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Evaluation of the qualitative and quantitative traits of some Iranian local pomegranates as compared to "Wonderful" commercial cultivar

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ABSTRACT

Purpose: Diverse commercial cultivars as well as wild pomegranate genotypes are widespread throughout Iran. Such diversity considered as backbone of breeding programs. This study was aimed to comparative analysis of fruit traits of eight local pomegranate cultivars and a well-known, commercially adapted, "Wonderful" cultivar. **Research method:** The fruits were harvested and transferred to the laboratory. The fruit, aril and skin parameters were measured and the data was analyzed as completely randomized design with three replications. **Findings:** The results clearly showed diverse differences among cultivars. The highest fruit weight, length, width, aril weight, aril diameter, aril fresh/dry weights, skin fresh/dry weights were found in "Gavkoshak". The highest calyx length and skin thickness were recorded in "Galookandeh". The "Torsh Oud", "Faroogh", "Galookandeh" and "Rubab" were detected to have hard seeds. The highest TSS, skin / aril anthocyanin and sucrose content were found in "Wonderful". The maximum amount of glucose and fructose were observed in the "Rubab". The results finally showed that "Gavkoshak" and "Rubab" cultivars had the greater ranks in terms of their physical fruit parameters. In terms of chemical properties, the best cultivars were "Wonderful" and "Rubab". The "Rubab", "Gavkoshak" and "Wonderful" are recommended as superior cultivars for either pomegranate production or future breeding programs. **Limitations:** There was no limitation. **Originality/Value:** The "Wonderful" is an introduced one and the comparative analysis of pomegranates of Fars origin concurrently with this new plant material would be valuable. Furthermore, the pomological traits of these local cultivars were not also studied earlier.

INTRODUCTION

Pomegranate (*Punica granatum* L.) belongs to the Lythraceae family, is one of the most important fruits that grows well in the subtropical and Mediterranean regions. Native to Iran and the Himalayas in northern India, it has been cultivated since ancient times in the Mediterranean regions of Asia, Africa and Europe. It is currently widely cultivated in Spain, Egypt, Russia, France, China, Japan and the United States (Sarkhosh et al., 2021). The most critical step in any breeding program is screening and identifying superior genotypes, which is very costly and time consuming (Ashrafi et al., 2023; Gunnaiah et al., 2021). As far as Iran is both the center of pomegranate origin and the center of its diversity (Sarkhosh et al., 2006), Iran has the richest gene pool of pomegranate for future breeding programs. Therefore, while having more accurate information about the morphological and genetic characteristics of this plant, it is possible to modify or create newer promised cultivars. Zahravy and Vazifeshenas (2017) studied 117 pomegranate genotypes collected from different parts of Yazd province, Iran. They observed high degree of diversity among pomegranates with Yazd origin. Furthermore, they could separate the genotypes into distinct clusters and distinguished groups to be used for future breeding programs. Most recently, Ashrafi et al. (2023) evaluated the morphological diversity in 103 wild pomegranates (Punica granatum L. var. spinosa) in the northeastern area of Iran using 46 traits related to trees, flowers, and fruits. The pomegranate fruit is one of the most important horticultural products due to the presence of polyphenols, anti-oxidant and anti-fungal compounds (Shahsavari et al., 2021) and the review of the literature revealed that, proper shape and size, skin color, aril color, water content, sugar and acidity are considered as important quality characteristics of pomegranate fruit. There are many differences among genotypes for these characteristics, which are mainly influenced by genetics, regional conditions and harvest time (Sarkhosh et al., 2006; Gunnaiah et al., 2021). Varasteh et al. (2009) examined five cultivars of Iranian commercial pomegranates including 'Rubab Neyriz', 'Malas Torsh Saveh', 'Malas Yazdi', 'Kolah Ferdows' and 'Naderi Natanz'. They observed significant differences with respect to physical characteristics such as fresh/dry fruit weights, diameter, length and volume of fruit, length to diameter ratio, fruit neck diameter, skin (%), juice (%), aril (%) and thickness. In another study undertaken by Usanmaz et al. (2014), the yield and pomological characteristics of three pomegranate cultivars, including Wonderful, Acco and Herskovitz, grown in Cyprus were examined. The results showed that there were significant differences in fruit weight and yield of each individual tree. Research conducted by Tatari et al. (2011) to study some morphological and biochemical traits of fruit, eleven commercial pomegranate cultivars were evaluated using 26 quantitative and qualitative traits of fruit. The results showed that there was a significant difference among cultivars, which indicates diversity in each trait. Some morphological and biochemical characteristics of the fruits of 21 pomegranate cultivars were evaluated by Beigi et al. (2012), in order to determine the best form of their consumption in the food processing industry. They concluded that taste index (fruit flavor), aril color, seed hardiness, edible quality and fruit juice quality were more effective role in processing. Also, their results showed that most of these cultivars were more suitable for fruit juice, jelly and marmalade. Fernandes et al. (2017) showed that a significant difference was observed among 9 cultivars for TSS content, which varied between 14.87 and 18.04 degrees Brix for Parfianka and Wonderful cultivars, respectively. In a similar study, performed on fifteen pomegranate cultivars collected from the collection garden of Yazd Research Center, Iran, the average concentrations of vitamin C, TSS, TA and pH respectively were 0.08-0.27 mg per 100 g, 0.42-2.05%, 12.1-18.3 degrees Brix and 3.05-4.08 were reported (Barzegar et al., 2004). The studies performed on the peels of pomegranate fruits by analyzing a broad, bio-diverse pomegranate collection comprised of

