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Original Article

Pomological and biochemical changes in pomegranate (*Punica granatum* L. cv. 'Hicaznar') fruits harvested at different mature periods

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Abstract:

Pomegranate is a fruit species beneficial for human health due to its high antioxidant capacities and other bioactive compounds. In this study, the pomological and biochemical changes of pomegranate fruits harvested at four different ripening stages in the Hicaznar variety were determined. The fruits were harvested at the stage where the seeds turned white (August 5), the stage where the color change in the seeds began (September 5), the stage where the seeds turned pink (September 29), and the stage where the seeds turned red (October 20). In line with this aim, fruit weight, fruit width, fruit length, total soluble solids, pH, titratable acidity, total phenolic content, total flavonoid content, and total antioxidant capacity were determined in fruit samples. Fruit weight ranged from 132.7 to 546.49 g, fruit length ranged from 71.00 to 114.0 mm, fruit width ranged from 67.22 to 99.35 mm, total soluble solids ranged from 10.43% to 15.23%, total acidity ranged from 0.99% to 2.76%, pH ranged from 2.98 to 3.37, total phenolic content ranged from 490.40 to 570.73 mg gallic acid equivalent 100 g^{-1}, total flavonoid content ranged from 5.85 to 7.28 mg catechin equivalent 100 g^{-1}, and total antioxidant capacity ranged from 83.64% to 88.46%. In this study, as maturity progressed in the 'Hicaznar' variety, increases in fruit weight, fruit length, fruit width, and total soluble solids content were observed. Conversely, decreases in titratable acidity, total phenolic content, and antioxidant capacity were observed as maturity progressed.

Key words:
antioxidant capacity, Hicaznar, *Punica granatum*, total phenolic content, total flavonoid content

Apstrakt:

Pomološke i biohemijske karakteristike plodova nara (*Punica granatum* L. cv. 'Hicaznar') ubranih u različitim periodima zrelosti

Nar je vrsta voća korisna za ljudsko zdravlje zbog visokog antioksidativnog kapaciteta i prisustva drugih bioaktivnih jedinjenja. U ovoj studiji određene su pomološke i biohemijske promene plodova nara varijeteta Hicaznar, ubranih u četiri različite faze zrenja. Plodovi su ubrani u fazi kada je seme bilo bele boje (5. avgust), u fazi kada je započela promena boje semena (5. septembar), u fazi kada je seme postalo ružičasto (29. septembar) i u fazi kada je seme poprimilo crvenu boju (20. oktobar). U skladu sa ovim ciljem, u uzorcima plodova određeni su masa ploda, širina i dužina ploda, ukupne rastvorljive suve materije, pH, titrabilna kiselost, ukupan sadržaj fenola, ukupan sadržaj flavonoida i ukupni antioksidativni kapacitet. Masa plodova varirala je od 132,7 do 546,49 g, dužina ploda od 71,00 do 114,0 mm, širina ploda od 67,22 do 99,35 mm, sadržaj ukupnih rastvorljivih suvih materija od 10,43% do 15,23%, ukupna kiselost od 0,99% do 2,76%, pH vrednost od 2,98 do 3,37, ukupan sadržaj fenola od 490,40 do 570,73 mg ekvivalenta galne kiseline na 100 g, ukupan sadržaj flavonoida od 5,85 do 7,28 mg ekvivalenta katehina na 100 g^{-1}, dok je ukupni antioksidativni kapacitet iznosio od 83,64% do 88,46%. U ovoj studiji je utvrđeno da su, kako je sazrevanje napredovalo kod varijeteta 'Hicaznar', masa ploda, dužina, širina i sadržaj ukupnih rastvorljivih suvih materija rasli. Suprotno tome, uočen je pad titrabilne kiselosti, ukupnog sadržaja fenola i antioksidativnog kapaciteta sa napredovanjem zrelosti.

