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Deer apple (*Malus trilobata*) fruit grown in the Mediterranean region: identification of some components and pomological features

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Abstract

Deer apple (*Malus trilobata*) fruit is present naturally in the Mediterranean region and can be used for many different purposes, such as consuming as fresh and dried fruits, using as herbal tea flavorings, making vinegar, and pickle. Also, it is traditionally used against various health problems like cholesterol, shortness of breath, diabetes, and hypertension. Many researchers have studied some properties of deer apple fruit, such as the ecology of the species, fruit and seed properties, body form, and phenology. In this study, besides pomological properties, the organic acid, phenolic compound, sugar, and aroma composition of the deer apple fruit were determined for the first time. Malic acid (27.5 mg/g) is the most abundant organic acid in deer apple, while fructose (351 mg/g) is the most abundant sugar. It was determined that the deer apple contains various phenolic compounds such as protocatechuic acid, chlorogenic acid, caffeic acid, epicatechin, rutin, and quercetin. Acetic acid, nonanal, hexanal, acetoin, acetaldehyde, n-octanal, hept-2(E)-enal are the most abundant aroma compounds.

Keywords: deer apple; *Malus trilobata*; pomological features; phenolic composition; organic acid; aroma.

Practical Application: This article identifies organic acid, sugar, phenolic and aroma compounds contents of deer apple fruit as well as pomological features.

1 Introduction

The use of plant protection chemicals against various apple diseases such as powdery mildew, brown rot, fly speck, sooty blotch, codling moth, and leaf curling is indispensable in traditional apple farming. While pesticides are essential in modern agricultural practices, numerous laboratory and epidemiological studies have reported that certain pesticides are associated with carcinogenesis, immunotoxicity, neurotoxicity, behavioral disorders, reproductive dysfunction, endocrine disruption, developmental disabilities, skin conditions, and respiratory diseases such as asthma (Lozowicka, 2015). However, it has been reported that domestic processes such as washing, peeling, and juicing may not be sufficient to remove some pesticide residues (Słowik-Borowiec & Szpyrka, 2020; Kong et al., 2012). Considering that apple is the third most-produced fruit in the world and children may be affected more in this regard, the importance of the subject increases even more (Shahbandeh, 2022). This situation reveals the necessity of closer examination of wild apple species such as deer apple (*Malus trilobata)*, which are far from agricultural lands and have a low risk of pesticide residues. In a study identifying new biocontrol agents for *Malus domestica* pathogens through the isolation of microflora associated with *Malus trilobata*, it was reported that fungal growth on trees and fruits (*Penicillium expansum* and *Botrytis cinerea*) could be inhibited. Again, in the study, it is suggested that the microbiota of commercial species can be restored with the help of wild species such as deer apple (Khoury et al., 2021).

The deer apple is a small tree in the Rosaceae family, usually 5-10 m in length, but under appropriate conditions, it grows up to 12-18 m. It is an uncommon tree with little recognition (Korakis et al., 2006; Yilmaz & Ok, 2012; Yilmaz & Yüksel, 2014; Zahreddine et al., 2008). Poiret firstly described deer apple in 1810 as *Crataegus trilobata* Poiret, and it was turned into a monotypic genus by the name of *Eriolobus trilobatus* (Poir.) by Romoer in 1847 (Browicz & Karaca, 1993; Yilmaz & Yüksel, 2014, 2016). Today it is used with the name of *Malus trilobata* (Yilmaz & Yüksel, 2014). Deer apple is present only naturally in the Mediterranean region in the world. According to the records, this species is found in Greece, Bulgaria, Turkey, Palestine, Lebanon, and Israel (Browicz, 1972; Boratyński et al., 1992; Yilmaz & Yüksel, 2016; Zahreddine et al., 2007). The distribution of deer apple is generally between 350-1450 m in height. It is most frequently grown in altitude between 500-1000 m. The highest altitude in Turkey was found at 1600 m in Saphane Mountain in Kütahya. In Lebanon, this altitude goes up to 1700-1800 m. The lowest altitude detected is in Bulgaria with 50 m (Yilmaz & Ok, 2012). In regions where deer apple is growing, summer is long and dry (Yilmaz & Yüksel, 2014, 2016). The soil where it grows is generally rocky, limy, or rich in limestone (Yilmaz, 2012). It is usually grown in leafy forests and maquis shrubland as single or clustered (Gultekin et al., 2007). However, due to its ornamental plant feature, it is one of the species that could

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be used in park and garden afforestation of urban and rural settlements (Yilmaz et al., 2019).

