Pomological traits, chemical composition, and antioxidant activity of white mulberry genotypes (*Morus alba*)

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Abstract

Given its nutritive value, mulberry is consumed both fresh and in various processed forms. This study aimed to investigate the pomological traits, chemical composition, and antioxidant activity of the fruits of white mulberry genotypes. Folin-Ciocalteau colorimetric method and aluminum chloride colorimetric method, respectively, were used to measure the content of total flavonoids and total phenols. Antioxidant properties were evaluated using a DPPH radical scavenging assay. Using HPLC glucose and fructose were found and analyzed. In all samples glucose was the dominant sugar with the highest concentration. The level of fructose (4.28 g/100 g) and glucose (5.06 g/100 g) in fruits of genotype 2 and the amount of total acid (0.21%) in the fruits of genotype 3 were higher than other genotypes. Compared to genotype 2, the antioxidant capacity of genotype 3 was noticeably higher (22%), as measured by the DPPH assay. The study demonstrated that genotypes had a significant impact on the chemical properties of mulberry fruits. A strong positive correlation was found between fructose and pH. Findings revealed useful information about chemical composition of white mulberry genotypes, which can be utilized in food industry and as valuable genetic resources for breeding programs.

Keywords: genotypes, *Morus alba*, sugars, total acid, white mulberry

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Introduction

Mulberry (*Morus sp.*) belongs to the family Moraceae which comprises about 40 genera and more than 1000 species. Morus consists of 24 species and one subspecies, with more than 100 known varieties (Shahidi, 2012). The most popular mulberry species with edible fruits grown in Iran are *Morus alba*, *Morus nigra*, *Morus rubra*, and *Morus laevigata*.

Mulberry fruit can be eaten as a pastry, utilized for tarts, pies, and jams, squeezed and made into a beverage and syrup, and handled into wine (Vaughan and Geissler, 2009). Additionally, waste vinegar and bekmes are made from mulberry fruits (Janick, 2003). The fruit of the mulberry tree is used to treat anemia, weakness, dizziness, fatigue, and nausea. It can help get rid of constipation, improve digestion, increase gastric juice secretion, and treat chronic digestive tract diseases. In traditional Chinese medicine, the fruit has a lot of significance because it is used to treat hair graying before it starts. In Chinese medicine, it is also used to treat diabetes and constipation

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and also to purify the blood (Singh and Choudhary, 2012).

According to Şengul et al. (2021), fresh mulberry contains 7.8-9.0% carbohydrates, 0.5-1.4% protein, 0.3-0.5% fatty acids (linoleic, stearic, and oleic acids in seeds), 1.1-1.8% free acid (primarily malic acid), 0.9-1.3% fiber, 0.8-1.0% ash, and 85-88% moisture. Additionally, mulberry fruits contain a lot of phenolic compounds, such as carotenoids, flavonoids, and anthocyanins (Huang et al., 2013). The antioxidant power of the fruit is due to the presence of ROS scavengers such as phenolic compounds (Lee et al., 2009). Ripe fruits are rich in anthocyanins, which are excellent antioxidants with stronger free radical scavenging effects than vitamin C (Du et al., 2008).

The mulberry fruit is a great source of vitamin C which is a powerful natural antioxidant. In addition, it contains sufficient amounts of vitamin A and some B vitamins (Paunovic et al., 2020). B vitamins help the body break down carbohydrates, proteins, and fats by acting as co-factors (Farhangi et al., 2014). Sugars are the basic raw material for the synthesis of other nutrients like pigments, amino acids, vitamins, and aromatic substances, as well as the primary component of fruit quality and flavor (Gao et al., 2020). According to Eyduran et al. (2015), the fructose content in all mulberry types is between 4.05 and 7.70 g / 100g and the glucose content of all types of mulberry fruit ranges from 5.33 to 9.43 g / 100 g. The fruit sugar content can vary significantly depending on genotype, environment, and other factors (Gundogdu et al., 2017).

Organic acids of fruit are one of the key factors in fruit flavor and have a significant impact on flavor and human health. Organic acids like malic, citric, and tartaric acids were highlighted in a number of studies that are important for the prevention and elimination of kidney stones (Eyduran et al., 2015). Malic acid (123-218 mg/g) is the most common organic acid in mulberry, followed by citric acid (21-41 mg/g) (Ercisli and Orhan, 2008). Organic acids also have a significant impact on the organoleptic properties of fruits and can help preserve their nutritional value. Depending on their nature, organic acids are frequently used in food industry as antioxidants, acidulating agents, or preservatives (Vega et al., 2021).

