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Comparison between quality and bioactive compounds of pomegranate from two producing areas

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Abstract

The consumption of fruits rich in antioxidants has increased in recent years, an example of this is the pomegranate (*Punica granatum* L.). The cultivation of pomegranate shows great expectations due to its profitability and its adaptability to development in arid zones. In this research, an imported sample and 'Wonderful' variety of pomegranate from Coyame, Chihuahua, Mexico was used. Quality parameters and bioactive compounds were evaluated to inform the consumer, about the quality of the fruits produced in the north of the country. The results showed significance between the different treatments, the American samples AME_2 had the largest fruits, but with the highest content of peel and cartilage, as well as the lowest percentage of arils. On the other hand, Chihuahuan COY_NE pomegranates had an average weight, a low percentage of peel and cartilage, and a higher percentage of arils. In addition, all the Coyame batches had a higher content of bioactive compounds compared to the American samples. In general, the qualities and attributes of Coyame's pomegranates compared to imported ones, obtained better results in most of the variables evaluated. It is recommended to bring forward the harvest at the end of September in the Coyame area since it was observed that the samples from this area were overripe, and this is of the utmost importance to maintain the quality of the fruit.

Keywords: antioxidants; antioxidant capacity; color index; *Punica granatum*; total phenols; 'Wonderful'

Introduction

The consumption of fruits rich in antioxidants has increased in recent years, an example of which is the pomegranate (*Punica granatum* L.), which is one of the oldest edible fruits that has been widely cultivated in tropical and subtropical countries. There are more than 1,000 cultivars of *Punica granatum*, originating in the Middle East and extending throughout the Mediterranean, to eastern China and India, as well as in the southwestern United States, California, and Mexico (Çam *et al.*, 2009).

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Cultivation of pomegranate shows great expectations due to its profitability and its adaptability to development in arid zones with few water requirements, being developed and produced in conditions in which other fruit trees would not do so profitably (Moreno, 2010). Data on total area and world production are currently not reported due to the rapid increase in cultivation in recent years. In 2014, an approximate production of 3 million tons (t) was estimated and in 2017 the estimated production was 3.8 million tons (Karapetsi *et al.*, 2021).

In 2020, it was reported that Mexico has a planted area of 1,262 ha, of which 1,146.25 ha are harvested for a total production of 8,769.36 t. The state of Chihuahua has a planting extension for the cultivation of pomegranate of 45 ha, of which 40 ha are harvested with a production of 615 tons in 2020 (SIAP, 2020).

The increase in demand for pomegranate is due to the benefits it brings to human health. The antioxidant capacity of fruit is defined as the joint action of antioxidants such as vitamins C and E, polyphenols, mainly phenolic acids, flavonoids, carotenoids and terpenoids (Viuda-Martos *et al.*, 2011). In particular, pomegranate juice is gaining popularity around the world for its characteristics such as color, flavor, and antioxidant compounds (Hegazi *et al.*, 2021). Moreover, pomegranate skin, seeds, and juice are reported to contain considerable amounts of phenolic compounds such as flavonoids, ellagitannins, mainly punicalagins, ellagic acid, and punicalins (Akhavan *et al.*, 2015; Derakhshan *et al.*, 2018), which is related to antioxidant activity.

Several studies have shown the therapeutic effect of pomegranate peel, arils and flowers, since they have contributed as protection against hepatic oxidative stress, kidney damage, and anticancer activity, it is reported that pomegranate peel extract contains punicalagin and acid ellagic cells capable of inhibiting fatty acid synthase and adipogenesis, so they could have a potential effect in the prevention and treatment of obesity (Ambigaipalan *et al.*, 2016). In turn, it is reported that it has some estrogens such as estradiol, estrone and estriol, which suggests that pomegranate is clinically recommended in depressive states and bone loss in menopausal women (Karimi *et al.*, 2017). In addition, the phenolic compounds of this fruit can be used as natural antioxidants for skin health in the cosmetic area since pomegranate products were shown to inhibit protein and DNA damage caused by UVB rays (Kandylis and Kokkinomagoulos, 2020).

Fruit quality parameters play an important role in the concentration of bioactive compounds present in pomegranate (Mirdehghan *et al.*, 2006). To determine the quality of the pomegranate it is necessary to take into account the size, the color of the shell as well as the absence of visual defects in it such as sunburn, cracks, cuts and bruises, other characteristics that must be taken into account in the pomegranate quality are the color of the aril, sugar content and acidity (García-Pastor *et al.*, 2020). It is important to mention that the quality of the fruit and the concentration of bioactive compounds will be affected by the cultivar, the growing region, the climate, the maturity, the age of the trees, the storage circumstances, the cultural practice, and the irrigation (Çam *et al.*, 2009; Tarantino *et al.*, 2020).