The deer apple tree is blooming in May, and the flowers stay on the trees for a month. It is emphasized that these trees can be used as park and garden trees because of its highly decorative appearance when flowering (Doygun & Ok, 2006; Yilmaz & Ok, 2012). Deer apple begins to bear fruit in late May and early June. The shape of the fruit varies from an oblong egg-like to globular, and its color is between light yellow and dark brown. Maturing fruits fall to the ground in October and November. In this process, a color change is also observed on the leaves, and it loses its all leaves during December (Tashev & Petkova, 2006; Petkova & Tashev, 2007; Yilmaz & Ok, 2012). The fruits that are matured and fallen to the tree bottoms in October and November remain on the ground for months. Animals such as deer and horse can feed on these long-standing fruits in autumn and winter. Therefore, it is believed that it is called as deer or horse apple. Deer apple fruits can be used for many different reasons such as consuming as fresh and dried fruits, using as herbal tea flavorings, making vinegar and pickle. Deer apple fruit is also traditionally used against various health problems such as cholesterol, shortness of breath, diabetes, and hypertension (Yilmaz & Yüksel, 2014, 2016).

High storage stability compared to commonly consumed apple varieties, lack of softening as in traditional apples in dessert and compote production, unique taste, texture and aroma, and the belief that it is an organic product increase the interest of the people of the region in deer apple. Some studies have been done about deer apples such as the ecology of the species, fruit and seed properties, body form, phenology, and usage by local people (Petkova & Tashev, 2007; Tashev & Petkova, 2006; Yilmaz, 2012; Yilmaz & Yüksel, 2016). However, a study has not been observed considering the food area related to deer apple. Therefore, in this study, it was aimed to identify the organic acid, phenolic compound, sugar, and aroma composition of deer apple as well as the pomological properties.

2 Materials and methods

2.1 Materials

Deer apple (*Malus trilobata*) fruit samples were collected from the trees in Nuru village (36°25′N 33°35′E) in Silifke district of Mersin province, Turkey. All fruit samples collected were at the same ripening stage (ripe). Stained, damaged, and unsuitable fruits were removed, and the remaining fruits were used in analyses. After the seeds were removed and sliced, the thirty deer apple fruits were dried in a drying oven at 55 °C, and then ground into powder. The fresh and ground product was stored at +4 °C in an airtight manner prior to analyses. Fresh fruit was used in pomological and aroma analyses, while the ground product was used in organic acid, phenolic compound profile and sugar analyses. Chemicals used in the analyses were obtained from Merck, USA.

2.2 Investigation of pomological features

Firstly, the length, diameter, and weight characteristics of deer apple samples were examined. After the fruit is divided into two, the color properties of the fruit flesh and the fruit peel were determined. The seeds extracted from the split fruits were also weighed. The pomological analyzes mentioned above were carried out in twenty replicates. In each replicate one fruit sample was used. In dry matter analysis, one fresh fruit sample was divided into four and placed in a drying oven at 105 °C for 4 h. Dry matter analysis was performed in five replicates. After the five fresh fruits were chopped and pureed, analyses of pH, Brix, percent acidity, and density were carried out in five replicates (Association of Official Analytical Chemists, 1990).

2.3 Organic acid analysis

The organic acid analysis was carried out by modifying the methods used by Alhendawi et al. (1997) and Kordis-Krapez et al. (2001). Five grams of ground deer apple were homogenized with 50 mL of 2% phosphoric acid. The mixture was filtered with filter paper, and 1 mL of the filtrate was diluted with 1 mL of extraction solution (0.01 M potassium dihydrogen phosphate solution adjusted to pH 8.0). One mL of diluted solution was passed through a solid-phase cartridge (Supelco C18), which was conditioned with 3 mL of methanol and washed with 10 mL of distilled water. The eluate was taken up into a tube and the cartridge was washed with 1 mL extraction solution. The eluates were combined, and 20 µL of this solution was subjected to HPLC for analysis.