Ključne reči:
antioksidativni kapacitet, Hicaznar, *Punica granatum*, ukupan sadržaj fenola, ukupan sadržaj flavonoida

Introduction

Pomegranate (*Punica granatum* L.), which belongs to the *Lythraceae* family, is part of the *Punica* genus. It is adapted to tropical and subtropical climates, perennially deciduous, and grows in shrub form, reaching heights between 1.5 m and 5 m (Onur & Tibet, 1988). The fruit obtained its commercial name, „Pomuni granatum", meaning „seeded apple" in the Middle Ages. The Carthaginians, a Phoenician colony, initiated pomegranate trade in the Mediterranean Basin, hence its mention in ancient sources as the „Carthaginian (Phoenician) Apple" (Kurt et al., 2013).

Pomegranate is native to Iran and Afghanistan, the Caucasus, the Middle East, and Anatolia. Nowadays, cultivation occurs not only in its homeland but also in the Mediterranean Basin, the southern coasts of Europe, the Americas, the Far East, and Australia. The widespread dispersal of pomegranate seeds is also related to birds consuming them and spreading the seeds through their feces across vast areas (Stover & Mercure, 2007; Glozer et al., 2008). Due to being within the homeland boundaries of pomegranate, Türkiye exhibits significant diversity in varieties (Kelebek et al., 2010). In recent years, pomegranate production in Türkiye has significantly increased from 537,847 tons (2018) to 681,460 tons (2022) (TÜİK, 2024), marking a 21.07% increase in the last five years. Currently, there are no official statistics regularly maintained by the Food and Agriculture Organization (FAO) or EUROSTAT.

Pomegranate (*Punica granatum* L.) is among the first fruits cultivated globally and is known for its health benefits, commercial value, and frequent mention in cultural contexts. With the recent increase in production, there has been a diversification in pomegranate consumption. The most well-known product is pomegranate molasses, along with its juice, wine, liqueur, concentrate, soda, syrup, jam, and jelly. Apart from being a food item, it is utilized in the chemical, cosmetic, and pharmaceutical industries for citric acid, vinegar, dye, ink, and cologne production. Pomegranate, containing around 28-30% tannins in its peel and being a significant source of oil from its seeds, varies in oil content from 6.6% to 19.3% depending on the variety and cultivation region (Gölükçü et al., 2008).

Recent medical studies have revealed that pomegranate, in addition to its high antioxidant content, contains anticarcinogenic, antimicrobial, antiviral, and anti-atherosclerotic compounds that can reduce blood pressure and LDL oxidation, aid in treating Alzheimer's and heart diseases, and enhance resistance against certain types of cancer; its juice has positive effects on blood parameters. Particularly because of its antioxidants, pomegranate strengthens the body's defense system. Studies indicate that pomegranate juice has protective effects against skin cancer and prostate cancer in men (Aviram et al., 2004; Reddy et al., 2007; Bell & Hawthorne, 2008; Oğuz et al., 2011).

It has been found that pomegranate juice has three times higher antioxidant activity than red wine or green tea and 2.6 to 8 times higher antioxidant activity than those found in grapes/cranberries (Gil et al., 2000; Rosenblat & Aviram, 2006). Additionally, numerous studies worldwide have been conducted on the chemical properties and health beneficial compounds of pomegranate (Zarei, 2017; Adiletta et al., 2018; Mekni et al., 2019; El Moujahed et al., 2022; Parashuram et al., 2022).

It has been reported that the nutritional content of fruit species significantly changes according to their ripeness level, with higher phenolic compound levels found in green fruits than in ripe fruits (Choi et al., 2012; Wu et al., 2012; Bayar & Şan, 2017). Therefore, this study aimed to compare the pomological and biochemical properties of Hicaznar pomegranates harvested at different maturity time.

Materials and Methods

The study was conducted in 2023. Fruits of the „Hicaznar" variety, which had reached twenty-five years of age and were cultivated by a private company in the Serik district of Antalya, were used as the material. Fruit samples were collected on four different maturity time (05.08.2023. (MT1), 05.09.2023. (MT2), 29.09.2023. (MT3), 20.10.2023. (MT4)) (**Fig. 1**), with three replicates and ten fruits per replicate, for pomological and biochemical analysis. Samples for biochemical analysis were stored at -20 °C until analysis.