Based on the importance and demand of the pomegranate crop, it is of the utmost importance to publicize the quality of the pomegranates that are produced, so the objective of this study was to evaluate the quality parameters of the pomegranate produced in the state of Chihuahua and the imported pomegranate.

Materials and Methods

Sample collection and preparation

The samples were taken on October 11, 2019, the variety used in this investigation was 'Wonderful' (*Punica granatum* L.), completely randomly collected in six different lots from producers in the Coyame area (Latitude: 28.6353, Longitude: 106.089 28° 38′ 7″ North, 106° 5′ 20″ West) in the state of Chihuahua. In turn, random samples of American pomegranates were taken in two different supermarkets in the municipality of Chihuahua for later analysis.

Experimental design

The experimental design was carried out in completely randomized blocks, there were eight treatments, five repetitions, and five fruits per repetition. For bioactive compounds, a composite sample was performed per replicate, each with three analytical replicates.

Quality parameters

Fruits were left at room temperature for seven days and subsequently, the following quality parameters were measured:

Fruit weight (w)

Fruits were weighed individually with a digital scale with a capacity of 5 kg and a precision of ± 0.1 g, the results were expressed in grams (g).

Fruit diameter

The fruit size was obtained from the equatorial (ED)and polar diameter (PD), measuring the largest part of the fruit from both poles, making the readings with a graduated vernier in millimeters, with a precision of ± 0.01 mm.

Diameter-length ratio (D/L)

It is a ratio between the equatorial diameter and the polar diameter, where the polar diameter represents the length.

Percentage peel, cartilage, arils

It is a ratio between the total weight of the fruit and the individual weight of each of the parts of the fruit, later converted into a percentage giving a total of 100%.

The density of juice, juice, bagasse, and juiciness percentage

30 grams of composite sample were taken per repetition, and they were processed in a juice extractor (Turmix, TUO5, USA), the juice was measured in a 50 ml graduated cylinder and left to stand until there was phase separation, to proceed to quantification. of the amount of juice and bagasse. For the density of juice which was reported in g mL^{-1} and the percentage of juiciness obtained from the extract, the methodology proposed by Oviedo-Mireles *et al.* (2021). For the calculations of juice (g mL^{-1}) and bagasse (g), the following formulas were used:

$$Juice = (density\ of\ juice) * \left(\frac{\%\ of\ juiciness}{100}\right) \quad (1)$$

$$Bagasse = density\ of\ juice - juice \quad (2)$$

Juice color

For the color, 40 mL of juice were taken in a beaker and the reading was taken with a Minolta Chromatometer (CR-300, Minolta, Japan). Color parameters were expressed as tristimulus colorimetric measurements, L*, a*, b*, C and H°. Negative L* indicates darkness and positive L* indicates lightness, negative a* indicates the green color, and high positive a* indicates a red color, a high positive b* indicates a more yellow color, and negative b* indicates a blue color. The chroma (C*) value, calculated as $C^* = (a^{*2} + b^{*2})1/2$, indicates the intensity or saturation of the color. Hue angle (H°), a parameter that has shown to be effective in predicting the visual appearance of color, was calculated using the formula $H° = tan^{-1} (b^*/a^*)$, where 0° or 360 ° = red-purple, 90° = yellow, 180° = green, and 270° = blue (Solomon *et al.*, 2006). The juice color index (CI) was calculated according to Tzulker *et al.* (2007) with the following equation:

$$CI = \frac{180 - H°}{L^* + C*} \quad (3)$$

Total Soluble Solids (TSS)

To determine the amount of sugar in the fruit expressed as total soluble solids (TSS), a Red Rooster 90681 refractometer scale from 0 to 32 °Brix was used. Approximately 0.5 ml of the juice was taken, which was placed on the surface of the refractometer and the reading was taken (Zhang and Whiting, 2011).

Titratable Acidity (TA)

To determine the titratable acidity, expressed as a percentage of ascorbic acid, 10 mL of juice per sample were taken, six drops of 1% phenolphthalein indicator were added (0.5 g of phenolphthalein plus 70 mL of ethyl alcohol, calibrated to 100 mL with distilled water) and titrated with 0.1 N NaOH (2.15 g of NaOH, 97% purity, calibrated to 500 mL) until a wine color was obtained; the volume used was converted to the equivalent of ascorbic acid in percent using the following formula:

$$Titulable\ acidity = \frac{\left(\frac{0.1*mL}{10}\right)*96}{10} \quad (4)$$

Sugar/Acidity ratio (TSS/TA)

It was determined from the total soluble solids for each part of acid content, expressed as a part of sugar for one part of acid (Flores *et al.*, 2018). For this process the following formula was used:

$$\text{Ratio}\,\frac{\text{Sugar}}{\text{Acidity}} = \frac{\text{TSS}}{\text{TA}} \quad (5)$$

Bioactive Compounds

For the determination of the bioactive compounds, a sample composed of 5 fruits was made, and a total of 2 g of arils were taken and macerated manually in 20 mL of 80% methanol. The samples were left to stand for 24 h and then the supernatant was taken for the determination of total phenolic compounds and total antioxidants.

