± 21.52^{e}	31.45 ± 2.02^{bc}
SPGh	3.37 ± 0.09^{hi}	13.80 ± 0.33^{abc}	1.08 ± 0.17^{cd}	10.87 ± 2.45^{c}	19.24 ± 0.10^{d}	6.44 ± 0.13^{klmn}	10.57 ± 2.23^{hi}	476.73 ± 25.41^{f}	24.36 ± 3.27^{fgh}
BPN	3.57 ± 0.04^{efgh}	14.25 ± 0.37^{ab}	1.09 ± 0.09^{de}	13.08 ± 2.34^{c}	19.5 ± 0.18^{cd}	7.41 ± 0.17^{ijkl}	12.99 ± 0.84^{fghi}	544.25 ± 25.32^{e}	27.22 ± 0.74^{cdefg}
TSK	3.93 ± 0.11^{abc}	11.67 ± 0.23^{de}	2.31 ± 0.04^{a}	5.04 ± 4.58^{c}	21.09 ± 0.22^{ab}	7.63 ± 0.22^{hijk}	16.08 ± 1.50^{bcdef}	295.79 ± 22.79^{j}	15.59 ± 3.04^{l}
DA	3.83 ± 0.10^{bcd}	12.85 ± 0.19^{cd}	0.96 ± 0.04^{e}	13.33 ± 1.29^{c}	19.03 ± 0.17^{def}	5.72 ± 0.30^{mn}	16.96 ± 0.84^{bcd}	358.15 ± 16.21^{ghi}	22.82 ± 2.35^{ghij}
SK	3.73 ± 0.10^{cdef}	14.32 ± 1.09^{ab}	1.02 ± 0.07^{e}	14.03 ± 2.41^{c}	19.48 ± 0.35^{cd}	10.07 ± 0.25^{cd}	14.32 ± 0.84^{cdefg}	335.46 ± 11.84^{hij}	19.46 ± 2.14^{ijkl}
TSF	3.58 ± 0.25^{efgh}	15.07 ± 1.13^{a}	2.44 ± 0.08^{a}	6.17 ± 3.03^{c}	19.93 ± 0.36^{cd}	10.32 ± 0.33^{c}	17.40 ± 0.84^{bcd}	645.9 ± 19.96^{d}	25.34 ± 2.57^{defgh}
LPK	3.74 ± 0.04^{cdef}	13.50 ± 0.64^{bc}	1.00 ± 0.04^{e}	13.50 ± 0.61^{c}	18.3 ± 0.25^{efg}	5.56 ± 0.18^{n}	10.35 ± 1.50^{hi}	483.4 ± 44.75^{ef}	24.83 ± 1.21^{efgh}
KB	3.16 ± 0.35^{i}	13.22 ± 0.93^{bc}	1.28 ± 0.14^{cd}	10.46 ± 0.48^{c}	17.81 ± 0.49^{gh}	7.20 ± 0.29^{jkl}	11.67 ± 1.10^{ghi}	519.59 ± 23.80^{ef}	29.12 ± 1.45^{cde}

Means of 20 fruits in each column followed by different letters are significantly different ($P < 0.05$); ±, standard deviation.

dows') to 2.44 (g 100 g^{-1}) ('Torsh Shahvar Ferdows'). Similar results were also reported by Fadavi et al. (2005). The concentration of total sugars was between 13.23 ('Agha Mandali Save') and 21.72 (g 100 g^{-1}) ('Save Pust Sefeed'). Poyrazoglu et al. (2002) reported total sugars values of some pomegranate cultivars Turkey between 13.9 and 16.06 (g 100 g^{-1}). The maturity index (TSS/TA) is responsible for the taste and flavor of pomegranate, which some author used for classifing the pomegranate cultivars (Martinez et al., 2006; Cam et al., 2009a). 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 5.04 to 46.31, which 'Alak Shirin Save' had the highest MI (Table 3). According to Martinez et al. (2006) cultivars can be ordered: TSK, TSF, MS, MY and MPS as sour, SPSe, ZY, SPGh, BPN, DA, SK, LPK, KB, AMS, SDSF and PSD as sour-sweet and SPG, SPS, ASS and SDGF as sweet. Previous studies have also reported variable ranges of maturity index (Viswanath et al., 1999; Martinez et al., 2006; Cam et al., 2009a; Sarkhosh et al., 2009). According to the results, cultivar type plays an important role in terms of their total soluble solids, pH, titrable acidity, total sugars and maturity index of the pomegranate juice. All the cultivars investigated were suitable for direct consumption and production of pomegranate juice because they had the high levels of soluble solids.