The weight of the fruit samples (g) was measured using „HZK-210FA" precision digital scales. Ten cucumber samples were weighed and selected for each genotype. Additionally, the lengths (cm) and width (mm) of the fruits were measured (Kılıç et al., 2022). After cleaning, the harvested fruits were peeled and filtered. The pH was measured using „ADWAN AD12" digital pH meter. The titratable acidity (TA) of the fruit juice was determined according to the method described by Balikçi et al. (2021). Pure water was added to 10 ml of fruit juice until the total volume reached 100 ml, and the mixture was titrated (with „BRAND Titrette" brand buret) with 0.1N NaOH until the pH reached 8.1. The color values were determined using „CR-400 minolta (Japan)" colorimeter. The total soluble solid content (SSC) was determined using „HI 96,801" handheld refractometer (Kılıç et al., 2022).

Fig. 1. Color change of fruits harvested on different maturity time (1: MT1, 2: MT2, 3: MT3, 4: MT4)

Total phenolic content was determined using Folin-Ciocalteu's chemical as described in the study conducted by Singleton & Rossi (1965). For this purpose, homogenized fruit pulp puree was subjected to extraction process in tubes for one hour using acetone, water and acetic acid (70:29.5:0.5) solution. Then, Folin-Ciocalteu's chemical and pure water were mixed on the extraction and waited for 8 minutes, then 7% sodium carbonate was added. After two hours of incubation, the absorbance of the solution that acquired a bluish color was read on a spectrophotometer (Model T60U, PG Instruments, USA) at 750 nm wavelength. The obtained results were calculated in gallic acid as µg gallic acid equivalent (GAE) g^{-1} fresh fruit flesh.

Total flavonoid content was determined according to the method described by Dewanto et al. (2002) and modified by Çelik et al. (2023). 1.25 ml of double distilled water was added to 250 µl of extract. Then, 5% sodium nitrite ($NaNO_2$) was added to the mixture and incubated for 6 min. After incubation, 150 ml of 10% aluminum chloride ($AlCl_3x6H_2O$) solution was added to the mixture and 0.5 ml of 1 M sodium hydroxide (NaOH) was added after 5 min to neutralize the solution. Then, the absorbance values of the samples were measured at 510 nm using a UV spectrophotometer (Model T60U, PG Instruments, USA).

Antioxidant activity was evaluated using a method involving DPPH radical scavenging. 100 µl of the extract was made up to 2 ml with 0.1 Mm DPPH solution and incubated for 30 min at room temperature (Kumaran & Karunakaran, 2006). After incubation, absorbance was measured at 517 nm using a UV spectrophotometer (Model T60U, PG Instruments, USA).

The data obtained from the research were subjected to analysis of variance using the MINITAB 17 software package. Tukey's multiple comparison test was used to determine significant differences between the means ($p< 0.05$).

Results and discussion

In the study, data and statistical results regarding fruit weight, fruit length, and fruit width of the Hicaznar variety harvested at different ripening stages are presented in **Tab. 1**. Statistically significant differences were determined in terms of fruit weight, fruit length, and fruit width among different ripening stages (p<0.05). According to the obtained data, the highest fruit weight, fruit length, and fruit width were observed on the harvest date 'MT4' (546.49 g, 114.0 mm, and 99.35 mm, respectively), whereas the lowest fruit weight, fruit length, and fruit width were recorded on the harvest date 'MT1' (132.7 g, 71.00 mm, and 67.22 mm, respectively). Fruit weight, fruit length, and fruit width of fruits harvested at four different periods in the Hicaznar variety showed a significant increase with maturity. The results obtained in this study were found to be similar to those of Özsayın (2012). It was determined that fruit weight increased by more than 1.5 times in the last 21 days (from September 29th to October 20th). Similarly, Bayar & Şan (2017) reported approximately 1.5 times increase in fruit weight, 1.2 times increase in fruit width, and approximately 1.3 times increase in fruit length between September 6th and October 3rd in their study on Hicaznar. Similar results have been reported by different researchers (İkinci & Dursun, 2021).