The physicochemical characteristics of white mulberry genotypes have been the subject of numerous studies (Hassanpour and Firooz Barandoozi, 2020). There have been global reports of some studies on the sugar variation of white mulberry genotypes. Eyeduran et al. (2015) indicated that genotypes directly affected the amount of fructose and glucose in mulberry. In addition, they discovered that white mulberry genotypes had fructose and glucose levels of approximately 4.05 to 7.70 and 5.33 to 9.43 g/100 g, respectively. Gundogdu, et al. (2018) suggested that genotypes affect the amount of fructose and glucose in mulberry fruits. In addition, they mentioned that the genotypes of white mulberry contained between 4.65 and 8.13 g of glucose and 3.53 and 6.16 g of fructose per 100 grams, respectively. Individual sugars from white mulberry genotypes grown in Iran have not been reported. Therefore, the objective of this study was to investigate the pomological traits, chemical composition and antioxidant activity in the fruits of white mulberry genotypes.

Material and Methods

Chemicals and standards

Standards of Sigma-Aldrich Chemical Co. for fructose, glucose, gallic acid, 2, 2-diphenyl-1-picrylhydrazyl (DPPH), acetonitrile, methanol, and Folin-Ciocaltaeu were used in the study. The sodium carbonate, rutin, and sodium hydroxide used in the study came from Merck (Darmstadt, Germany).

Plant materials

During May to June 2016, ripe fruit samples of white mulberry genotypes (*Morus alba*) were collected from the orchards of Roudehen in Tehran, Iran. The experiment had three replications with three genotypes and a completely random design. For each tree, about 1 kg of fruit were picked and transferred to the research facility in separate plastic bags. Sample bags were stored in a refrigerator at 5 ℃ for future analyses.

Juice analysis

Fruit juice was extracted with a juicer. The individual sugars were determined using HPLC method. Before analysis, all samples were centrifuged at 15,000 g for 20 minutes at 4 ℃ to remove any pulp or fine particles that might clog the column. Using a pH meter or phenolphthalein as an indicator, samples of the juice were titrated with 0.1 N sodium hydroxide (NaOH) to measure total titratable acid. A Jenway digital pH meter (model: 3510) was used to precisely measure and record the juice's pH values. Total soluble solids were measured using a refractometer (Kruss, Germany). Titration with potassium iodide was used for the measurement of ascorbic acid

Sugars

A Platin blue system (Knauer, Berlin, Germany), with a binary pump and a Refractive Index (RI) detector, were used for the HPLC analysis. A Shodex Asahipak NH2P-50 4E column (250×4.6 mm) was used for the separation. The elution was performed isocratically using a mobile phase of acetonitrile/water (75/25, v/v) at a flow rate of 1.0 ml/min. The column temperature was maintained at 25 ℃, and the injection volume for each sample was 10 µl. The retention times of unknown peaks and standards were compared in order to identify sugar peaks. Fructose and glucose were dissolved in distilled deionized water separately, to make standard sugar solutions. A standard calibration curve was built up by injecting three times at three different concentrations. Using a standard calibration curve and peak areas, the concentrations of individual sugars were measured. The result was expressed as a gram compound per 100 grams (g/100g).

Physical traits

Fifty fruits from each tree were taken randomly to determine the physical characteristics. After drying in an oven at 80 degrees Celsius, the moisture content was determined. To measure the ash, the weighed fruits were put in a furnace at 560 ℃. A scale was used to measure the fresh and dry weights. Using a caliper, the fruit's length and diameter were measured. The ratio of length to diameter was used to determine the shape of the fruit.

Phenolic compounds

The method of Chen et al. (2010) for extracting phenolic compounds from fruits was used with slight changes. In a 200 ml spherical flask, 20 ml of methanol were added to approximately 2 grams of dried fruit powder. The flask was sealed tightly with paraffin film and placed in an ultrasonic bath for 20 minutes. The ultrasonic cleaning bath (Fisatom Scientific-FS14H) with the following dimensions was used for the extraction: 24 × 14 × 10 cm. The operating frequency was 40 KHz, and the total power was 90 W. The temperature was kept at about 40 ℃ for 20 minutes. Methanol was used to dilute the aqueous extract to 40 mm after it was passed through a 0.45 mm filter paper. The tops of the vials were sealed and stored at 4 ℃ in the refrigerator for subsequent analysis.