different cultivars from different countries were also already reviewed by Amir et al. (2019). Furthermore, the recent advancements in botanical, ethno-medicinal uses, agro-technological advancements, post-harvest management and molecular characterization of pomegranate were recently reviewd by Sau et al. (2021). Today, in addition to consuming fresh pomegranate, it is increasingly used in processing industries and it can be used in different ways, so by knowing all its properties, it would be possible to determine the best way to consume and process fruits (Martinez et al., 2006). The "Wonderful" cultivar is one of the commercial pomegranate cultivars that due to the aril red coloration, red juice and the big fruit size with thick skin, its cultivation has been developed in the past few years in areas with hot days and cool nights. Iran is one of the largest pomegranate producers in the world (Tehranifar et al., 2010) and just recently the Wonderful cultivar was established as commercial orchard in some areas such as Fars province. Although, local varieties and genotypes were grown most lately in Fars area, but introduction of new cultivars would be beneficial to improve pomegranate industry in this region. Furthermore, pomological traits of these local cultivars were also not completely studied earlier. Therefore, the present study was aimed to comparative analysis of fruit traits of eight local pomegranate cultivars as compared to a well-known, commercially adapted, "Wonderful" cultivar concurrently grown in the same region.

MATERIALS AND METHODS

The eight, locally grown pomegranate cultivars of Fars province named 'Rubab', 'Gavkoshak Kazerun', 'Ghalatun Edge', 'Faroogh', 'Torsh Oud', 'Shirin', 'Shirin Shahvar' and 'Galookandeh' (also known as Aghaei) were selected. The physical and biochemical traits of their fruits were compared with each other and also with globally known, commercial 'Wonderful' cultivar (produced under the same climatic conditions of the Fars province). The studied trees were grown in a same geographical region, with the same orchard management, water and soil properties. However, the fruits of each cultivar were harvested at the stage of commercial maturity which was special to that cultivar. So, fruits of different pomegranate cultivars were harvested according to local harvest time criteria (according to native grower's experience). Hence, the harvest time was varied from October to December, for all nine cultivars. The fruits were immediately transferred to the Horticulture Department, Faculty of Plant Production, Gorgan University of Agricultural Sciences and Natural Resources. The study was undertaken as a completely randomized design with three replications.

The physical traits such as weight, length, width and thickness of fruit, length and width of calyx, length, diameter and weight of both aril and seed were measured (fresh and dry weights of 100 undamaged aril). The thickness of the fruit skin, and its fresh and dry weights were also recorded. The level of seed firmness was also adjudged sensory by a group of seven individual men (25 to 45 years old). The aril taste, aril and skin color were qualitatively measured by the senses of sight and taste by the same panel taste team. Immediately after transferring the fruits to the laboratory, the total fresh weight of the fruits was measured (accuracy of 0.001 g). Then, each individual fruit was peeled and arils were completely extracted and number of total arils and their weights were recorded. The skins of each fruit and 100 undamaged arils were weighed and then placed in an oven at 105 °C to achieve a constant weight. The difference between secondary and primary weight was calculated as the percentage of skin or aril moisture content. The fruit juice was then extracted with a manual juicer.

The chemical traits such as pH, electrical conductivity, titratable acidity, amount of aril and skin anthocyanins, vitamin C, soluble solids, phenols, flavonoids, antioxidants, total sugars, glucose, sucrose and fructose were evaluated following standard procedures. The

titration method standardized by Kashyap et al. (2012) was used to measure vitamin C in pomegranate juice. The Fuleki et al. (1968) suggested spectrophotometric method was used to measure anthocyanin. The phenol content of fruit juices was measured following Singleton and Rossi (1965) method. The Folin-Ciocalteu is the key reagent in this procedure. The flavonoid was measured by Chang et al., (2002) method and the quercetin was used as standard. The antioxidant capacity was evaluated by Sun and Ho, (2005) DPPH method. The soluble carbohydrates were extracted by Omokolo (1996) method. Total sugars were measured by McCready et al., (1950), glucose by Miller (1959), fructose by Ashwell (1957) and sucrose by Van Handel (1968) procedures. The mean data comparison was performed through LSD at the level of 5% probability using SAS software.