Table 1. Fruit weight, fruit length, and fruit width values of Hicaznar variety at four different maturity time

Maturity Time	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)
MT1	132.70±39.40 ^{c}	71.00±12.36 ^{d}	67.22±1.10 ^{d}
MT2	282.78±3.24 ^{b}	86.73±5.23 ^{c}	80.30±1.15 ^{c}
MT3	354.30±83.30 ^{b}	91.21±8.42 ^{b}	90.26±0.83 ^{b}
MT4	546.49±5.62 ^{a*}	114.00±7.56 ^{a}	99.35±1.41 ^{a}

^{a,b,c} Values within a column with different superscripts differ significantly at p<0.05
** The study was carried out on a total of 80 fruits, with 3 replications and 20 fruits in each replication.

In this study, the data and statistical analysis results regarding SSC, pH, and TA of the Hicaznar variety harvested at different ripening stages are presented in **Tab. 2**. Statistically significant differences were determined in terms of SSC, pH, and TA among different ripening stages (p<0.05). According to the obtained data, the highest SSC and pH were observed on the harvest date 'MT4' (15.23% and 3.37, respectively), while the lowest SSC and pH were recorded on the harvest date 'MT1' (10.43% and 2.98, respectively). The highest TA was observed on the harvest date 'MT1' (2.76 g citric acid 100 g^{-1}), while the lowest TA was observed on the harvest date 'MT4' (0.99 g citric acid 100 g^{-1}). As a result, it was determined that the highest pH value of fruit juices (3.37) occurred during the commercial harvesting period (October 20th). The pH level in Hicaznar consistently increased with maturity. Consequently, it was observed that the titratable acidity content decreased consistently with the progression of ripeness. It was determined that the soluble solids content of Hicaznar fruit juices consistently increased with ripening. Kulkarni & Aradhya (2005) and Bayar & Şan (2017) reported in their studies that SSC (%), and pH level increased with ripening in pomegranate, while TA (g citric acid 100 g^{-1}) decreased. In another study, it was reported that the SSC content of Hicaznar variety ranged from 14% to 18.2% at commercial harvesting time, which is consistent with our results (Özsayın, 2012). The observed citric acid contents of the fruits in our study were similar to those reported by Karaca (2011). Karaca (2011) reported that the citric acid, malic acid, and tartaric acid contents of ripe fruits were 17,360 µg g^{-1}, 500 µg g^{-1}, and 590 µg g^{-1}, respectively. Mulas et al. (2013) found that the organic acid content in myrtle plants decreased with ripening.

Table 2. SSC, pH, TA values of Hicaznar variety at four different maturity times

Maturity Time	SSC (%)	pH	TA (g citric acid 100 g^{-1})
MT1	10.43±0.20 ^{d}	2.98±0.01 ^{b}	2.76±0.17 ^{a}
MT2	13.20±0.20 ^{b}	3.07±0.02 ^{b}	2.33±0.09 ^{b}
MT3	14.30±0.27 ^{c}	3.43±0.04 ^{a}	1.54±0.13 ^{c}
MT4	15.23±0.15 ^{a}	3.37±0.07 ^{a}	0.99±0.04 ^{d}

^{a,b,c} Values within a column with different superscripts differ significantly at at p<0.05
**The study was carried out on a total of 80 fruits, with 3 replications and 20 fruits in each replication

In this study, the data and statistical analysis results regarding total phenolic content, total flavonoid content, and total antioxidant content of the Hicaznar variety harvested at different ripening stages are presented in **Tab. 3**. Statistically significant differences were determined in terms of total phenolic content, total flavonoid content, and total antioxidant content among different ripening stages (p<0.05). According to the obtained data, the highest total phenolic content was observed on the harvest date 'MT1' (570.73 mg GAE 100 g^{-1}), while the lowest total phenolic content was recorded on the

Table 3. Total phenolic, total flavonoid, and total antioxidant capacity values of Hicaznar variety fruits at four different maturity time

Maturity Time	Total phenolic content (mg GAE 100 g^{-1})	Total flavonoid content (mg CAE 100 g^{-1})	Total antioxidant (inhibition %)
MT1	570.73±5.67 [a]	7.28±0.35 [b]	88.46±0.54 [a]
MT2	519.10±1.47 [b]	6.62±0.53 [bc]	88.46±0.09 [a]
MT3	498.64±3.62 [c]	5.85±0.18 [c]	87.60±0.51 [a]
MT4	490.40±5.60 [c]	10.67±0.30 [a]	83.64±0.77 [b]

