Organic Acids, Sugars and Bioactive Compounds of Promising Medlar (*Mespilus germanica* L.) Genotypes Selected from Turkey

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**ABSTRACT**

The Black Sea region of Turkey is where the Medlar population is most common, and Medlar usually grows naturally in this region. This study was carried out to determine the organic acids, sugars and bioactive compounds of promising Medlar (*Mespilus germanica* L.) genotypes which were grown in Tonya and Sürmene districts of Trabzon province (Black Sea Region of Turkey) in 2017 and 2018. Total of 15 genotypes were evaluated in the study, including 8 genotypes from Sürmene and 7 genotypes from Tonya. As a result, crude protein was ranged from 1.65 to 2.70%, crude oil from 0.10% to 9.40%, soluble solids contents from 9.80% to 20.20%, titratable acidity from 0.60% to 1.40%, ascorbic acid from 21.5 mg 100 g−1 to 44.2 mg 100 g−1, malic acid from 590.5 mg 100 g−1 to 1074.5 mg 100 g−1, succinic acid from 127.0 mg 100 g−1 to 419.0 mg 100 g−1, and citric acid from 2.0 mg 100 g−1 to 32.0 mg 100 g−1, fructose from 3255 mg 100 g−1 to 4726 mg 100 g−1, glucose from 2108 mg 100 g−1 to 3017 mg 100 g−1, sucrose from 127 mg 100 g−1 to 399 mg 100 g−1, carbohydrate from 47.3% to 73.1%, total phenolics from 41 mg GAE 100 g−1 to 411 mg GAE 100 g−1 and antioxidant activity 13.1 mmol TE 100 g−1 to 77.8 mmol TE 100 g−1. It was found large diversity regarding crude oil, SSC, titratable acidity, citric acid, glucose and antioxidant capacity of fruits among the genotypes. It can be said that the fresh fruits of promising Medlar genotypes are particularly promising for the use of nutraceuticals. In particular, Ton-20 and Ton-21 genotypes were remarkable due to their high-quality characteristics and total phenolic content.

**KEYWORDS**

Antioxidant activity; medlar; *mespilus germanica*; phytochemical; total phenolic

**Introduction**

Medlar is being widely consumed in many countries, and Turkey is one of them. Turkey has a rich populations of natural gene resources and the origin center of cultural and wild fruit species. There is large diversity in terms of fruit color, shape and taste in the cultivars and genotypes (Özbek, 1978). Indeed, a few previous studies (Akbulut et al., 2016; Akin and Bostan, 2018; Aygün and Taşçı, 2013; Bostan, 2002; Bostan and Islam, 2007; Çakır and Öztürk, 2019; Çakır et al., 2019; Duman, 2019; Ercişi et al., 2012; Közen and Bostan, 2016; Maral and Bostan, 2020; Özkan et al., 1997; Sarıyıldız, 2019; Uzun and Bostan, 2019; Yılmaz, 2015; Yılmaz and Gerçekcioğlu, 2013; Yılmaz et al., 2016) have also revealed the diversity of fruit traits and potential of Medlar genetic resources in Turkey. The Black Sea region of Turkey is the place where Medlar is grown common. Medlar grows naturally in this region.

Human has used different natural materials especially fruits and vegetables that are good natural antioxidants sources to prevent several diseases (Donno et al., 2017). Fruits and vegetables that are recommended for health and dietary fiber have historically held a place in dietary guidance because of
their concentrations of vitamins, minerals, and phytochemicals, especially antioxidants (Slavin and Lloyd, 2012). The interest in the role of antioxidants in health accelerates both the studies on the research of new antioxidant sources and the evaluation of existing antioxidant sources, etc. (Koca and Karadeniz, 2005). Furthermore, phenolics and lipids are important for fruit aroma and flavor, and nutritive values. Their balanced consumption is also reducing the risks of chronic diseases such as cancers and cardiovascular disease (Seçilmiş Canbay et al., 2015). Therefore, people have been showing interest in wild fruits in recent years especially because of their high nutritional values and therapeutic properties and new taste. For this purpose, the cultivation of many wild fruit species has accelerated (Bostan and Islam, 2007).

Medlar, one of these fruit species is indigenous to southwest Asia and possibly also southeastern Europe from northern Turkey to the Caucasus and Transcaucasus and the north-eastern part of Iran (Lim, 2012).