The organic acid analysis was carried out using a Shimadzu (Japan) brand HPLC instrument. The chromatographic separation was performed using a Prodigy ODS-2 (250 x 4.6 mm, 5µm) column. Ultrapure water was used as the mobile phase adjusted to pH 2.2 with phosphoric acid. The flow rate was 0.8 mL/min, and the injection volume was 20 µL. The column temperature was maintained at 30 °C. SPD-10Avp UV-VIS detector was used as a detector and 210 nm wavelength was selected. Analyses were done in triplicate.

2.4 Determination of phenolic compound profile

Ten grams of ground deer apple was weighed and approximately 0.1 g of BHT (butylated hydroxytoluene) and 30 mL of extraction solution (80% methanol with 1 mL hydrochloric acid) were added. Extraction was performed for 30 min in an ultrasonic bath. Ice cubes were used to keep the bath temperature constant. After the supernatant was taken into a vessel, 20 mL of the extraction solution was added to the lower phase and left in the ultrasonic bath for another 30 min. The upper phase was decanted and combined with the previous step. After filtration through Whatman filter paper, it was passed through a 0.45 µm syringe filter, and 20 µL was inject into HPLC (Shimadzu, Japan). The chromatographic separation was carried out using the Agilent Eclipse XDB-C18 (250 x 4.60 mm, 5 µm) column maintained at 30 °C. Diode array detector (DAD) was used, and the detection wavelength was 278 nm. Gradient elution was performed with mobile phase A (ultrapure water with 3% acetic acid) and B (Methanol) at 0.8 mL/min as follows: 0-0.1 min, 0-7% B; 0.1-20 min, 7-25% B; 20-28 min, 25-28% B; 28-35 min, 28-30% B; 35-50 min, 30% B; 50-60 min, 30-33% B; 60-62 min, 33-42% B; 62-70 min, 42-50% B; 70-73 min, 50-70% B; 73-75 min, 70-80% B; 75-80 min, 80-100% B; 80-81 min, 100-7% B; 81-90 min, 7-0% B. Analyses were done in triplicate.

2.5 Sugar analysis

Sugar analysis was applied by modifying the method used by Veberič & Stampar (2005). Ten grams of ground deer apple was weighed, and 40 mL of deionized water were added. The mixture was homogenized using a homogenizer (IKA T25 ultra-turrax, Germany) for 3 min at medium speed and then centrifuged at 25 °C and 4100 rpm for 20 min (Hettich, Germany). The supernatant was filtered through a 0.45 µm syringe filter, and 20 µL was inject into the HPLC system (Shimadzu, Japan). Chromatographic separation was performed using the Aminex HPX-87C carbohydrate (300 x 7.8 mm) column. Ultrapure water is used as the mobile phase. The flow rate was 0.6 mL/min, and the column temperature was set at 80 °C. RID 10A was used as the detector. Analyses were done in three replicates.

2.6 Analysis of aroma components

After preliminary experiments for the analysis of volatile flavor compounds, approximately 5 g of sample was weighed into 30 mL GC vials, and it was closed. Vials were kept at 50 °C for 10 min to allow the sample to reach equilibrium. Then, for solid-phase microextraction (SPME) application, a suitable fiber (85 µm Carboxen®/ Polydimethylsiloxane (CAR/PDMS)) was immersed into the vial, and it was provided to adsorb the volatile components in the top space for 40 min. The fiber was held in the injection chamber of the GC system for 10 min to desorb the adsorbed volatile components. In the analysis of volatile flavor components, a Hewlett Packard 7890 gas chromatograph equipped with a combined FID and an HP 5975 MS detectors and DB-624 capillary columns (30 m, 0.25 mm id, 1.4 µm film thickness) was used.

2.7 Statistical analysis

SPSS v25.0 statistical software was used in the statistical evaluation of the obtained data. Data were subjected to one-way ANOVA, and the difference between phenolic compounds was determined using Duncan's multiple range test at a significance level of 0.05.

3 Results and discussion

3.1 Pomological properties

The deer apples (*Malus trilobata*) used in this study were selected from the Mersin region, Turkey. Images of post-harvest apples are shown in Figure 1. The deer apple fruits that are green in the initial stages turn into yellowish color after ripening.