[a,b,c] Values within a column with different superscripts differ significantly at at $p<0.05$
**The study was carried out on a total of 80 fruits, with 3 replications and 20 fruits in each replication.

harvest date 'MT4' (490.40 mg GAE 100 g^{-1}). The highest total flavonoid content was observed on the harvest date 'MT4' (10.67 mg CAE 100 g^{-1}), while the lowest total flavonoid content was observed on the harvest date 'MT3' (5.85 mg CAE 100 g^{-1}). The highest antioxidant content in pomegranate was observed on the harvest dates 'MT1, MT2, MT3' (88.46, 87.60% inhibition, respectively), while the lowest antioxidant content was observed on the harvest date 'MT4' (83.64% inhibition). The total phenolic content in Hicaznar fruit juice was found to be higher in unripe fruits compared to ripe fruits. In the study, it was determined that the total phenolic content in fruit juice was at its highest level (530.70 mg GAE 100 g^{-1}) when the color change began (August 5th) and decreased with ripening. Similarly, the total antioxidant content was higher in unripe fruits (88.46% inhibition), and it decreased during the commercial harvesting period (83.67% inhibition). In contrast, the total flavonoid content increased with ripening, and the highest value (10.67 mg CAE 100 g^{-1}) was observed during the commercial harvesting period. Fadda & Mulos (2010), Siriamornpun et al. (2015), Eşiyok (2022), and Pepe et al. (2022) reported that the total phenolic content decreases with ripening. The amount of phenolic compounds and flavonoid compounds in fruit species can vary significantly depending on genotype, ecological conditions, and analysis methods, as reported in many studies (Wang et al., 2010; Vatansever, 2018; Demir & Başayiğit, 2022). In our study, it was found that there was a parallel decrease in the total phenolic content as the degree of ripeness increased. Consistent with our results, Al-Maiman & Ahmad (2002) reported a significant decrease in the total phenolic content of pomegranate fruits with ripening. Similarly, Siriamornpun et al. (2015) found that unripe green fruits of jujube contained more total phenolic content than ripe fruits.

Conclusion

In conclusion, the biochemical contents of 'Hicaznar' fruits significantly vary according to ripening stages. The total phenolic content, antioxidant level, and titratable acidity decrease as ripeness increases. Conversely, fruit weight, fruit length, fruit width, soluble solids content (SSC), and pH increase with ripening. Although the total phenolic content and antioxidant levels decrease with ripening, fruits should be harvested during the commercial harvesting period for fresh consumption.

References

Adiletta, G., Petriccione, M., Liguori, L., Pizzolongo, F., Romano, R., & Di Matteo, M. (2018). Study of pomological traits and Physico-chemical quality of pomegranate (*Punica granatum* L.) genotypes grown in Italy. *European Food Research and Technology*, *244*, 1427-1438. https://doi.org/10.1007/s00217-018-3056-x

Al-Maiman, S.A. & Ahmad, D. (2002). Changes in physical and chemical properties during pomegranate (*Punica granatum* L.) fruit maturation. *Food Chemistry, 76*(4), 437-441. https://doi.org/10.1016/S0308-8146(01)00301-6

Aviram, M., Rosenblat, M., Gaitini, D., Nitecki, S., Hoffman, A., Dornfeld, L., & Hayek, T. (2004). Pomegranate juice consumption for 3 years by patients with carotid artery stenosis reduces common carotid intima-media thickness, blood pressure and LDL oxidation. *Clinical Nutrition*, *23*(3), 423-433. https://doi.org/10.1016/j.clnu.2003.10.002

Balikçi, U., Yildirim, A., & Çelik, C. (2021). The effect of different plant growth regulators on the biochemical contents of the 'Hayward' kiwi cultivar. *Mustafa Kemal University Journal of Agricultural Sciences, 26*(2), 337–344. https://doi.org/10.37908/mkutbd.905959 .

Bayar, B. & Şan, B. (2017). Physical and biochemical changes in pomegranate (*Punica granatum* L. cv.'Hicaznar') fruits harvested at three maturity stages. *Horticulture (Series B)*, *61*, 63-68.