Total flavonoids

Aluminum chloride colorimetric assay was used to estimate total flavonoid contents. About 1 ml of diluted extract was added to 0.5 ml of a solution of $NaNO_2$ (5% w/v), followed by 0.5 ml of 10% $AlCl_3$ solution after 5 min, and the resulting solution was homogenized. Six minutes later, 5 ml of NaOH 1 M solution was added, and the resulting solution was mixed. The absorbance was measured at 415 nm after five minutes. Rutin was used as the standard, and the results were expressed as mg of rutin equivalents per g dry weight. About 16.2 mg of rutin was dissolved in 100 ml of 70% ethanol, shaken, and used to create the standard curve at concentrations of 0, 75, 100, and 125 mg/l (Chen et al., 2010)

Total phenols

The total phenol content was determined spectrophotometrically by utilizing Folin-Ciocalteu reagent**.** For estimation of total phenols, about 1 ml of the diluted extract was added to 0.5 ml of Folin-Ciocalteu reagent and shaken for 3 min with vortex. Then, 0.5 ml Na_2CO_3 (5 % w/v) was added. The mixtures were left for 3 hours at room temperature. The absorbance of the solution was estimated utilizing a spectrophotometer (UV 1600

Table 1
Statistical analysis of variation in juice compositions and fruit physical traits of white mulberry genotypes

	White Mulberry (Genotype 1)		White Mulberry (Genotype 2)		White Mulberry (Genotype 3)		
Compounds	Mean	SD	Mean	SD	Mean	SD	F value
Sugars							
1) Fructose (g/100g)	3.39b	0.19	4.28a	0.21	2.83b	0.16	**
2) Glucose (g/100g)	4.40b	0.17	5.06a	0.28	2.97c	0.22	**
Total	7.79	0.36	9.34	0.49	5.80	0.38	
Organic acids							
Total titratable acid (%)	0. 15ab	0.02	0.10b	0.02	0.21a	0.02	**
Ascorbic acid (mg/100g)	5.70b	0.16	4.00c	0.17	7.10a	0.22	**
pH	5.70ab	0.14	6.00a	0.10	5.30b	0.12	**
TSS (%)	14.00b	0.14	17.00a	0.12	9.00c	0.11	**
TSS/TA	93.33b	0.55	170a	1.52	42.85c	0.99	**
Juice (%)	55b	1.04	47c	1.21	60a	1.00	**
Moisture (%)	77.19b	0.43	75.30b	0.35	80.00a	0.57	**
Total dry matter (%)	22.81b	0.19	24.70a	0.22	20.00c	0.16	**
Ash (%)	5.32b	0.16	6.00a	0.21	4.17c	0.17	**
Fresh fruit weight (g)	1. 90b	0.24	2.80a	0.20	1.18c	0.14	**
Dry fruit weight²(g)	1.15ab	0.06	1.26a	0.07	1.00b	0.05	**
Fruit length (mm)	22.10b	1.17	25.90a	0.91	18.50c	0.89	**
Fruit diameter (mm)	12.88ab	0.71	14.50a	0.58	11.40b	0.48	**
Fruit shape index (Fl/Fd)	1.65a	0.10	1.76a	0.11	1.60a	0.12	NS
Fruit stalk length (mm)	6.50a	0.47	7.86a	1.00	5.81a	0.96	NS
Fruit stalk diameter (mm)	1.00a	0.10	1.11a	0.10	0.89a	0.07	NS
Total flavonoid (mg/gr DW)	0.74b	0.04	0.54c	0.02	0. 93a	0.05	**
Total phenol (mg/gr DW)	1.61ab	0.11	1.40b	0.10	1.92a	0.10	**
DPPH %	19ab	1.00	17b	0.98	22a	1.00	**

PC, Shimadzu, Tokyo, Japan) at 760 nm. The measure of total phenol was determined by a standard curve and the outcomes were expressed as mg gallic acid equivalent per g dry weight. The standard curve with concentrations of 0, 62.5, 125, and 250 mg/L was obtained by accurately weighing 6.2 mg of gallic acid and dissolving it in 25 ml of distilled water in the volumetric flask for the preparation of the standard solution (Chen, et al., 2010).