In the present study, some pomological characteristics such as fruit height, diameter, weight, seed weight, fruit flesh/seed ratio, dry matter, density, percent acidity, pH, Brix, and color values (fruit flesh and peel) were examined, and averages of the obtained data are represented in Table 1. Accordingly, the average length, diameter, and weight of the deer apple were 2.55 cm, 2.67 cm, and 12.84 g, respectively. L, a, b values were found to be 61.26, -1.44, 22.01 for the fruit flesh part and 59.40, -4.64, and 26.29 for the peel part, respectively. Besides, the dry matter content was 29.86%, the pH was 3.51, and the water-soluble solids (Brix) was 9°.

Tashev & Petkova (2006) have examined the *Eriolobus trilobata* fruit grown in Bulgaria and Greece and found that the average length of these fruits was 1.98 cm, the average diameter was 2.19 cm, and the average weight is 7.14 g. In another study, Li et al. (2014) studied ten different wild apples from *Malus* species and found their average diameter was 2.98 cm, and weight was 13.30 g. Gezer et al. (2012) investigated some nutritional and physical properties of the wild apple (*Malus silvestris* Mill.) grown in the Ermenek region in Turkey and determined the features of these fruits as 2.47 cm in length, 2.89 cm in diameter, 11.64 g in weight, 22.17% in dry matter, 4.1 in pH and 0.915 g/mL in density. Altuntas & Karaosman (2015) reported that the length, diameter, weight, density, pH, Brix, and titratable acidity of Japanese flowering wild apples (*Malus floribunda*) were 3.48 cm, 3.40 cm, 22.4 g, 1.03 g/mL, 3.94, 7.57°, and 0.31%, respectively.

Figure 1. Photographic images of post-harvest deer apples.

Table 1. Some pomological characteristics of deer apple fruit.

Height (cm)		Diameter (cm)	Weight (g)	Seed weight (g)	Fruit flesh/Seed ratio
2.55 ± 0.13		2.67 ± 0.17	12.84 ± 1.74	0.23 ± 0.07	58.81 ± 17.21
Dry matter (%)		Density (g/mL)	Acidity (%)	pH	Brix
29.86 ± 0.94		0.97 ± 0.03	0.32 ± 0.03	3.51 ± 0.02	9 ± 0.01
Color (Fruit flesh)			Color (Peel)		
L	a	b	L	a	b
61.26 ± 3.65	-1.44 ± 1.70	22.01 ± 1.66	59.40 ± 3.53	-4.64 ± 1.64	26.29 ± 6.46

Values were means ± standard deviation.

L, a, and b values for fruit flesh were found to be 54.6, 25.7, and 32.5, for fruit peel were 37.7, 24.6, and 21.5, respectively. The deer apple fruit has similar physicochemical properties with other crabapple cultivars. However, it has higher dry matter and water-soluble solids (brix) contents and lower pH value.

3.2 Organic acid content

Ten different organic acids (oxalic acid, tartaric acid, formic acid, malic acid, ascorbic acid, lactic acid, acetic acid, citric acid, succinic acid, and fumaric acid) standards were used in this analysis. Malic acid (27500 µg/g dry weight (DW)) and tartaric acid (1935 µg/g DW) were identified as the two most abundant organic acids in deer apple (Table 2). The presence of other organic acids (formic acid, ascorbic acid, lactic acid, acetic acid, citric acid, and succinic acid) was not observed. Since deer apple has high amount of malic acid and tartaric acid, it can be said that the acidity of this fruit comes from these two compounds.

In a study of 15 different apple varieties (*Malus domestica* Borkh.), average malic acid, citric acid, and ascorbic acid contents were 9190, 210, and 60 µg/g in fresh matter, respectively (Nour et al., 2010). Begić-Akagić et al. (2014) reported that the average malic acid, citric acid, and fumaric acid content of apple varieties was 2200 µg/g, 737 µg/g, and 1108 µg/g in wet basis, respectively. Our study shows that deer apple has much higher malic acid content and lower fumaric acid content than other apple varieties. Deer apple also contains oxalic acid and tartaric acid. The L-enantiomer of malic acid is known as apple acid, and it is mainly responsible for the flavor and sourness of apple varieties (Brittain, 2001). Generally, unripe fruits and wine have various amounts of malic acid. It is used in industry as a flavoring agent, acidity regulator, and it plays a role in the inhibition of main food pathogens (Joye, 2019).