3.3. Ascorbic acid and total anthocyanins

The results for ascorbic acid and total anthocyanins of the pomegranate from the different cultivars are displayed in Table 3.

As shown in Table 3, a great variation in terms of ascorbic acid content was observed among the pomegranate cultivars (9.91–20.92 mg 100 g^{-1}) and the differences were statistically significant ($P < 0.05$). Twenty pomegranate juices showed higher ascorbic acid values than pomegranate juice from 'Ganesh' variety (>10 mg 100 g^{-1}) reported by Kulkarni and Aradhya (2005).

Anthocyanins are a member of phenolics compounds that contributes to the red, blue, or purple colour of many fruits, including pomegranate juice, and they are well-known for their antioxidant activity. There were significant differences in the total anthocyanins content of the pomegranate cultivars, which 'Malase Yazdi' had the highest amount of total anthocyanins (30.11 mg cy-3-glu 100 g^{-1}) than the other cultivars (Table 3). Similar findings have been published for pomegranate of different cultivars grown in Turkey, with anthocyanins values between 8.1 and 36.9 mg 100 g^{-1} of juice (Cam et al., 2009b). These results indicated that the levels of ascorbic acid and total anthocyanins varied among different cultivars of pomegranate and there was a high genetic heterogeneity within the studied cultivars.

3.4. Total phenolics and antioxidant activity

The total phenolics and antioxidant activity analysis results for the pomegranate cultivars investigated are presented in Table 3.

A significant variation in total phenolics concentration was found among the twenty varieties of pomegranate studied and the values ranged from 295.79 to 985.32 (mg GAE 100 g^{-1}). The highest level of total phenolics was observed in 'Malas Pust Sefeed' and the lowest one in 'Torsh Shahvar Kashmar' (Table 3). The reported levels of this total phenolics in literature were 124.5 and 207.6 mg 100 g^{-1} by Ozgen et al. (2008); 208.3 mg 100 g^{-1} and 343.6 mg 100 g^{-1} by Cam et al. (2009b); 14.4 mg 100 g^{-1} and 1008.6 mg 100 g^{-1} by Tezcan et al. (2009) and 23.7 mg 100 g^{-1} and 930.4 mg 100 g^{-1} by Mousavinejad et al. (2009). Their results were in agreement with our results. The total phenolics content of pomegranate juices were greater than other juices such as turnip, sour cherry and red grape juice (Cam et al., 2009b). In regard to the chemical composition, since all twenty pomegranate cultivars used in this research were grown in the same location using similar agronomic practices, the differences in phenolic compounds showed that the genetic variability led to the variation in the biosynthesis of phenolic secondary metabolites in these cultivars.

The DPPH radical scavenging assay is commonly employed to evaluate the ability of antioxidant to scavenge free radicals. The degree of discoloration indicates the scavenging potentials of the antioxidant extract. In this study, the differences in antioxidant activity among the pomegranate cultivars were statistically significant and the values ranged from 15.59% to 40.72%. The highest and the lowest antioxidant activity were detected in 'Malas Pust Sefeed' and 'Torsh Shavar Kashmar', respectively (Table 3). Antioxidant activity has been reported for seven commercial pomegranate juices from Turkey 10.37–67.46% (Tezcan et al., 2009) and eight pomegranate juices from Iran 18.6–42.8% (Mousavinejad et al., 2009). The variation in comparison with the data of the present research may be the result of other factors such as the different pomegranate cultivars and sample extraction method used in the experiments. According to the results (Table 3), 'Malas Pust Sefeed' and 'Torsh Shavar Kashmar' cultivars had the highest and lowest levels of total phenolics and antioxidant activity, respectively. Thus it can be concluded that there was a close relationship between the total phenolics and antioxidant activity.