DPPH Assay

In the DPPH assay, the samples' antioxidant activity was measured using the method described by Muthiah et al. (2012) with a minor adjustment. In a nutshell, 2 ml of DPPH (2, 2-diphenyl-1-picryl-hydroxyl) was mixed with 0.2 ml of the extract. It was kept dark for 30 minutes at room temperature. The absorbance was estimated at 517 nm utilizing a spectrophotometer after 30 min. DPPH was expressed as percentage.

Data Analysis

One-way analysis of variance (one-way ANOVA) was used to determine the differences among genotypes. Duncan's multiple range test was used to compare the mean values ($P \leq 0.01$). SPSS 18 was used to analyze the statistical data. The relationships among variables were evaluated using Pearson's correlation coefficient.

Results

Fruit sugars

In this study, 2 sugars (fructose and glucose) were identified in mulberry juice by HPLC method (Fig. I, Table 1). Fructose was found in lower amounts than glucose. Mulberry's glucose content ranged from 2.97 g/100 g in genotype 3 to 5.06 g/100 g in genotype 2. Genotype 2 had a fructose content of 4.28 g/100 g while genotype 3 had a fructose content of 2.83 g/100 g. Additionally, the total sugar content ranged from 5.80 to 9.34 g/100 g.

The level of sugars differed significantly (P≤0.01) among mulberry genotypes (Table 1).

Total titratable acid (TA)

Total titratable acidity ranged from 0.10 to 0.21%. The level of sugars differed significantly among mulberries (P≤0.01). The TA level in genotype 3 was significantly higher than that of the other genotypes. Ascorbic acid demonstrated the same trend. The juice's TA content was found to be lower in genotype 2. Additionally, the ascorbic acid of fruit was seen to diminish in genotype 2 (Table 1).

pH, TSS, TSS/TA and juice contents

The value of pH, TSS, TSS/TA, and juice of all samples are presented in Table 1. pH, TSS, TSS/TA, and juice showed significant differences at P≤0.01. Genotype 3 showed the most minimal mean for pH, TSS, TSS/TA while genotype 2 showed the highest mean values. In addition, genotype 3 had a higher juice percentage (60 %) than genotype 2 (47 %) in this study.

Physical traits of fruits

The measures of the fruit's physical traits are given in Table 1. Significant differences were found among the three mulberries for physical characteristics. According to the findings, genotype 2 produced significantly heaviest fruits (2.80 g) while genotype 3 produced the lightest fruits (1.18 g). In terms of fruit length and diameter, genotype 2 produced significantly longest fruits (25.90 mm) while genotype 3 produced significantly smallest fruits (18.50 mm). Fruits from genotype 2 had the highest shape indexes, despite the fact that there were no significant differences among the three mulberries in terms of the fruit shape index (Fl/Fd). Additionally, genotype 2 produced significantly longest fruit stalks (7.86 mm), followed by genotype 1 (6.50 mm) and genotype 3 (5.81 mm).

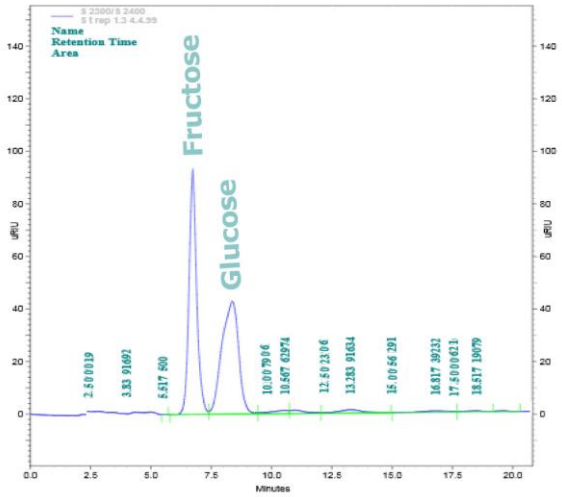

Fig I. HPLC chromatogram of sugars in white mulberry

Total flavonoid, total phenol and DPPH

Total flavonoids differed from 0.54 mg/g DW (genotype 2) to 0.93 mg/g DW (genotype 3). The total phenol content ranged from 1.40% in genotype 2 to 1.92 % in genotype 3. Additionally, the DPPH ranged from 17 to 22%. The values of total flavonoid, total phenol, and DPPH at P≤.01 were significantly different from one another. DPPH had the lowest values for genotype 2 while genotype 3 had the highest values (Table 1).