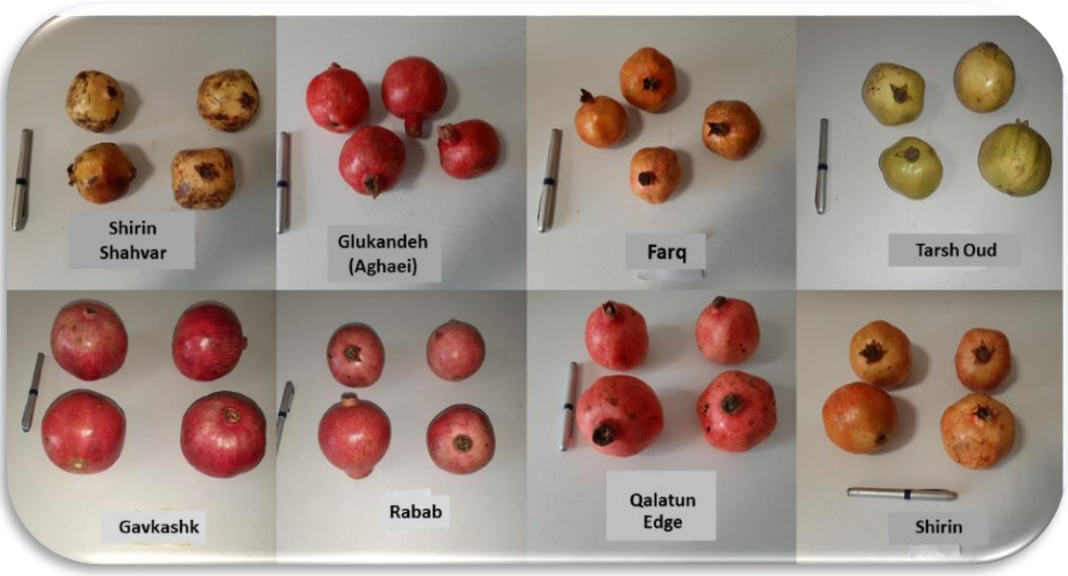

Fig. 1. The eight Iranian, locally grown pomegranate cultivars in Fars province.

Fig. 2. The fruits of commercially grown “wonderful” pomegranate cultivar.

Table 1. Some qualitative traits of nine pomegranate cultivars grown in Fars province, Iran.

Pomegranate cultivar	Skin color	Aril color	Fruit flavor
Torsh Oud	Pale Green	White Red	Sour
Faroogh	White Pink	White Pink	Sweet-Sour
Galookandeh (Aghaei)	Red	Dark Red	Sweet
Shirin Shahvar	White	White	Sweet
Shirin	White Pink	Pink	Sweet
Ghalatun Edge	Pink	Pink	Sweet-Sour
Rubab	Pink	Dark Red	Sweet-Sour
Gavkoshak Kazerun	Dark Pink	Red	Sweet-Sour
Wonderful	Dark Purple	Dark Red	Sweet-Sour

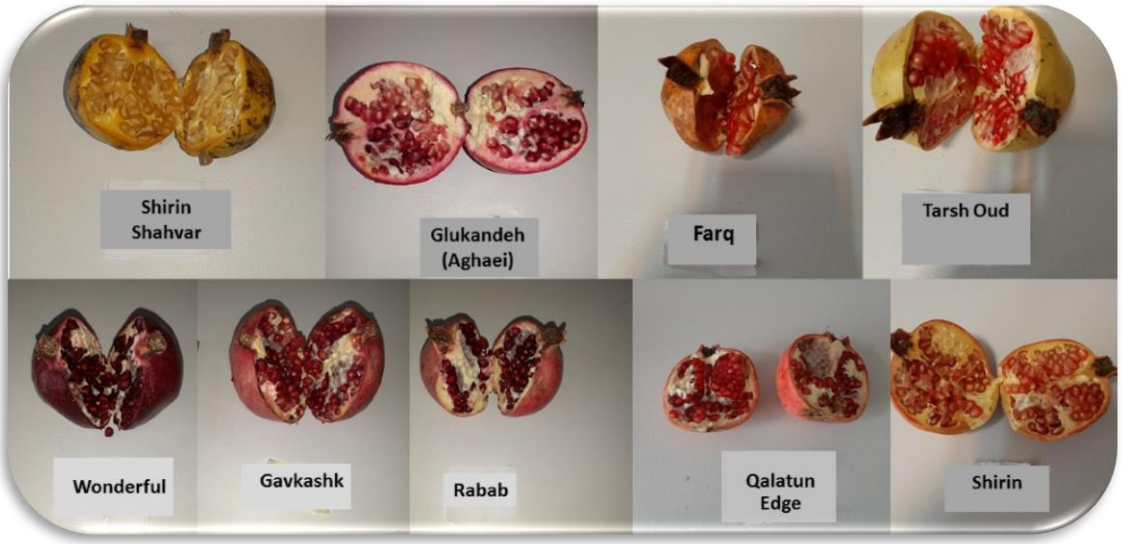

Fig. 3. The aril color of studied pomegranate cultivars.

RESULTS AND DISCUSSION

The qualitative characteristics of pomegranate fruit are considered with respect to consumer perception and commercial point of view. Some traits such as shape, size, skin color, aril color, water content, sugar and acidity are more significant in this regard (Sarkhosh et al., 2021). It was found that there are numerous differences among genotypes for these characteristics, which are mainly influenced by genetics, regional conditions and harvest time (Sarkhosh et al., 2006). Furthermore, fruit taste, aril color and seed firmness are the most effective traits in determining the best fruit consumption norms of these cultivars in processing industries (Beigi et al., 2012). Due to the relationship between some metabolites and quality traits, some traits such as taste, aril color, skin color and similar traits were measured qualitatively by the senses of sight and taste. Hence, Table 1 shows some qualitative traits of eight studied pomegranate cultivars as compared to “wonderful”. It is clear that different cultivars are very diverse with respect to these qualitative traits. The fruit flavor was varied from completely sour in “Torsh Oud” to absolutely sweet in “Shirin” as well as “Shirin Shahvar”. The same diverse trend was observed in fruit skin and aril color. It has been already stated that variability is backbone of breeding. So, such variability in qualitative traits of these cultivars would be useful in their future breeding programs.