Medlar fruit are edible but is left to blet for a few weeks after harvest to be eaten. Fruit may become brown and soft on the trees or after harvesting. Such fruits (over-ripe) have a sweet and slightly acid flesh which is ready to eat (Glew et al., 2003a; Lim, 2012). Medlar fruit, which are a climacteric fruit, are harvested in a tree (harvest). In this period when the fruit flesh is white, they cannot be consumed because of the high tannin content (Akçay et al., 2016). Some of the harvested product in October is stored in cold, dark and aerated places to soften the fruit. Another part of the crop is used to make pickles of this fruit which will be consumed as an appetizer in winter days (Glew et al., 2003b). Medlars are used for jam, marmalade, jelly, syrup, pickled, candied fruit, mixed jam, sauce, with cheese as a dessert, condiment for making fruit wine (Baird and Thieret, 1989). In traditional medicine, the pulp of the fruit is considered laxative, the leaves are astringent and the seed is lithontriptic (Lim, 2012).

Leaves, fruits, bark and wood of Medlar are also used in traditional medicine. The common medicinal benefits of Medlar are diarrhea treatment, cure of constipation, kidney and bladder stones, diuretic, elimination of oral abscess, elimination of stomach bloating, elimination of throat abscess, fattening, fever disposal, hematopoietic, internal hemorrhage treatment, regurgitation disposal cholera, prevention of enteritis, stimulation treatment of throat, strengthen fine skin, strengthen nerves, treatment of intestinal inflammation, treatment of large intestine infection, stopping abortion in woman with children, treatment of menstrual irregularities and treatment of Cutaneous leishmaniasis (Baird and Thieret, 1989; Baytop, 1999; Bibalani and Mosazadeh-Sayadmahaleh, 2012; Bignami and Tspiroudis, 1998; Kurbanova et al., 1998).

Medlar is an important fruit is especially rich in various sugars, organic acids, amino acids, pectin substances, carotene, polyphenols and other nutrients, minerals and trace elements (Akçay et al., 2016; Glew et al., 2003b; Lim, 2012). Fruit are very rich sources of bioactive compounds such as phenolics, and also be of different fatty acids (Seçilmiş Canbay et al., 2015), and polyphenol oxidase activity in Medlar fruit is considerably higher than that found in many other fruit species (Akçay et al., 2016). In addition, Medlar is a good source of natural antioxidants, and has potential of use in food and nutraceutical supplement formulations (Akbulut et al., 2016).

The large diversity in terms of fruit characteristics in the natural gene sources of Medlar offer significant selections in terms of both fruit quality and different uses. (Khadivi et al., 2019). In addition, the determination of phytochemical compositions of Medlar may be useful for in order to know how important Medlar fruit is nutritionally (Glew et al., 2003b). Furthermore, Future studies on the other chemical constituents including wild genotypes and cultivars of Medlar may enable food technologists to select Mespilus with improved nutritional quality (Glew et al., 2003a).

Although some studies have been made about the breeding by selection of Medlar genotypes in Turkey, detailed results about bioactive compounds of the promising genotypes studied in these studies were limited. Some similar studies have been done on Medlar previously. However, the genotypes in this study were selected from different regions not previously studied. In addition, these genotypes, each with a different source of genes, are promising candidates for the future.

This study aims to determine many chemical properties such as sugars, organic acids and bioactive compounds in the promising 15 Medlar genotypes previously selected from the Northern Turkey, and to complete the knowledge of chemical characterization of the Medlar genotypes.
Materials and Methods

Plant Material
This research was carried out to evaluate the sugars, organic acids and bioactive compounds of total 15 Medlar genotypes from Trabzon province (Northern Turkey) in 2017 and 2018 years. In the previous studies, 8 of these genotypes were selected in Sürmene district (Uzun and Bostan, 2019) and 7 of them were selected in Tonya district (Közen and Bostan, 2016) as a result of breeding studies in the region. The cultivation of trees is under general maintenance conditions. Samples of 30 fruits from each of 15 Medlar genotypes were randomly collected from the trees in late October in both years at tree maturity stage when the fruit skin is brown, the flesh is white and hard. Fruit samples were transferred to the laboratory for analyses in polyethylene bags 3 hours after collection.

Fruits were kept under laboratory conditions (at 21 ± 2°C temperature and 75 ± 2% relative humidity) until consumption stage.