Bell, C. & Hawthorne, S. (2008). Ellagic acid, pomegranate and prostate cancer - a mini review. *Journal of Pharmacy and Pharmacology, 60*(2), 139-144. https://doi.org/10.1211/jpp.60.2.0001

Choi, S.H., Ahn, J.B., Kim, H.J., Im, N.K., Kozukue, N., Levin, C.E., & Friedman, M. (2012). Changes in free amino acid, protein, and flavonoid content in jujube (*Ziziphus jujube*) fruit during eight stages of growth and antioxidative and cancer cell inhibitory effects by extracts. *Journal of Agricultural and Food Chemistry, 60*(41), 10245-10255.

Çelik, C., Binici, S., Yıldırım, A., Yıldırım, F., Şan, B., & Bayram, S. (2023). Determination of fruit characteristics and some biochemical contents of different tissues of 4 avocado (*Persea americana* Mill.) cultivarss grown in Antalya ecological conditions. *Anadolu Journal of Agricultural Sciences, 38*(1), 173–186. https://doi.org/10.7161/omuanajas.1132021

Demir, S. & Başayiğit, L. (2022). Classification of some biochemical properties with J48 classification tree algorithms in hyperspectral data. *Veri Bilimi, 5*(2), 20-28.

Dewanto, V., Wu, X., Adom, K.K., & Liu, R.H. (2002).. Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. *Journal of Agricultural and Food Chemistry, 50*(10), 3010–3014. https://doi.org/10.1021/jf0115589

El Moujahed, S., Dinica, R.M., Cudalbeanu, M., Avramescu, S.M., Msegued Ayam, I., Ouazzani Chahdi, F., & Errachidi, F. (2022). Characterizations of six pomegranate (*Punica granatum* L.) varieties of global commercial ınterest in morocco: pomological, organoleptic, chemical and biochemical studies. *Molecules*, *27*(12), 3847. https://doi.org/10.3390/molecules27123847

Eşiyok, H. (2022). *Effect of different storage on the physical and chemical properties of pomegranate* (*Punica granatum* L.) *seeds*. (Master thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Fadda, A. & Mulas, M. (2010). Chemical changes during myrtle (*Myrtus communis* L.) fruit development and ripening. *Scientia Horticulturae, 125*(3), 477-485. https://doi.org/10.1016/j.scienta.2010.03.024

Gil, M.I., Tomás-Barberán, 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. *Journal of Agricultural and Food Chemistry, 48*(10), 4581-4589. https://doi.org/10.1021/jf000404a

Glozer, K. & Ferguson, L. (2008). Pomegranate production in Afghanistan. *UCDAVIS College of Agricultural & Environmental Sciences,* (s 32).

Gölükçü, M., Tokgöz, H., & Kıralan, M. (2008). Some properties of important pomegranate (*Punica granatum*) cultivar's seeds grown in Turkey. *Gıda*, *33*(6), 281-290.

İkinci, A. & Dursun, E. (2021). Pomological and chemical properties of some pomegranate (*Punica granatum* L.) cultivars grown in Şanlıurfa. *International Journal of Anatolia Agricultural Engineering, 3*(3), 63-72.

Karaca, E. (2011). *The effect on phenolic compounds applied some of the procedures during production of pomegrane juice concentrate*. (Master thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Kelebek, H. & Canbaş, A. (2010). Organic acid, sugar and phenolic compounds and antioxidant capacity of Hicaz pomegranate juice. *Gıda, 35*(6), 439-444.

Kılıç, C.N., Yıldırım, A., & Çelik. C. (2022). Determination of phenological, morphological developments and pomological characteristics of different persimmon (*Diospyros kaki* L.) cultivars. *Turkish Journal of Science and Engineering, 4*(2), 82–87. https://doi.org/10.55979/tjse.1175295

Kulkarni, A.P. & Aradhya, S.M. (2005). Chemical changes and antioxidant activity in pomegranate arils during fruit development. *Food Chemistry, 93*(2), 319-324. https://doi.org/10.1016/j.foodchem.2004.09.029

Kumaran, A. & Karunakaran, R.J. (2006). Nitric oxide radical scavenging active components from *Phyllanthus emblica* L. *Plant Foods for Human Nutrition, 61*, 1-5.