The effect of cultivar on fruit weight, fruit length, fruit diameter, fruit thickness, calyx diameter, calyx length, skin thickness, skin fresh and dry weights, aril length and weight, seed length and diameter, seed weight were statistically significant (Table 2). The results of mean comparison (Table 3) showed that there is a significant difference among cultivars in terms of

physical characteristics. The "Gavkoshak Kazerun" cultivar had the highest fruit weight (593.67 g), fruit length (97.65 mm), fruit diameter (103.45 mm), skin fresh weight (203 g) and also the highest skin dry weight (60.92 g). However, the "Faroogh" cultivar had the lowest fruit weight (241.67 g), fruit length (73.92 mm), fruit diameter (78.83 mm), fruit thickness (72.42 mm), skin fresh weight (41.75 g) and also the lowest skin dry weight (12.02 g). The highest calyx length was related to "Galookandeh" cultivar (26.35 mm) and the lowest value of this trait was recorded in "Gavkoshak Kazerun" (14.23 mm) cultivar. The fruits of "Ghalatun Edge" had the highest calyx diameter (24.34 mm) and the lowest value (16.23 mm) was belonged to "Gavkoshak Kazerun". While the highest skin thickness with average (5.007 mm) was related to "Galookandeh" cultivar and the lowest skin thickness with average (1.79 mm) was observed in "Shirin Shahvar" cultivar. Gozlekci et al. (2000) reported that there is a close relationship between fruit weight and fruit volume. Their report is consistent with the results of the present study. Though "Gavkoshak Kazerun" fruits were bigger than "Wonderful" in terms of weight and size. However, according to Usanmaz et al (2014), "Wonderful" cultivar had different characteristics while grown in different geographical regions Moreover, Zarei et al. (2010) in their research examined six cultivars of commercial pomegranate such as Aghaei, Faroogh, Rubab, Shahvar, Shirin Bihesteh and Shirin Mahalis. They observed that highest fruit weight in "Shahvar" (346.63 g), while "Faroogh" (220.75 g) had the lowest fruit weight among the studied cultivars. As in our evaluated cultivars also, the fruits of "Faroogh" had lowest fruit size, it may be concluded that this cultivar has generally small fruit size. Formerly, Shulman et al. (1984) in a study in Palestine concluded that ecological differences and cultivar types cause differences in fruit weight of different pomegranate fruits. Similarly, working with grapefruit, Davise and Albrigo (1994) concluded that the reason for the high weight of cultivars is the genetic potential of these cultivars for rapid fruit growth and increase in fruit constituents. In terms of fruit size and weight, for larger consumption in domestic markets or for export, larger fruits are more preferred (Zamani, 2007), for which in our study "Gavkoshak Kazerun" cultivar is suitable. Tehranifar et al. (2010) in their study reported a significant difference in skin thickness among pomegranate cultivars. The highest fruit skin thickness was obtained in "Bajestani Khazari" cultivar (5.25 mm) and the lowest thickness was obtained in "Shirin Ghermez" (3.13 mm). Also, Zarei et al. (2010) via examining 6 pomegranate cultivars, stated that the highest fruit skin thickness was obtained in "Rubab" cultivar (3.55 mm) and the lowest thickness was obtained in "Shahvar" (2.03 mm). These data are also corroborating with the results of the present study. Pinhas et al. (1996) stated that the thickness of the skin varies in different citrus cultivars and in addition to genetic differences, environmental factors such as relative humidity, temperature and soil irrigation play role in the development of fruit skin thickness. The "Rubab" pomegranates are suitable for storage and export to remote areas due to its thicker skin (Zarei et al., 2010). The results of our research showed that the skin thickness of four pomegranate cultivars (Rubab, Ghalatun Edge, Shirin and Torsh Oud) did not differ significantly. Also, the highest skin thickness was recorded in "Galookandeh" fruits. Furthermore, the "Wonderful" fruits had lowest skin thickness. Hence, such fruits may not be appropriate for export to distant regions. The studied cultivars showed high variability in fruit dimensions as well. The "Gavkoshak Kazerun" fruits were so giant and their difference with other cultivars was obviously clear even without any statistical analysis. Zarei et al. (2010) already reported that "Shahvar" had the highest fruit length (87.92 mm), fruit diameter (115.65 mm) as well as the longest fruit crown length (24.26 mm) and crown diameter (32.26 mm) among 9 studied cultivars. They also found that "Shirin Bihesteh" cultivar had the shortest fruit length (67.38 mm) and fruit diameter (84.23 mm) and also the lowest fruit crown diameter (29.75 mm). They also stated that the lowest ratio of length to fruit diameter (0.75

mm) was observed in "Shahvar" cultivar and the highest ratio (0.86 mm) was observed in "Faroogh" cultivar. In the present study, the lowest ratio of length to fruit diameter (0.88 mm) was in Wonderful cultivar and the highest (1.02 mm) was measured in "Rubab". These morphological characteristics are directly related to how the fruit grows and develops. The ratio of length to diameter of the pomegranate fruit is a factor of beauty and uniformity (Zarei et al., 2010). Valero (2000) stated that these characteristics are directly related to the design and proper selection of packaging type for transportation and storage of fruits.