Total Phenols (TP)

Total phenol content was determined by the Folin-Ciocalteu method (Singleton and Rossi, 1965) using gallic acid (GA) as standard. For the determination, 750 µL of 20% Na2CO3, 1375 µL of distilled water, 250 µL of the 50% Folin-Ciocalteu phenolic reagent, and 250 µL of the sample supernatant were taken. The mixture was then incubated at room temperature in the dark for 60 minutes. Absorbance was measured at 725 nm on a DR 5000 Hach spectrophotometer. The results were expressed as mg of gallic acid per 100 g of fresh weight (mg GA 100 g^{-1}). A calibration curve was drawn in triplicate, using reagent grade gallic acid, the value of the equation was 7.4196x- 0.0154, with an r^2 of 0.9967.

Antioxidant capacity (AC)

The DPPH radical (1,1-diphenyl-1,2-picrylhydrazyl) is a stable compound that has an intense violet coloration and absorbs radiation at 517 nm so that its concentration can be determined by spectrophotometric methods (Kim *et al.*, 2002). The reaction was carried out by mixing 2950 µL of DPPH radical solution with 0.50 µL of the sample extract. The mixture was kept at room temperature and protected from light for 30 minutes. Subsequently, the absorbance at 517 nm was measured using a UV/Vis spectrophotometer. The results were expressed as mg of ascorbic acid per 100 g of fresh weight (mg AA 100 g^{-1}). The blank used was 80% methanol and a calibration curve was made. Using a high purity reagent grade ascorbic acid standard, and the calibration was in triplicate, the value of the equation was -24.261x + 0.9212, with an r^2 of 0.9951.

Statistical analysis

Statistical analysis was performed in completely randomized blocks. The data obtained were subjected to an analysis of variance for the proposed experimental design and the separation of means with the least significant difference (p ≤ 0.0.5). Pearson's correlation analysis was performed to determine the degree of pairwise linear (≤ 0.6000) relationships between fruit characteristics. Correlation coefficients measure the interdependence of two variables and indicate the strength and direction of a linear relationship between the two variables. For this process, the statistical package SAS (SAS Institute Inc., SAS/STAT Software: Usage and Reference, Version 6, First Edition, Cary, NC: SAS Institute Inc., 1989) was used.

Results and Discussion

The results obtained for the physical characteristics of the fruit are shown in Table 1, presenting significant differences in the different parameters evaluated.

Table 1. Physical characteristics of 'Wonderful' pomegranate

Treatment	w	ED	PD	D/L
COY_IR1	385.40 ab	92.82 a	77.63 b	1.19 ab
COY_IR2	346.00 bc	86.93 bc	75.70 bc	1.14 ab
COY_IR3	271.40 d	85.56 cd	74.44 bc	1.15 ab
COY_NE	306.06 cd	86.80 bc	75.97 b	1.14 ab
COY_RO	274.64 d	80.42 ed	70.82 cd	1.13 ab
COY_MA	262.24 d	76.65 e	65.98 d	1.49 a
AME_1	259.96 d	79.31 e	69.37 d	1.14 ab
AME_2	398.00 a	92.36 ab	92.59 a	1.00 b
MSD	47.066	5.8134	4.996	0.3933
CV	11.608	5.2723	5.120	25.790
μ	312.96	85.109	75.31	1.1770

Different letters between treatments denote significant differences (LSD, p < 0.05). Weight (g), equatorial diameter (mm), polar diameter (mm).