3.3 Phenolic compound content

In this study, the phenolic compound content of the deer apple was investigated using 23 different phenolic standards (Figure 2a). It has been determined that the deer apple contains phenolic compounds such as protocatechuic acid, chlorogenic acid, caffeic acid, epicatechin, rutin, and quercetin (Figure 2b). On a dry basis, chlorogenic acid had the highest value (2388 µg/g), while protocatechuic acid had the lowest value (89.9 µg/g) (Figure 3). Epicatechin (2036 µg/g) and rutin (980 µg/g) were the other two major phenolic compounds present in the deer apple along with chlorogenic acid (Figure 3).

Liu et al. (2018) studied the phenolic composition of five different crabapple cultivars and, on a wet basis, they found catechin, epicatechin, and chlorogenic acid content of *Malus* cv. 'Royalty' as 1909 µg/g, 16.24 µg/g, and 23.9 µg/g, respectively. In addition, they determined the catechin, rutin, and phlorizin content of *Malus* cv. 'Strawberry Parfait' as 143 µg/g, 2321 µg/g, and 86.9 µg/g, respectively. Li et al. (2014) reported that all of the wild apple varieties contained chlorogenic acid, epicatechin, rutin, hyperin, and phlorizin, while some varieties also contained caffeic acid, p-coumaric acid, and ferulic acid. They found phenolic content of the wild apple varieties as, 3.4 µg/g protocatechuic acid, 113 µg/g chlorogenic acid, 77.4 µg/g epicatechin, 176 µg/g rutin, 9.6 µg/g quercetin, 44.2 µg/g phlorizin, and 12.0 µg/g hyperin in wet basis. Karaman et al. (2013) studied the phenolic contents of apple varieties and determined the contents of chlorogenic acid, caffeic acid, epicatechin, catechin, and phlorizin as 51.8, 45.9, 22.9, 4.1, and 1.3 µg/g fresh weight (FW), respectively. In the present study, it is found that among the phenolic compounds, chlorogenic acid was the predominant phenolic, and it is 7-30 times higher than other apple cultivars. Epicatechin, the second most abundant phenolic compound present in deer apple, is also 8-40 times higher than other apple varieties. The deer apple also has a significant amount of rutin, caffeic acid, protocatechuic acid, and quercetin content. Moreover, the presence of catechin and phlorizin, which is found in other apple varieties, was not observed in deer apples. Chlorogenic acid has antimicrobial, antioxidant, anti-inflammatory, anti-obesity, anti-diabetic, and anti-hypersensitive features. It is effective against bacteria, yeasts, molds, and viruses; also, it helps decrease lipid oxidation and preservation of bioactive compounds (Santana-Gálvez et al., 2017; Joye, 2019). Epicatechin is a flavonoid found in the Rosaceae fruit family (apples, apricots, peaches, pears, and plums) and fruits such as black grapes, and blackberries, as well as in black tea and dark chocolate (Aadil et al., 2019; Farombi et al., 2019). Epicatechin and caffeic acid have antimicrobial and antioxidant activity (Zhang et al., 2020; Yilmaz & Toledo, 2004). Rutin is another flavonoid found in deer apple that has antioxidant, antimicrobial, anti-allergic, anti-inflammatory properties (Yang et al., 2008; Oliveira et al., 2006; Calabrò et al., 2005).

3.4 Sugar content

The sugar content of deer apple was studied, and the standard and sample chromatograms are given in Figure 4a-4b. Fructose (351 mg/g DW) was the predominant sugar component by far in the deer apple, and it was followed by glucose (66.4 mg/g DW) and sucrose (10.9 mg/g DW) with relatively low amounts.

In a study on sugar and organic acid profiles of 12 different apple varieties, it was determined that the average fructose, glucose, and sucrose contents were in the range of 34.9-60.2 g/

Table 2. Organic acid content of deer apple fruit.

	Malic acid	Tartaric acid	Oxalic acid	Fumaric acid
Organic acid content (µg/g DW)	27500 ± 26.38	1935 ± 6.15	544 ± 6.79	5.50 ± 0.28

Values were means ± standard deviation (n = 3).