Table 2. ANOVA for physical characteristics studied pomegranate cultivars.

Source of variation	DF	Fruit weight	Fruit length	Fruit diameter
cultivar	8	38187.33**	181.53**	183.975**
Error	18	2477.33	28.101	22.294
CV (%)	-	12.58	6.02	5.16

*, ** Designate significant difference at 5% and 1% probability with LSD test, respectively.

Table 2. (continued). ANOVA for physical characteristics studied pomegranate cultivars.

Source of variation	DF	Calyx diameter	Calyx length	Skin thickness	Skin fresh weight	Skin dry weight
cultivar	8	15.917**	42.458**	2.936**	8513.62**	808.602**
Error	18	2.461	2.427	0.088	890.350	56.406
CV (%)	-	8.44	7.71	9.46	21.66	18.19

*, ** Designate significant difference at 5% and 1% probability with LSD test, respectively.

Table 3. Physical characteristics of eight Iranian local pomegranate fruits as compared to "Wonderful".

Cultivar	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)
Torsh Oud	402.33^{c}	87.757^{bc}	91.18^{cde}
Faroogh	241.67^{d}	73.92^{e}	78.83^{f}
Galookandeh	289.33^{d}	83.34^{cd}	84.14^{ef}
Shirin Shahvar	282.67^{d}	77.57^{de}	85.25^{def}
Shirin	387.33^{c}	90.70^{abc}	91.45^{cde}
Ghalatun Edge	427.33^{bc}	91.71^{abc}	96.47^{abc}
Rubab	427.33^{bc}	94.72^{ab}	92.543^{bcd}
Gavkoshak	593.670^{a}	97.655^{a}	103.45^{a}
Wonderful	508.330^{ab}	88.393^{bc}	99.767^{ab}

Dissimilar letters in each column indicate a significant difference between them at the 1% level.

Table 3. (Continued). Physical characteristics of eight Iranian local pomegranate fruits as compared to "Wonderful".

Cultivar	Calyx diameter (mm)	Calyx length (mm)	Skin thickness (mm)	Skin fresh weight (g)	Skin dry weight (g)
Torsh Oud	17.55^{cd}	22.83^{bc}	3.71^{b}	119.26^{bc}	36.91^{cd}
Faroogh	16.51^{d}	20.04^{d}	2.46^{cd}	41.75^{d}	12.02^{e}
Galookandeh	20.47^{b}	26.35^{a}	5.007^{a}	142.23^{b}	31.77^{d}
Shirin Shahvar	16.44^{d}	17.98^{de}	1.79^{e}	76.43^{cd}	27.24^{d}
Shirin	18.65^{bcd}	16.95^{e}	3.54^{b}	137.94^{b}	48.02^{bc}
Ghalatun Edge	23.34^{a}	24.11^{ab}	3.36^{b}	168.68^{ab}	38.76^{cd}
Rubab	19.48^{bc}	20.51^{cd}	3.64^{b}	201.23^{a}	56.34^{ab}
Gavkoshak	16.23^{d}	14.23^{f}	2.77^{c}	203^{a}	60.92^{a}
Wonderful	18.54^{bcd}	18.78^{de}	2.06^{de}	148.78^{b}	59.43^{ab}

Dissimilar letters in each column indicate a significant difference between them at the 1% level.

There was a significant difference between cultivars in terms of physical properties of pomegranate arils and seeds (Table 3). "Gavkoshak Kazerun" had the highest amount of aril weight (0.54 g), aril diameter (8.78 mm), 100 fresh aril weights (54.60 g), and 100 arils dry weight (10.82 g). The lowest weight of 100 fresh arils (34.14 g) was recorded in "Wonderful" fruits. However, in terms of aril diameter, there was no significant difference among "Wonderful" (7.31 mm), "Ghalatun Edge" and "Torsh Oud" cultivars. "Shirin" cultivar had the highest (12.01 mm) and "Ghalatun Edge" (9.98 mm) had the lowest aril length among the studied cultivars. The lowest weight of arils in "Wonderful" fruits may be related to its seed firmness level. This cultivar had the medium seed firmness measured by our panel taste team (Table 4). The highest seed weight (0.045 g) and seed diameter (3.27 mm) were measured in "Shirin" cultivar and the lowest seed weight and diameter (0.027 g and 2.70 mm) were recorded in "Wonderful". In a similar study, Tatari et al. (2011) also showed the highest aril length and diameter (11.84 and 8.83 mm) for "Isfahan" and "Malas Shirin" respectively. Also, "Yousef Khani" and "Binikaj" had the lowest aril length and diameter (9.52 and 5.83 mm, respectively). Also, they observed the highest weight of 100 aril wet and dry weights (47.12 and 10.52, respectively) in "Naderi Badroud". Al-Maiman et al. (2002) attributed the significant difference between the amount of aril in fully ripe to semi-ripe and green fruits to metabolic changes during ripening. Varasteh et al. (2009) stated that fruit with thick skin is suitable for long-term storage in the refrigerator and export, but fruit with thin skin is suitable for processing and short-term storage in the refrigerator.