For the weight variable, the AME_2 pomegranates showed the fruit with the highest weight with 53.10% more than the AME_1 fruit, which showed to be the smallest fruit, in the case of the Mexican fruit, the one from the COY_IR1 lot was 48.25% higher compared to the lower weight fruit. For the 'Wonderful' in California, a mean weight of 345 g is reported (Wetzstein *et al.*, 2006), which coincides with the weights recorded in the COY_IR1 and COY_IR2 treatments. On the other hand, it was reported Condobolin, Australia, that pomegranates reached a maximum value of 675 g per fruit after 14 weeks of fruit set (Fawole and Opara, 2013), this result does not match with our results, which can be attributed to the area and climate in which pomegranates developed as mentioned by Tarantino *et al.* (2020). In the case of the equatorial diameter, (ED) COY_IR1, recorded the largest value, with 92.82 mm, and the smallest value was presented by COY_MA with 76.65 mm. For the polar diameter (PD) AME_2 had the largest value with 92.59 mm and the smallest value for COY_MA with 65.98 mm. Fawole and Opara (2013) report an equatorial diameter of 84.42 mm and a polar diameter of 74.81 mm in pomegranates of the 'Ruby', meanwhile, Tehranifar *et al.* (2010) reported values of 64.98-86.88 mm for the diameter equatorial and 69.49-81.56 mm of polar diameter, if we compare our results with the ones reported, COY_IR1 showed higher ED, while AME_2 higher PD. In the case of the diameter/length ratio (D/L) it indicates the shape of the fruits, the closer this value is to 1.0, the rounder its shape will be, therefore the AME_2 pomegranates showed a more symmetrical appearance, while

COY_MA had an oval shape, these values are similar to those reported by Tehranifar *et al.* (2010) where twenty varieties of Iranian pomegranates were compared.

Figure 1 shows the different percentages of peel, cartilage and arils. AME_1 pomegranate had the highest percentage of arils and therefore a lower percentage of peel, despite being one of the smallest fruits. The pomegranates with the highest percentage of peel were for COY_MA with 77.74% compared to AME_1, while the largest fruits of AME_2 had the lowest aril content with 33% less than AME_1. On the other hand, the Chihuahuan pomegranates from the COY_NE lot were the second with the highest content of arils, barely 1.6% less than the AME_1 fruits, in turn, COY_NE had 17% greater size and a lower percentage of cartilage than the American pomegranates, since both AME_1 and AME_2 had the highest percentage of cartilage inclusive of COY_MA. The percentage of peel and arils in the Iranian pomegranate experiment ranged from 32.28-59.82% and 37.59-65%, respectively (Tehranifar *et al.*, 2010). In this case, the percentage of shell in the results shown were lower than those reported, while the percentage of arils remained close to the range of Iranian pomegranates. In turn, Fawole and Opara (2013a) mention that the content of arils represents approximately 52% of the weight of the whole fruit, so only the fruits of AME_2 are below the estimated average.

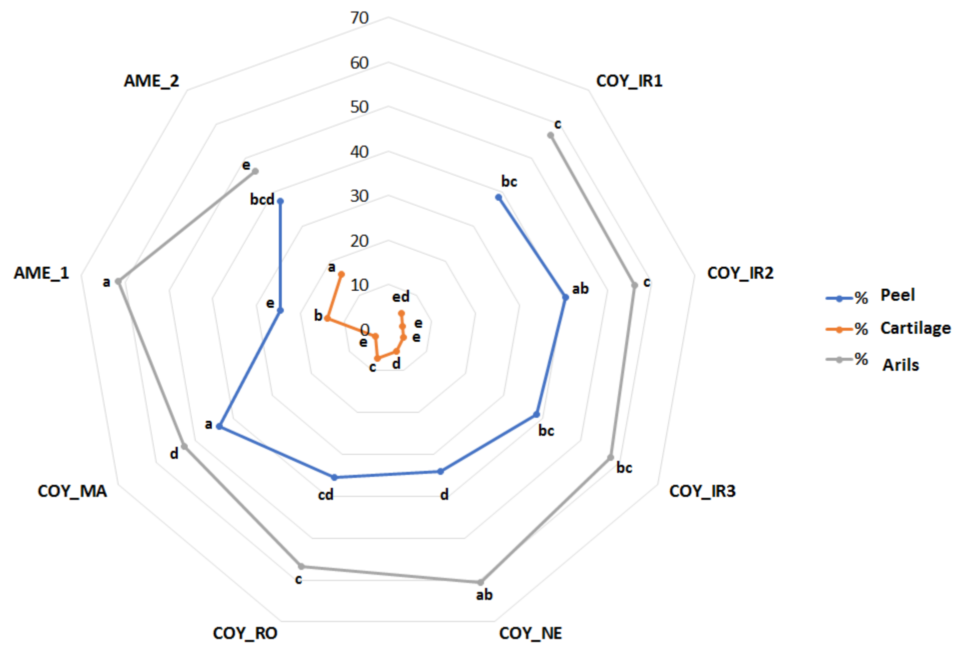

Figure 1. Percentages of peel, cartilage and arils in the treatments (%)
Different letters between treatments denote significant differences (LSD, $p < 0.05$).