Results of correlations

Fructose and pH were found to be positively correlated together (r = 0.96). Moreover, TSS and fructose were found to have a strong positive correlation (r = 0.95) with each other. A positive correlation was also observed between TSS and pH (r = 0.95). TSS also showed a high negative correlation with total acid and ascorbic acid about 0.96 (Table 2).

Table 2
Intercorrelations between 7 traits in a correlation matrix

	Fructose	Glucose	Total acid	Ascorbic acid	pH	TSS
Glucose	0.79*					
Total acid	-0.88**	-0.76*				
Ascorbic acid	-0.86**	-0.91**	0.95**			
pH	0.96**	0.91**	-0.83**	-0.89**		
TSS	0.95**	0.87**	-0.96**	-0.96**	0.95**	

Discussion

Findings of the study showed that content of fructose was from 2.83 to 4.28 g/100 g and the content of glucose was 2.97 to 5.06 g/100 g. Fructose and glucose contents assayed in our examination were lower than those reported by Eyduran et al. (2015), Gundogdu et al. (2018), Gecer et al. (2016), Gundogdu et al. (2011), Akin et al. (2016), and Amin and Attia (2003).

In this study, the fructose and glucose contents of the fruits in white mulberry at the full ripening stage were close to those reported by Negro et al. (2019), Aljane et al. (2016), and Mahmood et al., (2012). Negro et al. (2019) observed 3.20 g/100 g fructose and 3.20 g/100 g glucose. Aljane et al. (2016) reported 2.30 g/100 g fructose and 2.23 g/100 g glucose, and the fructose and glucose contents reported by Mahmood et al. (2012) were 4.97 g/100 and 3.21 g/100 g, respectively. Furthermore, higher glucose content was found in this study as compared with fructose in all mulberry genotypes while no sucrose was identified. The major sugar determined in white mulberry by Amin and Attia (2003), Aljane et al. (2016), and Mahmood et al., (2012) was fructose.

The titratable ascorbic acid contents of white mulberry in this study ranged from 4.00 to 7.10 mg/100 g accounting for from 0.10% to 0.21%, respectively. These values are close to those reported by Hassanpour and Firooz Barandoozi (2020) with 0.16%-0.28%, Elhami and Estiri (2009) with 0.24%-0.72%, Cocen et al. (2018) with 0.06%-0.37%, Yilmaz et al. (2012) with 0.06%-0.90%, Skender et al. (2019) with 0.01%-0.19%, Hepsağ et al. (2016) with 0.14%, Ercisli and Orhan (2007) with 0.25%, Imran et al. (2010) with 2%, Amin and Attia (2003) with 0.14%, Gungor and Sengul (2008) with 0.25%-0.28%, and Balik et al. (2019), with 1.12%-2.20% concentrations of titratable ascorbic acid in the white mulberry fruits harvested elsewhere.

There are also a number of studies that reported lower levels of ascorbic acid contents than the present study. These include 16.42 mg/100 g (Gecer et al., 2016), 13.40 to 18.22 mg/100 g (Eyduran et al., 2015), 24.42 mg/100g (Gundogdu et al., 2011), 16.68 mg/100 g (Akin et al., 2016), and 2 to 16 mg/100 g (Makhoul et al., 2017).

In this study pH contents of white mulberry ranged from 5.30 to 6.00. This is close to the findings of many studies reported around the world (Hassanpour and Firooz Barandoozi, 2020; Balik et al., 2019; Aljane et al., 2016; Hepsag et al., 2016; Gozlekci et al., 2014; Yilmaz et al., 2012; Abd EL-Malak et al., 2010; Elhami and Estiri, 2009; Ercisli and Orhan, 2009; Gungor and Sengul, 2008; Amin and Attia, 2003). On the other hand, Imran et al (2010) in their study reported a much lower pH (3.35) of the white mulberry fruit.