All analyzes in the samples were carried out at the consumption stage (the acrid taste decreased and about 50% of the fruit flesh turned brown) (Yilmaz, 2015). For this, samples of 30 fruits from each genotype in the consumption phase were first washed with pure water, then the seeds were removed, the fruits were sliced with a stainless knife and the fruits were crushed and homogenized with an electric blender without peeling.

Moisture, Ash, Crude Protein, Crude Oil, Carbohydrate, SSC and Titratable Acidity

For the total moisture analysis, 3 g of the shredded fruit sample were weighed with 0.001 g of sensitive precision balance. The weighed samples were kept in the oven at 103 ± 2°C until they reached a constant weight. It was then cooled in a desiccator and weighed. Moisture content was calculated as the weight difference before and after drying in the oven and expressed as a mean value (AOAC, 2000a).

For the amount of ash, 3 ± 0.1 g was weighed with 0.001 g sensitive precision balance from each milled Medlar sample. The samples placed in the crucible were kept in the oven at 103 ± 2°C until they reached a constant weight. It was then cooled in a desiccator and burned in an incinerator at 530°C for 8 hours. After burning samples were cooled and weighed in desiccator (AOAC, 2000b). Ash ratio is calculated by the formula below (Eq.1).

\[ Total \ Ash \ (\%) = \ \frac{A_0 \times 100}{A_1} \] (1)

\( A_0 \): Amount of ash (g)  
\( A_1 \): Dry weight of sample sample (g)

The total carbohydrate ratio was calculated by subtracting of total protein, fat, moisture and ash ratios of the samples from 100.

For the crude protein analysis, 0.5 g of each sample was weighed and placed in Kjehdahl tubes. The tube was poured into the tube as catalyst (K₂SO₄: CuSO₄) and 12 ml of concentrated sulfuric acid was added and the protein device (Gerhardt Vap40) was burned for 1 h at 420°C until the color was completely clear. After combustion, the sample placed in the distillation unit was distilled with boric acid (3% H₃BO₃) and sodium hydroxide (33%) solutions. The collected distillate was then titrated with 0.2 N hydrochloric acid solution. The amount of protein was calculated according to the following formula (AOAC, 2000c) (Eq.2).

\[ Protein \ (\%) = \frac{V \times S \times N \times 100 \times 5.30}{m} \] (2)

\( V \): HCl used for titration (ml)  
\( m \): Sample amount (g)  
\( S \): 0.014

The crude oil ratio was determined using a soxhelet device (AOAC, 2000d). The glass containers of the apparatus were dried in the oven and brought to constant weight and the beakers to be n-hexane
were dried and then tared. The temperature of the device is set to 130°C, which is suitable for n-hexane. The milled 5 g fruit samples were placed in the cartridge. The cartridges were placed in the soxhelet extraction device. 60 ml of n-hexane was placed in each beaker. The first step of the device took 30 minutes to immerse. The second step, washing, lasted 150 minutes. Final phase recovery was completed in 30 min. After recovery, the samples were placed in an oven at 105 ± 2°C. The oven was left for 1 hour. The samples taken from the oven were cooled in a desiccator and then weighed to 0.001 g of sensitive precision balance. After taking the total weight of the beaker, % crude oil was calculated with the following formula (Eq.3).

\[
\text{Oil} \, \% = \frac{(A2 - A1)}{mx}100
\]

A1: Weight of the beaker for constant weighing (g),
A2: Total quantity in the last weighing per beaker (g),
m: Sample weight (g)

Fruit flesh was homogenized with a blender, and filtered homogeneous fruit juice. In filtered juice the soluble solids content (SSC) was determined by a digital hand refractometer (Greinorm Refraktometre 0–80 Brix, Germany), and titratable acidity (TA) was determined by titrating 20 ml of fruit juice (50% diluted) using 0.1 N NaOH and automatic titrator (BRAND Titrette, Germany).

**Ascorbic Acid, Organic Acids and Sugar Contents**

Ascorbic acid analysis was performed by spectrophotometric technique using reflectoquant device (Merc, RQflex plus 10, Germany) and ascorbic acid test kit (Merck 116981).