Table 2 shows the qualities of pomegranate juice, for the first parameter, juice density, the fruits of COY_IR2 had the densest juice with 25.27% more than AME_2, which had the lowest density, this refers to the grams of fruit used to obtain a milliliter of juice, therefore, AME_2 used 1.82 g to obtain 1 ml of juice, of which 1.48 were liquid and 0.3378 were bagasse. In a study carried out on pomegranates of the 'Taifi', it is mentioned that of the total edible portion of the fruit, 63.58% represents the juice content, while 36.21% is seed waste (Maiman and Ahmad, 2002), Wetzstein *et al.* (2011) mention that the fresh weight of the seed is 33 mg, so the density of the juice may depend on the size of the seeds of each fruit and therefore the percentage of juiciness. In this case, it could be speculated that the seeds of the COY_MA treatment were larger than the rest of the treatments, for which a higher content of bagasse was obtained and therefore a high juice density.

Table 2. Quality parameters of the pomegranate juice of the 'Wonderful'

Treatment	Density of juice (g mL^{-1})	Juice (g mL^{-1})	Bagasse (g)	Juiciness (%)	TSS (°Brix)	TA (% ascorbic acid)	TSS/TA
COY_IR1	1.93 bc	1.76 b	0.1713 c	91.16 a	18.46 a	0.1747 de	119.93 a
COY_IR2	2.28 a	2.02 a	0.2642 cb	88.51 a	18.64 a	0.1555 e	124.86 a
COY_IR3	2.00 b	1.73 bc	0.2747 bc	86.33 ab	17.32 c	0.2438 cd	72.49 bc
COY_NE	1.98 bc	1.76 b	0.2231 c	88.87 a	18.20 a	0.2928 c	62.23 bc
COY_RO	2.03 b	1.68 bc	0.3555 ab	82.60 cb	17.92 b	0.2073 de	86.60 b
COY_MA	2.06 b	1.65 bcd	0.4109 a	80.15 c	16.88 c	0.3129 c	55.12 cd
AME_1	1.90 bc	1.56 cd	0.3358 ab	82.24 bc	17.29 c	0.5318 b	34.80 de
AME_2	1.82 c	1.48 d	0.3378 ab	81.44 c	16.83 c	0.6263 a	27.52 e
MSD	0.1824	0.1797	0.1034	4.8433	0.5324	0.0762	26.427
CV	7.0255	8.1226	26.9058	4.3896	2.3228	18.485	27.964
μ	2.0040	1.7072	0.2967	85.165	17.693	0.3181	72.943

Different letters between treatments denote significant differences (LSD, $p < 0.05$).

In the case of juiciness, the highest percentage of juice was for COY_IR1 with 91.16% and with the least amount of bagasse; in two studies carried out on pomegranates of the 'Ruby', the juiciness was 49.29 ml and 67.20 ml in 100 g of arils (Fawole and Opara, 2013; Fawole and Opara, 2013b), on the other hand, the percentage of juice for the cultivar 'Wonderful' grown in Condobolin, Australia had an average yield of 37% of the total weight of the fruit (Fawole and Opara, 2013), while the cultivation of this variety in Israel had a range of 18-40%, which justifies it. due to the differences in climatic conditions that explain the great variation (Fawole and Opara, 2013a), even so, the fruits of COY_MA, being the pomegranates with the lowest juice content, are well above the aforementioned data.

Regarding the parameters of TSS, TA and sugar-acidity ratio (TSS/TA), the fruits of COY_IR1, COY_IR2 and COY_NE were the sweetest ones and therefore with the lowest acidity content. Poyrazoglu *et al.* (2002) mention a range of soluble solids from 16 to 19 °Brix for pomegranate crops in Turkey. In turn, an increase from 10.30 °Brix in immature fruit to 19.56 °Brix in fully ripe fruit is reported (Zarei *et al.*, 2011). In California, the 'Wonderful' harvest begins at 17.0 °Brix and TA 1.9% (Karapetsi *et al.*, 2021), this agrees with what was reported by Fawole and Opara (2013) who consider a TA value of 1.8% as the standard of more satisfactory maturity, this parameter tends to decrease as the days after flowering increase, while the TSS increase, which denotes that these parameters are related to the physiological development of the fruit (Khodabakhshian *et al.*, 2017). In this study, the TA ranged between 0.1555-0.6263%, while in an experiment carried out on ten varieties of pomegranate, it was found that the bittersweet varieties ranged from 0.82-1.14% and the sweet ones from 0.40-0.68% (Fadavi *et al.*, 2005), therefore the titratable acidity indicates that the fruits had a high sugar content, especially those from Coyame. In the case of the TSS/TA ratio, it provides the maturity index, and is commonly used to define the "flavor" of the pomegranate fruit during development (Fawole and Opara, 2013a), the values obtained from the TSS/TA ratio AC in this study were 27.52-124.86, while Fawole *et al.* (2012) mention a range of 45.69-63.13 in three varieties of pomegranate. Melgarejo and Salazar (2006) share with us a maturity index classification for Spanish cultivars where sour varieties have values of 5-7, 17-24 for bittersweet and 31-98 for sweet cultivars. Holland *et al.* (2009) reported that the 'Wonderful' is bittersweet, when comparing the results with these indices, it is observed that the samples had a maturity index above the sweet varieties, except AME_2 with 27.52. According to Boroychov-Neori *et al.* (2009) TSS/TA ratio increases as the pomegranate matures, so in this case, it can be seen that Mexican fruits were overripe at the time of analysis compared to imported pomegranates that showed the lowest maturity index.