4. Conclusion

Statistically significant differences were observed between pomegranate cultivars investigated in parameters measured except the length/diameter ratio of fruit. This indicates that cultivar is the main factor determining the physico-chemical properties and antioxidant activity in pomegranates. Among the twenty cultivars studied, MY, MPS, SPSe, SPS KB and MS cultivars showed the highest content of total phenolics, antioxidant activity, total anthocyanins, ascorbic acid, total soluble solid and total sugars, which are suitable for fresh consumption and health benefits. In addition, the results provide important information of the physico-chemical properties of pomegranate cultivars which can be useful for developing fruit processing industry and selection of superior desirable pomegranate genotypes for bringing to commercial cultivation. However, there are many other cultivars in Iran, more studies of physical and chemical properties are required for them.

Acknowledgements

The authors would like to acknowledge from Department of Horticulture of Ferdowsi University of Mashhad for the cooperation. We thank Ferdowsi University of Mashhad for financial support (Research project No. P461-27/02/09). We thank Y. Nori, S. Homayon and L. Ghoreshi for their assistance with various aspect of this study.

References

Al-Maiman, S.A., Ahmad, D., 2002. Changes in physical and chemical properties during pomegranate (*Punica granatum* L.) fruit maturation. Food Chem. 76, 437–441.

Anonymous, 2005. Statistical Book of Agricultural of Iran. Iranian Statistical Centre, Tehran, Iran.

AOAC, 1984. Official Methods of Analysis, 14th ed. Association of Official Analytical Chemists, Washington DC, U.S.A.

Aviram, M., Dorafeld, L., Rosenblat, M., Volkova, N., Kaplan, M., Coleman, R., Hayek, T., Presser, D., Fuhrman, B., 2000. Pomegranate juice consumption reduces oxidative stress, atherogenic modifications to LDL, and platelet aggregation: studies in humans and in atherosclerotic apolipoprotein E-deficient mice. Am. J. Clin. Nutr. 71, 1062–1076.

Brand-Williams, W., Cuvelier, M.E., Berset, C., 1995. Use of a free radical method to evaluate antioxidant activity. Food Sci. Technol. 28, 25–30.

Cam, M., Hisil, Y., Durmaz, D., 2009a. Characteristion of pomegranate juices from ten cultivars grown in Turkey. Int. J. Food Prot. 12, 388–395.

Cam, M., Hisil, Y., Durmaz, G., 2009b. Classification of eight pomegranate juices based on antioxidant capacity measured by four methods. Food Chem. 112, 721–726.

Fadavi, A., Barzegar, M., Azizi, M.H., Bayat, M., 2005. Physicochemical composition of 10 pomegranate cultivars (*Punica granatum* L.) grown in Iran. Food Sci. Technol. Int. 11 (2), 113–119.

Gil, M.I., Tomas-Barberan, F.A., Hess-Pierce, B., Holcroft, D.M., Kader, A.A., 2000. Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing. J. Agric. Food Chem. 48, 4581–4589.

Giusti, M.M., Wrolstad, R.E., 2001. Characterization and measurement of anthocyanins by UV–visible spectroscopy. In: Wrolstad, R.E., Schwartz, S.J. (Eds.), Current Protocols in Food Analytical Chemistry. John Wiley and Sons, New York, pp. 1–13.

Gonzalez-Molina, E., Moreno, D.A., Garcia-Viguera, C., 2009. A new drink rich in healthy bioactives combining lemon and pomegranate juices. Food Chem. 115, 1364–1372.

Heshi, A.B., Garande, V.K., Wagh, A.N., Katore, H.S., 2001. Effect of pre-harvest sprays of chemicals on the quality of pomegranate fruit (*Punica granatum* L.) cv. G-137. Agri. Sci. Digest 21 (1), 25–27.

Holcroft, D.M., Gil, M.I., Kader, A.A., 1998. Effect of carbon dioxide on anthocyanins, phenylalanine ammonia lyase and glucosyltransferase in the arils of stored pomegranates. J. Am. Soc. Hortic. Sci. 123 (1), 136–140.