Organic acid (citric, malic, succinic) and sugar (sucrose, glucose and fructose) analyzes of Medlar samples were carried out by HPLC with small changes in the method of Lee and Coates (2000). 100 g of each sample was taken for analysis and mashed after digestion with a mechanical shredder. It was then diluted to 12.5 g puree/100 ml dH2O. The obtained samples were centrifuged at 10000xg for 10 minutes and the upper clear part was filtered through 0.45 μm filters. Filtered sample (10 μl) was then directly injected into the Thermo Ultimate 3000 (Thermo Scientific, Sunnyvale, CA) model RSDAD and ERC RefractoMax 520 refractive index detector HPLC to determine the organic acid and sugar content of the samples. As the carrier phase, 5 mM sulfuric acid solution (0.0085 N) was passed through 0.25 μm filters and degassed in the ultrasonic water bath. Isocratic elution was performed at a flow rate of 0.3 ml/min for 50 min at 30°C. The external standard method was used to determine the organic acid and sugar concentrations in the samples. For this purpose, calibration solutions were prepared in 5 different concentrations from citric, malic, succinic, sucrose, glucose and fructose (Sigma & Aldrich) standards. By using equations, organic acid and sugar contents of Medlar samples were determined (Eq.4).

\[
\begin{align*}
\text{citric} & : y = 3.4828x+0.3136 \quad R^2 = 0.9997, \\
\text{malic} & : y = 2.8946x-0.1181 \quad R^2 = 0.9991, \\
\text{succinic} & : y = 1.8998x+0.3136 \quad R^2 = 0.9999, \\
\text{sucrose} & : y = 0.3158x-0.0064 \quad R^2 = 0.9999, \\
\text{glucose} & : y = 0.4346x+0.0091 \quad R^2 = 0.9999 \quad \text{and} \\
\text{fructose} & : y = 0.4650x+0.1914 \quad R^2 = 0.9997
\end{align*}
\]

**Total Phenolics**

Total phenolic compounds were determined using Folin-Ciocalteu’s chemical. First, 200 μL of fresh fruit extract was taken and 4.4 ml of purified water was added. Then, 100 μL of Folin-Ciocalteu reagent and 2% sodium carbonate (Na2CO3) were added and left for incubation for 2 hours. After incubation, a bluish color solution will be measured at 760 nm wavelength on the spectrophotometer and the results are expressed in gallic acid, expressed as mg GAE 100 g⁻¹fw (fresh weight) (Beyhan et al., 2010).
**Antioxidant Activity**

In antioxidant assays, 0.26 mM DPPH (1,1-diphenyl-2-picrylhydrazil) solution was prepared for DPPH analysis. 2.8 ml of ethylalcohol and 1 ml of DPPH solution were added to 200 µl of fruit extract and incubated for 30 minutes in the dark after vortexing. Absorbance values were determined at 517 nm in the spectrophotometer after the incubation of the samples. The absorbance values obtained are expressed as µmol Trolox equivalent g−1 fresh weight (mmol TE 100 g−1 fw), calculated by Trolox standards lope scale (Brand-Williams et al., 1995).

**Statistical Analysis**

The experiment was designed according to a completely randomized with 3 replications. Results were subjected to analysis of variance (ANOVA) test for mean comparison (SAS JMP Statistical Discovery 13.2 software statistical program) and LSD test (using p< .05) which was used to test the differences in quality parameters (the content of Organic acids, sugars and bioactive compounds). Experimental results were expressed as mean ± standard deviation by means of 2 years (2017 and 2018).

**Results and Discussion**

The result of the quality traits, organic acids, sugars and bioactive compounds of Medlar fruit samples are presented in Table 1–4.

**Moisture, Ash, Crude Protein, Crude Oil, SSC and Titratable Acidity**

The moisture content was above 68% of the fruit weight and ranged from 68.2% (Sür-15) to 75.8% (Ton-9). These findings are similar to the results of previous researches (Ercisli et al., 2012; Haciseferoğulları et al., 2005; Sabry and Rizek, 1982; Vargas et al., 2009). In this study, the change of the moisture content of the fruits according to the genotypes was found statistically insignificant (Table 1).

The ash value (2.20–6.75%) determined in the genotypes in our study was higher than the previous studies that ranged from 0.6% to 1.96% (Haciseferoğulları et al., 2005; Kalyoncu et al., 2013; Sabry and Rizek, 1982; Vargas et al., 2009), and was found statistically insignificant (Table 1).