Table 3. Color of 'Wonderful' pomegranate juice

Treatment	Color			C*	H°	CI
	L*	a*	b*			
COY_IR1	28.99 ab	3.338 a	-0.810 a	3.438 a	-14.01 ab	5.986 c
COY_IR2	29.39 a	3.718 a	-0.700 a	3.786 a	-10.78 ab	5.751 c
COY_IR3	28.77 ab	3.184 ab	-0.730 a	3.278 ab	-13.79 ab	6.055 bc
COY_NE	28.60 b	3.496 a	-0.538 a	3.536 a	-8.784 a	5.874 c
COY_RO	28.85 ab	3.626 a	-0.710 a	3.710 a	-12.10 ab	5.912 c
COY_MA	28.84 ab	2.446 bc	-0.790 a	2.580 bc	-18.68 b	6.327 b
AME_1	28.81 ab	2.444 bc	-0.974 a	3.934 a	-51.58 c	7.071 a
AME_2	27.02 c	2.062 c	-3.076 b	2.414 c	-20.59 b	6.813 a
MSD	0.6413	0.7438	0.5851	0.7901	9.8593	0.339
CV	1.7271	18.890	-43.385	18.289	-40.497	4.209
μ	28.659	3.039	-1.041	3.334	-18.792	6.224

Different letters between treatments denote significant differences (LSD, $p < 0.05$). L*(lightness/darkness), a*(green/red), b* (yellow/blue), C* (Chroma), H° (Hue angle) and CI (Color index).

For the color of the juice, significant differences were observed in the color coordinates between treatments (Table 3), COY_IR1, COY_IR2, COY_NE and COY_RO presented the highest values of a*. The increase in the green-red coordinate, a*, is unrelated to the increase in biosynthesis and the accumulation of anthocyanin pigments, responsible for the intense red color of ripe pomegranate fruits. The characteristic garnet color of pomegranate juice is presented with high values of a* and C* and low values of b* and H° (Legua *et al*., 2016). The CI was used to provide an objective criterion of the maturity index through the color of the juice, therefore, American pomegranates compared to Coyame pomegranates occupy higher values to achieve the maturity index that provides the organoleptic characteristics of the grenade. As pomegranate fruits ripen, color coordinates evolve (Manera *et al*., 2013), studies on color in the 'Wonderful' have shown that pigmentation increases during the ripening process (Shwartz *et al*., 2009), which continues to increase its intensity even when the TSS content reached the maximum (Fawole and Opara, 2013a), in turn, the color of the juice is widely related to the conditions in which the crop develops (Shulman *et al*., 1984), therefore these reports could also indicate the state of maturity in which the Coyame fruits were found compared to foreign pomegranates, as well as the influence of their place of origin.

On the other hand, the fruits from Coyame had a higher content of total phenols (TP) compared to the American fruits that had the lowest ranges. Reza *et al.* (2011) mention a range of 11.62-21.03 mg gallic acid equivalents per gram of extract (mg GAE g^{-1}), while Li *et al.* (2006) reported 24.4 mg equivalents of tannic acid per gram, the results obtained are higher than those reported, even export pomegranates showed higher values, these differences can be attributed to the different extraction methods, the varieties as well as the area where they were grown. However, Fredes *et al.* (2014) report a range of 3.8-4.0 g GAE kg^{-1} in the 'Wonderful', these data are closer to the data obtained for Coyame pomegranates. In turn, it has been reported that in pomegranates, as well as in many other crops, the level of antioxidant activity can be attributed to the total phenolic level (Gil *et al*., 2000), where hydrolysable tannins represent 92% of its antioxidant activity. The group of hydrolysable tannins contains punicalagin isomers, which were suggested to be responsible for about half of the total antioxidant capacity of pomegranate juice, in addition to ellagic acid, gallic acid, and punicalin (Tzulker *et al*., 2007).