Kulkarni, A.P., Aradhya, S.M., 2005. Chemical changes and antioxidant activity in pomegranate arils during fruit development. Food Chem. 93, 319–324.

Martinez, J.J., Melgarejo, P., Hernandez, F., Salazar, D.M., Martinez, R., 2006. Seed characterisation of five new pomegranate (*Punica granatum* L.) varieties. Sci. Hortic. 110, 241–246.

Melgarejo, P., Artes, F., 2000. Organic acids and sugar composition of pomegranate juice. Eur. Food Res. Technol. 4, 30–31.

Mousavinejad, G., Emam-Diomeh, Z., Rezaei, K., Khodaparast, M.H.H., 2009. Identification and quantification of phenolic compounds and their effects on antioxidant activity in pomegranate juices of eight Iranian cultivars. Food chem. 115, 1274–1278.

Ozgen, M., Durgac, C., Serce, S., Kaya, C., 2008. Chemical and antioxidant properties of pomegranate cultivars grown in the Mediterranean region of Turkey. Food Chem. 111, 703–706.

Ozkan, M., 2002. Degradation of anthocyanins in sour cherry and pomegranate juices by hydrogen peroxide in the presence of added ascorbic acid. Food Chem. 78 (4), 499–504.

Poyrazoglu, E., Gokmen, V., Artik, N., 2002. Organic acids and phenolic compounds in pomegranates (*Punica granatum* L.) grown in Turkey. J. Food Comp. Anal. 15, 567–575.

Ranganna, S., 2001. Sugar estimation. In: Ranganna, S. (Ed.), Handbook of Analysis and Quality Control for Fruit and Vegetable Products, 2nd ed. Tata McGraw-Hill, New Delhi, p. pp.12-17.

Ruck, J.A., 1963. Chemical methods of analysis of fruits and vegetables. Dep. Agri. Canada, Publication No. 1154.

Sarkhosh, A., Zamani, Z., Fatahi, R., Ebadi, A., 2006. RAPD markers reveal polymorphism among some Iranian pomegranate (*Punica granatum* L.) genotypes. Sci. Hortic. 111, 24–29.

Sarkhosh, A., Zamani, Z., Fatahi, R., Ranjbar, H., 2009. Evaluation of genetic diversity among Iranian soft-seed pomegranate accessions by fruit characteristics and RAPD markers. Sci. Hortic. 121, 313–319.

Seeram, N.P., Aviram, M., Zhang, Y., Henning, S.M., Feng, L., Dreher, M., Heber, D., 2008. Comparison of antioxidant potency of commonly consumed polyphenol-rich beverages in the United States. J. Agric. Food Chem. 56, 1415–1422.

Shulman, Y., Fainbertein, L., Lavee, S., 1984. Pomegranate fruit development and maturation. J. Hortic. Sci. 48, 293–296.

Singh, R.P., Murthy, C., Jayaprakasha, G.K., 2002. Studies on the antioxidant activity of pomegranate (*Punica granatum* L.) peel and seed extract using in vitro models. J. Agric. Food Chem. 50, 81–86.

Singleton, V.L., Rossi, J.L., 1965. Colorimetry of total phenolics with phosphomolybdic–phosphotungstic acid reagents. Am. J. Enol. Vitic. 16 (3), 144–158.

Tezcan, F., Gultekin-Ozguven, M., Diken, T., Ozcelik, B., Erim, F.B., 2009. Antioxidant activity and total phenolic, organic acid and sugar content in commercial pomegranate juices. Food Chem. 115, 873–877.

Valero, C., Ruiz-Altisent, M., 2000. Design guidelines for a quality assessment system of fresh fruits in fruit centers and hypermarkets. Agric. Eng. Int. CIGR. J. Sci. Res. Dev., 1–20.

Viswanath, P., Al-Bakri, A.N., Nadaf, S.K., Amal, K., 1999. Correlations and variability in fruit characters of pomegranate. In: Faroda, A.S., Joshi, N.L., Kathju, S. (Eds.), Recent Advances in Management of Arid Ecosystem. Proceedings of a Symposium Held in India, March 1997, pp. 361–364.