In this study crude protein ranged from 1.65 (Sür-16) to 2.70% (Ton-19). The protein content previously reported between 0.5%-4.3% (Ercisli et al., 2012; Haciseferoğulları et al., 2005; Kalyoncu et al., 2013; Sabry and Rizek, 1982; Vargas et al., 2009). These findings differ slightly to those of previous results, was found statistically insignificant (Table 1).

In this study crude oil was determined as 0.10–9.40% (Table 1), and generally more high in genotypes of Tonya districts. The genotypes have large diversity regarding the crude oil. In other studies, it was observed that this value ranged from 0.00–4.09% (Ayaz et al., 2002; Haciseferoğulları et al., 2005; Kalyoncu et al., 2013; Sabry and Rizek, 1982; Vargas et al., 2009). The crude oil content in our genotypes was slightly higher than literature results.

The soluble solids contents (SSC) were found very variable among genotypes from 9.80 to 20.20% (Table 1). This value was usually above 10%. Previously a wide variation on SSC from 6.80% to 26.00% (Akçay et al., 2016; Altuntaş et al., 2013; Aygün and Taşçı, 2013; Bostan, 2002; Bostan and İslam, 2007; Çakır and Öztürk, 2019; Duman, 2019; Ercisli et al., 2012; Kalyoncu et al., 2013; Özkan et al., 1997; Saryıldız, 2019; Selcuk and Erkan, 2015; Yılmaz et al., 2016). Our results within the range of the values reported in the literature.

The titratable acidity was between 0.60% (Sür-16 and Ton-5) and 1.40% (Ton-10), and this trait were also found very variable among genotypes (Table 1). In previous studies, while there was a wide variation between genotypes in terms of titratable acidity value as 0.03–7.24% (Akçay et al., 2016; Akin
and Bostan, 2018; Altuntaş et al., 2013; Aygün and Taşçı, 2013; Bostan, 2002; Bostan and İslam, 2007; Çakır and Öztürk, 2019; Duman, 2019; Haciseferoğlu et al., 2005; Maral and Bostan, 2020; Nezhadghan and Hassanpour 2017; Özkan et al., 1997; Petö et al 2016; Sarıyıldız, 2019; Selcuk and Erkan, 2015; Wazbinska, 2007; Yılmaz et al., 2016), variation in our genotypes was low.

**Ascorbic Acid**

Medlar is one of the important fruit in terms of ascorbic acid content. Ascorbic acid within the studied genotypes was ranged from 21.5 mg 100 g⁻¹ (Ton-10) to 44.2 mg 100 g⁻¹ (Ton-9) (Table 2). The content of ascorbic acid in different Medlar genotypes was reported to be of 2.64–87.20 mg 100 g⁻¹ (Akbulut et al., 2016; Akın and Bostan, 2018; Çakır and Öztürk, 2019; Duman, 2019; Ercisli et al., 2012; Glew et al., 2003a, 2003b; Maral and Bostan, 2020; Özkan et al., 1997; Ozturk et al., 2019; Petö et al., 2016; Rop et al., 2011; Sarıyıldız, 2019; Selcuk and Erkan, 2015; Vargas et al., 2009; Ważbińska, 2007; Yılmaz et al., 2016) in different agroecological conditions of Turkey and other countries. Differences in ascorbic acid contents could result from the variations in genotypes, variety, ecological factors, years and harvesting period. Furthermore, The decrease in ascorbic acid content in plants may also be the result of the oxygen level of the surrounding air, the amount of light reaching the plants, variations in endogenous plant growth regulators and the temperature (Roman et al., 2013). On the other hand, Rop et al. (2011) determined that ascorbic acid in Medlar fruit decreased gradually from the date of full bloom and decreased to 50 mg 100 g⁻¹ on the 154th day and to 29 g 100 g⁻¹ on the 164th day of consumption maturity. Our genotypes have a lower value, but are among the range in the literature.