Table 4. Aril characteristics of eight Iranian local pomegranate cultivars as compared to "Wonderful".

Cultivar	Aril weight (g)	Aril length (mm)	Aril diameter (mm)	Seed weight (g)
Torsh Oud	0.324 ^{e}	10.68 ^{cd}	7.31 ^{bc}	0.0383 ^{ab}
Faroogh	0.451 ^{bc}	11.76 ^{ab}	8.50 ^{a}	0.0387 ^{ab}
Galookandeh	0.413 ^{cd}	10.91 ^{bcd}	8.34 ^{ab}	0.0396 ^{ab}
Shirin Shahvar	0.329 ^{de}	10.81 ^{bcd}	7.16 ^{c}	0.0427 ^{a}
Shirin	0.447 ^{bc}	12.005 ^{a}	8.19 ^{abc}	0.045 ^{a}
Ghalatun Edge	0.31 ^{e}	9.98 ^{d}	7.32 ^{bc}	0.0386 ^{ab}
Rubab	0.499 ^{ab}	11.69 ^{abc}	8.61 ^{a}	0.0363 ^{ab}
Gavkoshak	0.547 ^{a}	11.82 ^{ab}	8.78 ^{a}	0.0392 ^{ab}
Wonderful	0.346 ^{de}	10.95 ^{bcd}	7.31 ^{bc}	0.0271 ^{b}

Dissimilar letters in each column indicate a significant difference between them at the 1% level.

Table 4. (Continued). Aril characteristics of eight Iranian local pomegranate cultivars as compared to "Wonderful".

Cultivar	Seed diameter (mm)	Seed length (mm)	Weight of 100 fresh arils (g)	Weight of 100 fresh arils (g)
Torsh Oud	3.02 ^{bcd}	7.48 ^{ab}	38.04 ^{de}	7.75 ^{cd}
Faroogh	3.151 ^{abc}	7.68 ^{a}	46.18 ^{bc}	8.17 ^{bcd}
Galookandeh	3.257 ^{ab}	6.60 ^{de}	43.53 ^{c}	8.81 ^{bc}
Shirin Shahvar	2.817 ^{de}	7.23 ^{bc}	39.006 ^{d}	7.32 ^{d}
Shirin	3.279 ^{a}	7.34 ^{abc}	43.77 ^{c}	9.09 ^{b}
Ghalatun Edge	3.089 ^{abc}	7.20 ^{bc}	34.82 ^{de}	7.46 ^{d}
Rubab	3.192 ^{abc}	6.62 ^{de}	49.90 ^{b}	10.75 ^{a}
Gavkoshak	3.0023 ^{cd}	6.55 ^{e}	54.60 ^{a}	10.82 ^{a}
Wonderful	2.703 ^{e}	6.98 ^{cd}	34.14 ^{e}	7.46 ^{d}

Dissimilar letters in each column indicate a significant difference between them at the 1% level.

Table 5. The strength of the pomegranate seed softness evaluated by a seven member's panel taste team.

Cultivar/Panel member	Torsh Oud	Faroogh	Galookandeh	Shirin Shahvar	Shirin	Ghalatun Edge	Rubab	Gavkoshak	Wonderful
1	H*	H	H	M	M	M	M	M	M
2	M	M	H	H	M	M	H	M	M
3	M	H	M	M	H	M	H	M	M
4	H	M	H	M	M	M	H	M	M
5	H	H	H	H	M	M	M	M	M
6	H	H	M	H	M	H	H	M	M
7	H	M	H	M	M	M	M	M	M
Result	H	H	H	M	M	M	H	M	M

* The hard (H) and medium (M) seed softness.

The seed softness is one of the important determining factors in the quality and type of pomegranate fruit consumption. The softer the seeds of pomegranate fruit, the higher the quality and marketability (Mirjalili, 2002). Therefore, soft seed cultivars are mostly used in fresh food, frozen and canned arils and jams. The hard seed cultivars are used in the production of juices, jellies, pastes, vinegar, marmalades and Lavashak (a special roll-dried fruits, most common in Iran). The hard seed pomegranates also are used as a powder in food (Beigi et al., 2012). In our study, the degree of seed softness was evaluated in three levels (soft, medium, hard). Among the cultivars studied (Table 5), the "Torsh Oud", "Faroogh", "Galookandeh" and "Rubab" were detected to have hard seeds. The rest of the cultivars were found to have moderate seed firmness. The "Wonderful" and "Gavkoshak" were evaluated as moderate soft seed cultivars. None of the studied local cultivars as well as "Wonderful" was soft seed pomegranate.