Regarding the antioxidant capacity (AC), the batches COY_IR1 and COY_IR3 showed the highest levels with 57.96 and 58.26 mg AA 100 g^{-1} respectively, while COY_NE and COY_RO had values below the average obtained, which was 48,336 mg AA 100 g^{-1}.

Table 4. Bioactive compounds of the pomegranate 'Wonderful'

Treatment	Total phenols (mg GA 100 g^{-1})	Antioxidant capacity (mg AA 100 g^{-1}).
COY_IR1	196.71 b	57.966 a
COY_IR2	205.00 ab	56.588 ab
COY_IR3	244.73 a	58.262 a
COY_NE	206.22 ab	39.196 d
COY_RO	201.81 b	39.208 d
COY_MA	183.95 b	48.298 bc
AME_1	29.75 c	46.903 cd
AME_2	28.81 c	40.478 cd
MSD	40.024	4.2548
CV	19.055	13.275
µ	162.12	48.336

Different letters between treatments denote significant differences (LSD, $p < 0.05$).

Mirdehghan *et al.* (2006) report values of 73.54 mg equivalents of ascorbic acid per 100 g in the variety Mollar de Elche, in varieties produced in California a maximum value of 5.79 mmol equivalents of Trolox per g is reported (Ambigaipalan *et al.*, 2016). These differences between the reported values and those obtained in this research can be attributed, as in the phenol content, to the extraction conditions, analytical methodologies, and cultivation areas as mentioned by Raffo *et al.* (2006).

The correlation of the different variables can be seen in Table 5. The weight and the diameters of the fruit are proportional, this means that the three increase simultaneously, Al-Maiman and Ahmad (2002), show in their experiment how the three variables increase at the same time from an immature fruit to one in its total maturity, this can be attributed to the fact that the size of the fruit is related to the number and size of the cells present in the mesocarp, in addition, in the pomegranate the size of the fruit is influenced by the quality of the flower and the pollination process since each aril is the result of a fertilized ovule (Wetzstein *et al.*, 2011).

The percentage of peel has a positive correlation with H° and the amount of juice, in turn, the percentage of peel affects the percentage of arils. The percentage of cartilage was negatively correlated with the amount of juice, bagasse, TSS/TA ratio, and the number of total phenols, which indicates a state of immaturity of the pomegranate since, in addition, it is positively correlated with TA and CI. Mayuoni-Kirshinbaum and Porat (2014), emphasize the importance of acidity levels in the juice, since acidity influences the perception of pomegranate flavor, especially since it affects the stage of maturity and the time of harvest of the fruit pomegranates harvested early are more acidic and astringent than those harvested at optimum ripeness.

On the other hand, the state of maturity could be responsible for the following correlations. The amount of juice had a positive relationship with the increase in H° and with the number of total phenols, while TA and CI interact negatively. Bagasse tends to increase as the juiciness percentage, H°, TSS, TSS/TA ratio, and total phenols increase, which causes a decrease in TA and CI content. Shwartz *et al.* (2009) report that the ripe pomegranate fruits were less acidic than the immature ones and the content of soluble solids was higher in completely ripe fruits, for which the TSS/TA ratio increased from immature to mature fruits, in turn, Al-Maiman and Ahmad (2002) mention that ascorbic acid content decreases significantly with advancing maturity and total and individual sugars reach maximum levels, which can be attributed to starch hydrolysis (Kulkarni and Aradhya, 2005).