**Organic Acids**

The major organic acid identified and quantified at consumption stage was malic acid. The malic, succinic and citric acid contents of the Medlar genotypes were between 590.5 and 1074.5 mg 100 g⁻¹, 127.0–419.0 mg 100 g⁻¹ and 2.0–32.0 mg 100 g⁻¹, respectively. The change of organic acids except of citric acid compared to genotypes was found insignificant (Table 2). Previous findings on the content of malic acid, succinic acid and citric acid were determined between 428 and 1733 mg 100 g⁻¹ (Akın and Bostan, 2018; Glew et al., 2003a, 2003b; Selcuk and Erkan, 2015), 57.0–570.04 mg 100 g⁻¹ (Akın and Bostan, 2018; Selcuk and Erkan, 2015), and 0–553.74 mg 100 g⁻¹ (Akın and Bostan, 2018; Ozturk

Table 1. Moisture, ash, crude protein, crude oil, SSC and titratable acidity content of promising medlar fruits.

| Genotypes | Moisture (%) | Ash (%) | Crude protein (%) | Crude oil (%) | SSC (%) | Titratable acidity (%) |
|-----------|--------------|---------|-------------------|---------------|---------|------------------------|
| Sür-06    | 69.7± 3.8    | 2.20± 0.70 | 1.90± 0.90        | 0.75± 1.58    | 15.80± 3.58 | 2.30± 0.15             |
| Sür-07    | 69.9± 2.9    | 2.75± 1.05 | 2.20± 0.60        | 1.25± 0.60    | 20.20± 2.90 | 2.90± 0.15             |
| Sür-09    | 69.1± 5.9    | 3.00± 1.30 | 2.00± 1.10        | 1.10± 0.80    | 15.40± 1.40 | 0.90± 0.20             |
| Sür-15    | 68.2± 6.2    | 2.65± 1.15 | 1.85± 0.55        | 1.80± 1.20    | 16.20± 1.20 | 1.00± 0.05             |
| Sür-16    | 69.1± 6.4    | 3.70± 2.10 | 1.65± 0.45        | 0.85± 0.15    | 15.40± 1.90 | 0.60± 0.05             |
| Sür-17    | 68.7± 7.0    | 4.45± 2.85 | 2.15± 0.25        | 0.10± 0.05    | 15.00± 0.60 | 0.70± 0.00             |
| Sür-19    | 68.9± 3.4    | 2.45± 0.85 | 1.90± 0.90        | 0.30± 0.05    | 14.80± 1.90 | 0.70± 0.05             |
| Sür-20    | 68.1± 5.0    | 2.80± 1.00 | 2.65± 0.85        | 5.70± 5.55    | 14.20± 0.40 | 0.80± 0.20             |
| Ton-05    | 73.1± 3.6    | 4.20± 2.50 | 1.70± 0.70        | 0.30± 0.10    | 12.00± 1.40 | 0.60± 0.05             |
| Ton-09    | 75.8± 2.5    | 3.20± 0.80 | 2.65± 0.45        | 0.90± 0.95abcd| 14.20± 0.70 | 0.70± 0.00             |
| Ton-10    | 70.3± 4.3    | 2.75± 0.75 | 1.85± 0.55        | 0.30± 0.00    | 16.40± 0.80 | 1.40± 0.10             |
| Ton-19    | 69.8± 5.3    | 6.60± 4.50 | 2.70± 0.10        | 0.20± 0.15    | 16.20± 1.50 | 0.80± 0.05             |
| Ton-20    | 71.4± 6.7    | 4.25± 1.85 | 2.20± 0.90        | 8.20± 3.80    | 17.20± 0.40 | 0.80± 0.10             |
| Ton-21    | 68.2± 4.1    | 3.10± 1.10 | 2.40± 0.30        | 9.40± 8.90abcd| 15.00± 0.40 | 0.70± 0.10             |
| Ton-25    | 70.2± 3.9    | 6.75± 4.35 | 2.45± 0.65        | 1.00± 0.80    | 9.80± 0.80  | 0.80± 0.10             |

Mean and standard deviation values of each sample is given (n= 3). Different letters in superscript for each sample indicate the significant differences at p< 0.05.
et al., 2019; Selcuk and Erkan, 2015), respectively. Our results within the range of the values reported in the literature. On the other hand, it is stated that the amount of citric acid in Medlar decreases gradually from full bloom to harvest, and it decreases to 0.3 mg 100 g⁻¹ after harvest (Glew et al., 2003a, 2003b).

**Sugars**

The major sugars in Medlar are fructose, glucose and sucrose (Glew et al., 2003a). Also Baird and Thieret (1989) reported that the Medlar fruit contained more fructose than glucose and traces of xylose. In this study, the major sugars at consumption stage were determined fructose, glucose and sucrose, respectively, such as in the previous studies (Table 3).