The biochemical parameters of the evaluated pomegranate cultivars were shown in Table 6. In the present study, the pH of the fruit juice was found in the range of 2.32 to 3.67. The highest pH (3.67) was related to Shirin and the lowest (2.32) was related to Ghalatun Edge cultivar. The recorded pH of Wonderful cultivar was 2.53. Cam et al. (2009) in Turkey reported pH in 10 pomegranate cultivars ranging from 2.82 to 3.85. Gadže et al. (2012) observed pH values between 2.9 to 4. Similarly, the pH was recorded from 2.98 and 3.68 (Ozgen et al., 2008), from 2.93 to 3.59 (Ferrara et al., 2014), from 2.81 to 3.90 (Radunić et al., 2015), and from 3.49 to 5.14 (Melgarejo et al., 2015). Mphahlele et al. (2016) stated that fruit juice extraction method significantly affects the content of pH, TA, TSS: TA ratio, fruit juice yield and color. They stated that whole fruit juice had the lowest pH (1.85) than halved juice (2.67). Numerous factors such as fruit variety, maturity, and postharvest transport contribute to differences in pH values (Opara et al., 2009). The highest amount of electrical conductivity (5.14 mmoh/cm) was related to the Torsh Oud cultivar and the lowest amount (3.76 mmoh/cm) in Shirin Shahvar, which of course there was no statistically significant difference with Shirin, Galookandeh (Aghaei) and Gavkoshak Kazerun cultivars.

The highest amount of TSS (Table 6) was related to Wonderful cultivar (18.56%) and the lowest amount (14.06%) was recorded in Galookandeh (Aghaei) cultivar. Barzegar et al. (2004) studied 15 pomegranate cultivars and found that the average percentage of TSS from 12.1 to 18.3°Brix, which corresponds to the range TSS measured in our experiment. Increased TSS can be attributed to the hydrolysis of starch to simple sugars, which is considered as an indicator of fruit maturity (Kulkarni et al., 2005). The highest and lowest acidity were recorded in Torsh Oud and Shirin respectively (Table 6). The titratable acidity is observed in the final stages of fruit growth and when the fruit is fully ripe and has the highest amount of

soluble solids (Al-Maiman et al., 2002). With the ripening of pomegranate fruit on the tree, a decrease in titratable acidity and a parallel increase in TSS, pH and color intensity are observed (Kader, 2006). Sarkhosh et al. Reported 21 pomegranate cultivars with the highest and lowest acidity levels of 0.94 and 0.15, respectively (Sarkhosh et al., 2009). MirJalili stated that low-acid cultivars are commercially valuable, so the degree of marketability of the pomegranate flavor depends on the taste of the people of each country. In Iran, sweet pomegranate with sweet or sour taste has more fans. Sweet pomegranate with soft seeds and watery grains is more popular (Mirjalili, 2016). The data showed that the highest amount of vitamin C (4.4 mg per 100 ml) was related to Ghalatun Edge cultivar and the lowest amount was related to Rubab (0.968 mg per 100 ml). The amount of vitamin C of Wonderful cultivar was estimated to be 2.112 mg per 100 ml, which was not significantly different from Galookandeh. Kulkarni et al. (2005) reported that the amount of vitamin C in Ganesh cultivar at the beginning of growth is 36 mg per 100 ml of fruit juice, which decreases when the fruit is reached to the ripening, stage (10 mg per 100 ml of fruit juice). Mirjalili et al. (2018) stated that cultivar and climatic conditions have a significant effect on factors such as vitamin C, acidity, EC and TSS.

The evaluated cultivars had a significant difference in terms of total phenol content, so that the highest and lowest total phenols were 1.71 (Wonderful) to 7.44 mg/g (Faroogh). The highest amount of flavonoids (2.21 mg/g) was reported for Faroogh cultivar. Fernandes et al. (2017) examined the flavonoid content of the nine pomegranate cultivars and the results showed that Katirbasi and CG8 cultivars had the highest flavonoid content, while Parfianka, Wonderful 2 and Cis 127 cultivars had the lowest amount. In the present study, the lowest flavonoid content was recorded in Wonderful cultivar. It has been shown that the decrease in ascorbic acid and phenolic compounds and the increase in sugar in the late stages of maturity are due to changes in the metabolic activity of fruits that lead to the synthesis of anthocyanins and lead to the polymerization of phenol towards anthocyanin formation (Kulkarni et al., 2005).

The results of mean comparing data for antioxidant percentage, different sugars and anthocyanin pigment in both skin and arils were shown in Table 7. It is obvious that highest amount of antioxidants (46.512% of free radicals) was related to Ghalatun Edge cultivar. The antioxidant capacity range of seven Turkish commercial cultivars has also been reported from 10.37 to 67.46 (Tezcan et al., 2009), which is consistent with the results of the present study. Borochov-Neori et al. (2009) concluded that the antioxidant capacity of pomegranate depends on the type of cultivar and environmental conditions during fruit ripening and ripening. As it was already mentioned in Table 1, the studied genotypes were sweet or sour-sweet in flavor. The highest amount of total sugars (85.493 mg/g) was related to Shirin Shahvar cultivar (a sweet flavor cultivar) and the lowest amount of total sugars is with average (493.49 mg). 65 mg / g) were observed in Torsh Oud as well as Ghalatun Edge cultivars. Kulkarni et al. (2005) reported that the content of total sugars, reducing sugars and soluble solids increases with the maturation of pomegranate fruit. The amount of glucose, fructose and sucrose for all nine pomegranate cultivars also shown in Table 7. The highest amount of sucrose (6.082 mg/g) was observed in Wonderful cultivar. Most of the total soluble solids in fruit juice are sugars, so that there is a strong direct relationship between the amount of total soluble solids and the amount of glucose and fructose in pomegranate (Shwartz et al., 2009). Studies have shown that "Bhagwa" pomegranate mainly contains reducing sugars, the main part of which is fructose and glucose. In addition, fructose concentration was higher than glucose during fruit ripening in the studied cultivar (Fawole et al., 2013). However, other studies have shown that glucose in other pomegranate cultivars is higher than fructose. Al-Maiman et al. (2002) showed that ripe fruits had a higher glucose ratio (53.5%) than fructose (46.6%). But Ozgen et

al. (2008) stated that glucose in six pomegranate cultivars from the Mediterranean region of Turkey was higher than fructose, which is consistent with our results.