Table 5. Correlation of the variables with greater significance

	w	ED	PD	%Peel	%Cartilage	%Arils	Juice	Bagasse	% Juiciness	C	H°	TSS	TA	TSS/TA	TP
ED	**0.826** <.0001														
PD	**0.781** <.0001	**0.719** <.0001													
%Peel	0.2585 0.1072	0.1182 0.4676	0.1319 0.4172												
%Cartilage	0.1393 0.9311	0.1017 0.5323	0.4243 0.0064	-0.575 0.0001											
%Arils	-0.419 0.0071	-0.217 0.1770	-0.548 0.0002	**-0.618** <.0001	-0.282 0.0777										
Juice	-0.138 0.3925	-0.034 0.8335	-0.313 0.0490	**0.601** <.0001	**-0.806** <.0001	0.0548 0.7369									
Bagasse	0.2723 0.8977	0.3459 0.0288	0.0019 0.9904	0.3936 0.0120	**-0.680** <.0001	0.1975 0.2218	0.5539 0.0002								
% Juiciness	0.1916 0.2361	0.3297 0.0377	0.0057 0.9719	0.0563 0.7300	-0.357 0.0236	0.2797 0.0804	0.2286 0.1558	**0.832** <.0001							
C	-0.131 0.4177	0.0300 0.8538	-0.218 0.1757	-0.383 0.0147	-0.124 0.4430	0.5434 0.0003	-0.055 0.7326	0.1618 0.3185	0.2736 0.0876						
H°	0.2351 0.1441	0.3169 0.0463	0.1128 0.4880	**0.612** <.0001	-0.551 0.0002	-0.200 0.2140	**0.692** <.0001	**0.610** <.0001	0.2993 0.0606	-0.123 0.4465					
TSS	0.2927 0.0668	0.3153 0.0475	-0.028 0.8635	0.0653 0.6889	-0.472 0.0021	0.3680 0.0194	0.2778 0.0826	**0.715** <.0001	0.5737 0.0001	0.3876 0.0135	0.3465 0.0285				
TA	0.0572 0.7256	0.0209 0.8980	0.3584 0.0255	-0.402 0.0100	**0.857** <.0001	-0.343 0.0301	**-0.739** <.0001	**-0.702** <.0001	-0.425 0.0061	-0.255 0.1119	-0.548 0.0002	**-0.610** <.0001			
TSS/TA	0.2829 0.0768	0.1922 0.2347	-0.043 0.7889	0.3450 0.0315	**-0.641** <.0001	0.2128 0.1872	0.4307 0.0055	**0.675** <.0001	0.4598 0.0028	0.2627 0.1014	0.4265 0.0061	**0.707** <.0001	**-0.831** <.0001		
TP	-0.154 0.3401	-0.034 0.8340	-0.321 0.0403	0.5111 0.0008	**-0.869** <.0001	0.2342 0.1458	**0.818** <.0001	**0.648** <.0001	0.3508 0.0264	0.2077 0.1983	**0.677** <.0001	0.3867 0.0137	**-0.826** <.0001	0.5759 0.0001	
CI	-0.087 0.5900	-0.207 0.1997	0.1325 0.4150	-0.443 0.0041	**0.729** <.0001	-0.159 0.3267	**-0.709** <.0001	**-0.691** <.0001	-0.424 0.0063	-0.386 0.0137	**-0.829** <.0001	-0.541 0.0003	**0.764** <.0001	**-0.618** <.0001	**-0.826** <.0001

Bold numbers indicate high correlations. Only variables with significant correlations are shown

Concerning the increase in the color concentration of the juice, the content of phenols also tends to increase, which causes a positive interaction between H° and total phenols. In cherries, the increase in total phenols was associated with the greater accumulation of anthocyanins. Likewise, the levels of anthocyanins in the aril juice increased significantly during ripening in the 'Wonderful' pomegranate (Shwartz *et al.*, 2009). In the case of the CI, its increase or decrease during the progression of maturity may be due to the increase in the content of anthocyanins and the decrease in phenols, since it is reported that phenols are probably consumed in the biosynthesis of the flavylium ring during maturity. formation of the anthocyanin pigment, which causes a reduction in its content, in addition, an additional increase in TSS and a slight decrease in the content of anthocyanin pigments are reported due to the progress in the maturation of the pomegranate. This onset of anthocyanin discoloration is associated with decreased acidity, which may be the cause of internal aril decomposition in overripe pomegranate fruits (Kulkarni and Aradhya, 2005).

Although the antioxidant capacity depends mainly on the content of phenols, the attractiveness of the fruit to consumers is mainly related to physical parameters and sensory quality, in addition to the benefits to human health that its consumption provides, which vary depending on the cultivation and climatic conditions during pomegranate ripening (Borochov-Neori *et al.*, 2009).

Conclusions

The quality parameters and bioactive compounds had significant differences between the Chihuahuan and imported pomegranates, this is due to the different degrees of maturity in which the pomegranate was harvested, as well as the characteristics of the places of origin of the fruit. The COY_NE lot had the fruits with the best qualities, even over pomegranates of foreign origin. Coyame pomegranates possess the quality and the necessary attributes to rival imported pomegranates. It is recommended to start the harvest of Chihuahuan pomegranates at the end of September to increase the quality and shelf life of the fruits. In turn, the color index can be a great tool for predicting the stages of maturity and quality. This work must be complemented with an edaphoclimatic study.

Authors' Contributions

Conceptualization: JMSP; Methodology: NGTB, LCNM, RMYM; Validation: JMSP, NGTB; Formal analysis: JMSP, RPL; Investigation: NGTB, LCNM, RMYM; Data curation: JMSP, RPL; Funding acquisition: JMSP, ES, RPL; Project administration: JMSP; Writing: NGTB, LCNM; Review and editing: NGTB, JMSP, ES, LCNM. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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