TSS content of the fruits under investigation in our study (9.00%-17.00%) was generally lower than those reported in the literature including 14.53%-23.50% (Balik et al., 2019), 13.53%-22.15% (Skender et al., 2019); 7.27% (Aljane et al., 2016), 21.13% (Hepsag et al., 2016), 22.59% (Bajpai et al., 2014), 17.80%-30.67% (Yilmaz et al., 2012), 17.27% (Gozlekci et al., 2014), 19.12% (Abd EL-Malak et al., 2010), 20.40% (Ercisli and Orhan, 2009), 18.50%-27.00% (Elhami and Estiri, 2009), 21.25%-28.50% (Gungor and Sengul, 2008), 16.25% (Amin and Attia, 2003). On the other hand, Ionica et al. (2017) reported a lower TSS content (12.70%) in the mulberry fruit, which is close to our finding.

White mulberry had a moisture content of 75.30%-80 % and a juice content of 47%-60 % in this study. The juice percentages in this study are similar to the findings of Yilmaz et al. (2012), which ranged from 40.67% to 64.67%. On the other hand, the juice and moisture contents were 77.72% and 79.92%, respectively in Amin and Attia (2003) showing slightly higher values for these attributes. Gungor and Sengul (2008) reported the moisture content ranging between 72.85% and 79.75%. Also, Negro et al. (2019), Skender et al. (2019), Abd EL-Malak et al. (2010), Imran et al., (2010), Elhami and Estiri (2009), and Ercisli and Orhan (2007) found that the moisture contents of white mulberry were 77.6%, 77.84%-86.46%, 76.53%, 81.72%, 69.50%-72.00%, and 71.5%, respectively. The moisture levels in the current study were higher than those reported by Elhami and Estiri (2009) and also Ercisli and Orhan (2007).

Total dry matter and ash of the fruits recorded in the current study were 20%-24.70% and 4.17%-6.00%, respectively. These results are different from those of Elhami and Estiri (2009), who found that total dry matter and ash in white mulberry were 28.00-30.50% and 1.15%-1.24%, respectively. Total dry matters of white mulberry in Ercisli and Orhan (2007), Ionica et al. (2017) were 29.50%. and 17.69%, respectively. Imran, et al. (2010) found total dry matter and ash contents of 18.28% and 0.57%, respectively in the white mulberry fruits under study. The ash content of white mulberry fruits in our study was higher than a number of studies reported in the literature including Skender et al. (2019), Gungor and Sengul (2008), Abd EL-Malak et al. (2010), and Attia (2003) who found ash contents of 0.70%-0.96%, 2.20%-2.65%, 1.27%, and 1.02%, respectively.

Fresh fruit weight was estimated from 1.18 to 2.80 g in this study. These results were near to those reported by Skender et al. (2019) who reported fresh fruit weights ranging from 1.25 g to 2.24 g. Fruit weight in the studies by Yilmaz et al. (2012), Hassanpour and Firooz Barandoozi (2020), Cocen et al. (2018), Balik et al., (2019), Ercisli and Orhan (2007), Aljane, et al., (2016), Gozlekci et al. (2014), Bajpai et al. (2014), Hepsag et al. (2016), and Amin and Attia (2003) were reported 0.66-3.07 g, 0.71-4.24 g, 0.77-2.46 g, 1.38-3.38 g., 3.49 g, 1.58 g, 2.85 g, 1.34 g, 3.85 g, and 2.59 g, respectively. The value of fresh fruit weight in our study was lower than that of Ercisli and Orhan (2007) and Hepsag et al. (2016).

Fruit length and diameter ranged from 18.50 to 25.90 mm and from 11.40 to 14.50 mm, respectively in this study. These results were within the ranges reported by Balik et al., (2019) who found white mulberry fruit length and diameter of 17.39-27.01 mm and 10.89-15.42 mm, respectively. The white mulberry fruit length and diameter ranged 16.69-26.34 mm and 8.86-14.13 mm in the study reported by Cocen et al. (2018). Hassanpour and Firooz Barandoozi (2020) found a diameter of 10.39-15.55 mm and a length of 14.48-29.60 mm. Skender et al. (2019) recorded a diameter of 5.50-7.10 mm and a length of 12.50-15.20 mm. Gozlekci et al. (2014) reported that the white mulberry fruit had a length of 22.06 mm and a diameter of 12.55 mm. The fruit length and diameter were 25.62 mm and 16.82 mm in Hepsag et al. (2016). Aljane et al. (2016) reported that the white mulberry fruit had a diameter of 13.78 mm and a length of 21.38 mm. According to Amin and Attia (2003), the white mulberry fruit had a diameter of 13.50 mm and a length of 21.30 mm. The level of total dry matter in our study was in line previously reported. Our study's fruit length and diameter were higher than those found by Skender et al. (2019).