One of the processes that occur during fruit ripening is the hydrolysis of starch, which accumulates into simple sugars in the early stages of fruit growth. Starch and sucrose are converted to glucose during fruit ripening (Wills, 1981). Also it has been reported that the increase in total soluble solids and total sugars during fruit ripening was due to hydrolysis of starch to sugar (Zarei et al., 2011).

Table 6. The comparative analysis of certain physicochemical properties of eight Iranian local pomegranate cultivars as compared to "Wonderful".

Cultivar	pH	EC (mmoh/cm)	TSS (%)	Vitamin C (mg/100 ml)	Acidity (mg/100 ml)	Total phenols (mg/g)	Total flavonoids (mg/g)
Torsh Oud	2.66 de	5.14 a	16.2 c	1.82 bc	0.805 a	7.112 ab	1.825 b
Faroogh	2.92 c	4.32 bcd	14.93 d	1.78 bc	0.424 b	7.442 a	2.21 a
Galookandeh	3.023 c	3.91 d	14.06 e	2.11 b	0.271 de	6.681 ab	2.181 a
Shirin Shahvar	3.35 b	3.76 d	16.2 c	1.78 bc	0.175 f	6.497 ab	1.859 b
Shirin	3.67 a	4.09 d	16.13 c	1.93 bc	0.157 f	6.001 b	1.881 b
Ghalatun Edge	2.32 f	4.72 abc	15.4 d	4.4 a	0.288 cd	4.698 c	1.916 b
Rubab	2.65 de	4.86 ab	16.26 c	0.96 d	0.247 e	1.796 d	1.225 c
Gavkoshak Kazerun	2.82 cd	3.79 d	17.4 b	1.67 c	0.317 c	4.633 c	2.194 a
Wonderful	2.53 ef	4.17 cd	18.56 a	2.11 b	0.283 cd	1.702 d	1.019 c

Dissimilar letters in each column indicate a significant difference between them at the 1% level.

Table 7. The comparative analysis of certain carbohydrates, anthocyanins and antioxidant properties of eight Iranian local pomegranate cultivars as compared to "Wonderful".

Cultivar	Antioxidant (%)	Glucose (mg/100 g)	Fructose (mg/100 g)	Sucrose (mg/100 g)	Total sugars (mg/100 g)	Aril anthocyanin (micromole /g)	Skin anthocyanin (micromole /g)
Torsh Oud	42.201 a	24.61 c	3.73 f	4.771 bc	65.48 d	0.163 e	0.086 g
Faroogh	21.872 b	19.92 d	4.104 ef	4.553 bc	71.76 c	0.143 e	0.109 fg
Galookandeh	14.511 c	21.80 d	5.205 bc	4.746 bc	80.56 b	0.675 b	0.446 b
Shirin Shahvar	18.682 bc	26.34 bc	4.63 cde	4.835 b	85.49 a	0.108 e	0.15 ef
Shirin	12.432 d	20.17 d	4.74 cd	4.182 c	72.69 c	0.337 d	0.137 fg
Ghalatun Edge	46.512 a	24.71 c	4.59 de	4.541 bc	65.49 d	0.407 d	0.204 de
Rubab	9.569 e	30.17 a	5.84 a	6.008 a	69.16 cd	0.692 ab	0.384 c
Gavkoshak Kazerun	17.28 bc	27.48 b	5.77 ab	6.003 a	69.08 cd	0.506 c	0.223 d
Wonderful	16.719 bc	26.72 bc	5.75 ab	6.082 a	69.04 cd	0.761 a	0.857 a

Dissimilar letters in each column indicate a significant difference between them at the 1% level.

The Wonderful pomegranate fruits had a dark red color (Fig. 2). Among the evaluated cultivars, the Wonderful cultivar had the highest level of skin / aril anthocyanins (Table 7). The level of Redness depends on the concentration and type of anthocyanins. Also, pH is an important factor in the expression of anthocyanins because they are more stable in acidic than in alkaline or neutral media. In the acidic environment, the most stable anthocyanin profile can be seen (Cea, 2011).

CONCLUSION

The detailed results were already shown in the result and discussion. However, the results clearly showed that "Gavkoshak Kazerun" and "Rubab" cultivars had the greater ranks in terms of their physical fruit parameters. In terms of chemical properties, the best cultivars were "Wonderful" and "Rubab". In overall, based on the results of the present study,

"Rubab", "Gavkoshak Kazerun" and "Wonderful" cultivars are recommended as superior cultivars for either pomegranate production or future breeding programs.

Conflict of interest

The authors have no conflict of interest to report.

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