Kurt, H. & Şahin, G. (2013). A study of agricultural geography: Pomegranate (*Punica granatum* L.) cultivation in Turkey. *Marmara Coğrafya Dergisi, 27*, 551-574.

Mekni, M., Kharroubi, W., Cheraief, I., & Hammami, M. (2019). Pomological, organoleptic and biochemical characterizations of Tunisian pomegranate fruits *Punica granatum* L. *American Journal of Plant Sciences, 10*(07), 1181. https://doi.org/10.4236/ajps.2019.107084

Mulas, M., Fadda, A., & Angioni, A. (2013). Effect of maturation and cold storage on the organic acid composition of myrtle fruits. *Journal of the Science of Food and Agriculture, 93*(1), 37-44. https://doi.

org/10.1002/jsfa.5724

Oğuz, H.İ., Ukav, İ., & Eroğlu, D. (2011). Güneydoğu Anadolu Bölgesi'nde nar (*Punica granatum* L.) üretimi ve pazarlanması. *GAP VI. Tarım Kongresi*, *9*(12), 108-112.

Onur, C. & Tibet H. (1988). Nar özel sayısı. *Derim Dergisi, 5*(4), 192.

Özsayın, S. (2012). *Determination of nutritional status, some fruit quality parameters and antioxidant activity of pomegranate orchards* (*Punica granatum* L.) *in Antalya region*. (Master thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Parashuram, S., Singh, N.V., Gaikwad, N.N., Corrado, G., Roopa Sowjanya, P., Basile, B., & Marathe, R.A. (2022). Morphological, biochemical, and molecular diversity of an Indian ex situ collection of pomegranate (*Punica granatum* L.). *Plants, 11*(24), 3518. https://doi.org/10.3390/plants11243518

Pepe, A.V., Yıldırım, F., Yıldırım, A., & Çelik, C. (2022). Determination of fruit quality and antioxidant properties of some blueberry (*Vaccinium corymbosum* L.) cultivars cultivated in soilless culture. *Mustafa Kemal University Journal of Agricultural Sciences, 28*(3), 513-521. https://doi.org/10.37908/mkutbd.1280524

Reddy, M.K., Gupta, S.K., Jacob, M.R., Khan, S.I., & Ferreira, D. (2007). Antioxidant, antimalarial and antimicrobial activities of tannin-rich fractions, ellagitannins and phenolic acids from *Punica granatum* L. *Planta Medica, 53*(05), 461-467. https://doi.org/10.1055/s-2007-967167

Singleton, V.L. & Rossi, J.A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture*, *16* (3), https://doi.org/144-158. 10.5344/ajev.1965.16.3.144

Siriamornpun, S., Weerapreeyakul, N., & Barusrux, S. (2015). Bioactive compounds and health implications are better for green jujube fruit than for ripe fruit. *Journal of Functional Foods*, *12*, 246-255. https://doi.org/10.1016/j.jff.2014.11.016

Stover, E.D. & Mercure, E.W. (2007). The Pomegranate: A New Look at The Fruit of Paradise. *HortScience, 42*(5), 1088-1092. https://doi.org/10.21273/HORTSCI.42.5.1088

TÜİK. (2024). Turkish Statistical Institute. https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=1/ (Access date: 06.05.2024)

Vatansever, A. (2018*). Determination of physico-chemical and biochemical properties of pomegranate and its products*. (Master thesis). https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Wang, R., Ding, Y., Liu, R., Xiang, L., & Du, L. (2010). Pomegranate: constituents, bioactivities and pharmacokinetics. *Fruit, Vegetable and Cereal Science and Biotechnology, 4*(2), 77-87.

Wu, C.S., Gao, Q.H., Guo, X.D., Yu, J.G., & Wang, M. (2012). Effect of ripening stage on physicochemical properties and antioxidant profiles of a promising table fruit „pear-jujube" (*Zizyphus jujuba* Mill.). *Scientia Horticulturae, 148*, 177-184. https://doi.org/10.1016/j.scienta.2012.09.026

Zarei, A. (2017). Biochemical and pomological characterization of pomegranate accessions in Fars province of Iran. *SABRAO Journal Breeding Genetics, 49*(2), 155-167.