The fruit stalk diameter and length ranged from 0.89 to 1.11 mm and from 5.81 to 7.86 mm, respectively in this study. These results were within the range found by Cocen et al. (2018), who found the fruit stalks diameter of white mulberry from 0.51 to 1.33 mm and a length of 5.56 to 11.07 mm. The stalk lengths of white mulberry fruits in studies by Hassanpour and Firooz Barandoozi (2020), Balik et al. (2019), Skender et al. (2019), Aljane et al., (2016), Gozlekci et al. (2014), and Hepsağ et al (2016) were 4.65-12.71 mm, 7.50-11.90 mm, 2.00-3.70 mm, 6.75 mm, 8.01 mm, 3.76 mm, respectively. In our study, we found a higher level of fruit stalk length than those reported by Skender et al. (2019).

Total phenol ranged from 1.40 to 1.92 mg GAE/g dry weight (DW) in our study while total flavonoid ranged from 0.54 to 0.93 mg RE/g DW. Radojkovic et al. (2012) found that white mulberry contained 4.13 mg GAE /g DW of total phenol and 0.89 mg RE /g DW of total flavonoid. Total phenol and flavonoid contents of white mulberry fruits in Bajpai et al. (2014) were 3.47 mg GAE/g DW and 0.58 mg QE/g DW, respectively.

In their study on white mulberry fruits, Aljane et al. (2016) found 13.51 mg GAE/100 g FW (fresh weight) total phenol and 8.99 mg Catechin/g FW of total flavonoids. Abd EL-Malak et al., (2010) reported that white mulberry contained 143.73 mg GAE/100 g FW of total phenol and 23.22 mg of total flavonoid per 100 g FW. According to Ercisli and Orhan (2007), white mulberry contained 181 mg GAE/100 g FW of total phenol and 29 mg QE/100 g FW of total flavonoid. Furthermore, Gozlekci et al. (2014) reported that white mulberry contained 49 GAE/100 g FW of total phenol and 37.50 mg Catechin/g DW of total

flavonoids. Ionica et al. (2017) found that white mulberry contained 458.42 mg GAE/100 g FW of phenol and 78.04 mg QE/100 g FW of flavonoids. Total phenol contents of white mulberry in the study by Negro et al. (2019), Skender et al. (2019), Imran et al. (2010) were 141.2 mg GAE/100 g FW, 6.26-50 GAE/100g FW, 1650 mg/100 g FW, respectively. Total flavonoid content of our study was close to the levels reported by Radojkovic et al. (2012).

The DPPH content of white mulberry ranged from 22% to 33% in our research. Negro et al. (2019) reported similar outcomes and discovered approximately 18.50% DPPH in white mulberry. Aljane et al., (2016) found that white mulberry had DPPH levels of 66.62%, which was highly above the findings of the present study. On the other hand, Bajpai et al., (2014) found that white mulberry had DPPH levels of 4.35 mg/ml, which is remarkably lower than those in our study. Numerous variables including genotypes, environmental conditions, and other factors, influence the fruits' physicochemical traits (Gundogdu et al., 2017).

Conclusion

While application of fertilizer and irrigation affects the content of sugars in crops (Kumar et al., 2004), these operations were carried out uniform in this study so we did not believe that the variability observed in the study was a result of these factors.

In the present study we found that the sugars and total acids contents were significantly affected by genotypes and there was a great variation in most of the measured characters among three mulberries. Among the three mulberries examined, genotype 2 showed the highest content of fructose and glucose. The lowest levels of fructose and glucose were produced by genotype 3.

Findings revealed useful information about genotypes' chemical composition of white mulberry, which can be utilized in the food industry and provide valuable genetic resources for breeding programs. Additionally, the evaluation of new food and a dietary supplement may benefit from the obtained results. Future diet studies examining the role of mulberries in lowering disease risk will benefit greatly from these findings. Finlay, this study may be useful to producers, breeders, and processors because it expands our understanding of phytochemical properties of mulberry fruit such as antioxidant activity and phenolic compounds among different genotypes. Further research is required for the association between genotype and sugars

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