Fructose ranged from 3255 (Ton-25) to 4726 mg 100 g⁻¹ (Sür-7) in the 15 genotypes. In the previous researches (Akin and Bostan, 2018; Glew et al., 2003a, 2003b; Selcuk and Erkan, 2015), the lowest was 1200 mg 100 g⁻¹, and the highest was 7336 mg 100 g⁻¹. The difference of glucose content with respect to genotypes was significant. The lowest glucose content was observed in genotype Ton-25 (2108 mg 100 g⁻¹), and the highest in genotype Sür-7 (3017 mg 100 g⁻¹) as in fructose. Previously observed as 686–5739 mg 100 g⁻¹ (Akin and Bostan, 2018; Glew et al., 2003a, 2003b; Selcuk and Erkan, 2015). As can be seen, high levels of fructose and glucose were determined in Sür-7, and the low levels in Ton-25 genotype. Sucrose contents of the genotypes ranged between 127 mg 100 g⁻¹ (Ton-5)–399 mg 100 g⁻¹ (Ton-19). Previously observed as 106.0–228.4 mg 100 g⁻¹ (Akin and Bostan, 2018; Glew et al., 2003a, 2003b). The differences between the present and the previous results can be explained due to the different analyze stages of fruit, genotypes, ecology and years.

**Carbohydrate**

The carbohydrate content in the Medlar fresh sample is one of the components with the highest percentage (Vargas et al., 2009). The carbohydrate percentage was ranged from 47.3% to 73.1% in the present research (Table 4), and 23.04–24.0% in the previous studies (Sabry and Rizek, 1982; Vargas et al., 2009). The value of genotypes in this study was higher than others.
Table 3. Sugar contents of promising medlar fruits.

| Genotypes | Fructose (g 100 g⁻¹) | Glucose (g 100 g⁻¹) | Sucrose (g 100 g⁻¹) |
|-----------|----------------------|---------------------|---------------------|
| Sür-6     | 42.48±               | 489.5±              | 2733±               |
| Sür-7     | 47.26±               | 842.0±              | 3017±               |
| Sür-9     | 43.16±               | 815.5±              | 2505±               |
| Sür-15    | 39.83±               | 1019.0±             | 2626±               |
| Sür-16    | 40.53±               | 1065.0±             | 2663±               |
| Sür-17    | 39.82±               | 870.5±              | 2668±               |
| Sür-19    | 40.30±               | 711.5±              | 2657±               |
| Sür-20    | 35.81±               | 625.0±              | 2414±               |
| Ton-5     | 39.09±               | 76.5±               | 2579±               |
| Ton-9     | 44.78±               | 159.0±              | 2818±               |
| Ton-10    | 42.93±               | 1260.0±             | 2574±               |
| Ton-19    | 43.21±               | 807.5±              | 2748±               |
| Ton-20    | 33.93±               | 692.0±              | 2139±               |
| Ton-21    | 40.18±               | 842.0±              | 2561±               |
| Ton-25    | 32.55±               | 51.5±               | 2108±               |

Mean and standard deviation values of each sample is given (n= 3). Different letters in superscript for each sample indicate the significant differences at p< 0.05.

Total Phenolics

The polyphenol compounds are important plant constituents because of their free radical scavenging ability, facilitated by their hydroxyl groups (Roman et al., 2013). The total phenolic contents of the fruits of 15 medlar genotypes varied between 41 mg GAE 100 g⁻¹ in Ton-9 genotype and 411 mg GAE 100 g⁻¹ in Ton-20 genotype, and the difference of glucose content compared to genotypes was insignificant (Table 4). The total phenolic content of the Medlar genotypes in this study was found to be higher than in some previous studies carried in different regions of Turkey, and this value ranged from 9.0 to 293.0 mg GAE 100 g⁻¹ in the other studies (Ercisli et al., 2012; Akbulut et al., 2016; Yılmaz et al., 2016; Akin and Bostan, 2018; Maral and Bostan, 2020).

Rop et al. (2011) determined that the total phenolic content in the fruit gradually decreased after the full bloom in Medlar and decreased to 145 mg GAE 100 g⁻¹ on the 154th day, and 93 mg GAE 100 g⁻¹ on the 164th day; Selçuk and Erkan (2015) stated that the total phenolic content in the medlar decreased with storage time and that the initial value of 763.03 mg GAE 100 g⁻¹ decreased to 81.15 mg GAE 100 g⁻¹ after 60 days. As can be seen from these studies, the total phenolic content in the fruit can vary considerably according to the harvest time and the time after harvest.

Table 4. Carbohydrate, total phenolics and antioxidant activity of promising medlar fruits.

| Genotypes | Carbohydrate (%) | Total phenolics (mg GAE 100 g⁻¹) | Antioxidant activity (mmol TE 100 g⁻¹) |
|-----------|------------------|----------------------------------|-------------------------------------|
| Sür-6     | 49.5±             | 241±                             | 35.8±                               |
| Sür-7     | 63.0±             | 82±                              | 51.8±                               |
| Sür-9     | 52.0±             | 221±                             | 11.5±                               |
| Sür-15    | 48.3±             | 296±                             | 151.8±                              |
| Sür-16    | 52.1±             | 337±                             | 86.0±                               |
| Sür-17    | 51.0±             | 348±                             | 180.0±                              |
| Sür-19    | 47.3±             | 374±                             | 141.5±                              |
| Sür-20    | 60.1±             | 319±                             | 94.8±                               |
| Ton-5     | 58.6±             | 68±                              | 8.4±                                |
| Ton-9     | 73.1±             | 41±                              | 23.4±                               |
| Ton-10    | 50.6±             | 321±                             | 129.2±                              |
| Ton-19    | 58.6±             | 213±                             | 9.5±                                |
| Ton-20    | 72.3±             | 411±                             | 11.3±                               |
| Ton-21    | 66.2±             | 402±                             | 10.8±                               |
| Ton-25    | 60.9±             | 302±                             | 132.9±                              |

Mean and standard deviation values of each sample is given (n= 3). Different letters in superscript for each sample indicate the significant differences at p< 0.05.
**Antioxidant Activity**

Measurement of antioxidant activity is paramount in the evaluation of various food products and nutraceuticals for determining antioxidant benefits (Veljkovic et al., 2019). Medlar fruits can function as important natural antioxidant sources (Ercisli et al., 2012). Antioxidant activity of 15 Medlar genotypes varied between 13.1 mmol TE 100 g\(^{-1}\) and 77.8 mmol TE 100 g\(^{-1}\) (Table 4).

It was stated that there was high diversity in flesh antioxidant capacity in medlar fruits, and antioxidant capacity had the highest impact in separation of group in clustering analysis (Nezhadghan and Hassanpour, 2018), antioxidant activity can be affected by genetic features (Ercisli et al., 2012), there were large variations on antioxidant properties of Medlar genotypes (Akbulut et al., 2016), and total antioxidant activity showed differences by genotypes and years (Çakır et al., 2019). It has been determined that our genotypes also show significant differences in terms of antioxidant capacity. In other studies, in similar ecology, this value ranged between 6.2 and 90.1 mmol TE 100 g\(^{-1}\) (Akin and Bostan, 2018), 22.3 and 72.0 mmol TE 100 g\(^{-1}\) (Maral and Bostan, 2020).

**Conclusions**

In addition to being consumed as edible, Medlar has been evaluated in the production of many products such as jam, marmalade, pickle and fruit wine, and has had wide use in folk medicine from past to present due to its nutritional and health benefits.

This study also contributed to the detailed knowledge of the chemical and bioactive characteristics of new promising Medlar genotypes selected in the previous selection breeding studies from Turkey that are a high genetic potential.

The novelty results of this research are that new promising genotypes have higher values than previous genotypes, especially in terms of ash content, fat content, carbohydrate content and total phenolics. Ton-20 and Ton-21 genotypes were remarkable for their high-quality characteristics and total phenolic content. And the chemical content of fruits varies considerably according to especially the genotypes as well as factors such as ecology, growing conditions, years and harvest time.

The results show that Medlar genotypes are promising for the use of fresh fruits, especially nutraceuticals. Considering that these genotypes are more productive and quality when grown in cultural conditions, it can be an excellent nutrition alternative. On the other hand, these genotypes can also be an important source of income when cultivating economically. Local genotypes are noteworthy for breeders as they adapt well to the ecology in which they grow, as well as many quality criteria. We can say that Medlar adapted to the region also has the potential to contribute economically to the farmers with its different usage areas and evaluation methods.

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**Declaration Of Competing Interest**

The authors declare that they have no conflict of interest.

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