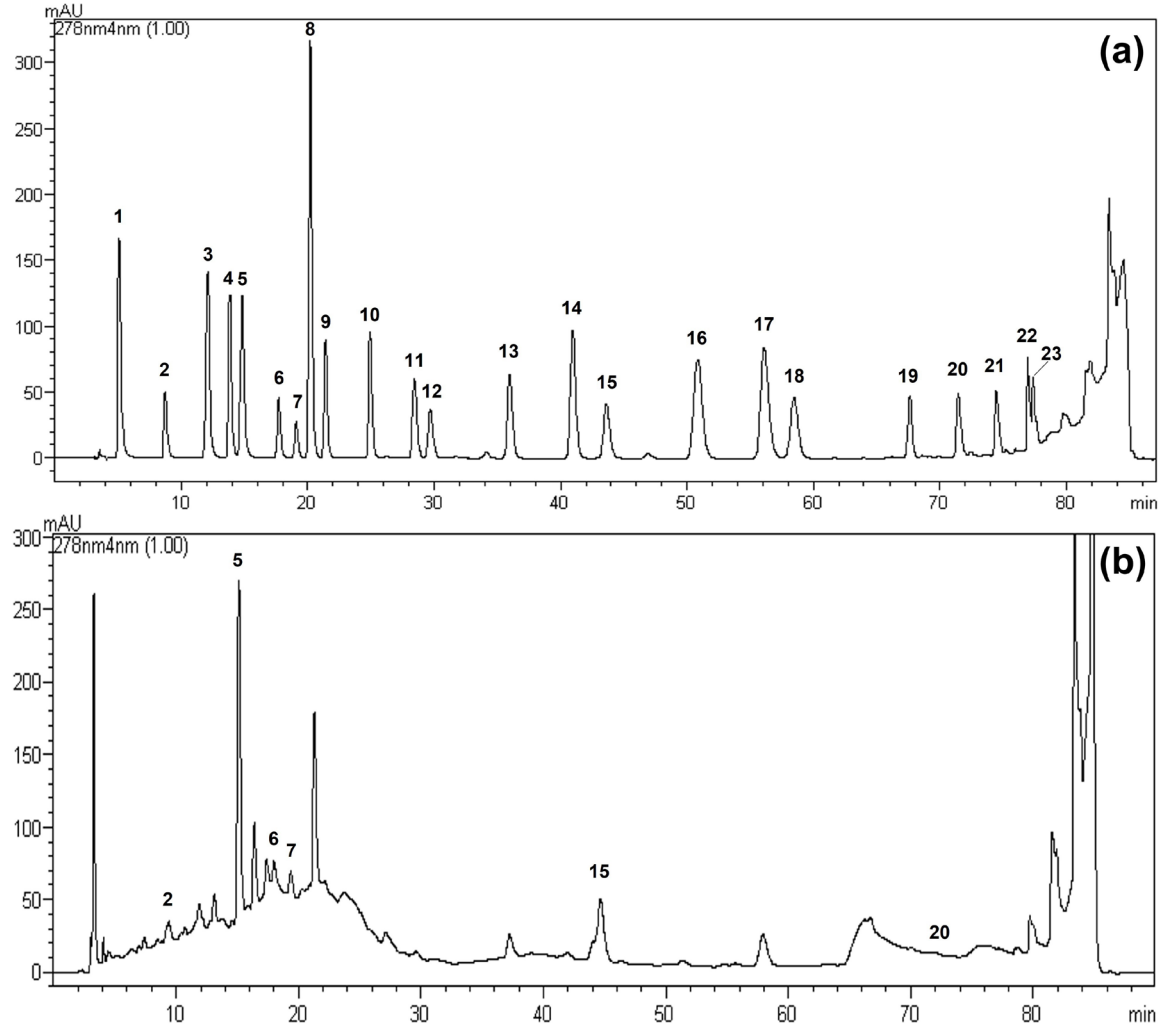

Figure 2. The phenolic standard chromatogram (a) and the sample chromatogram (b). 1: gallic acid; 2: protocatechuic acid; 3: catechin; 4: p-hydroxybenzoic acid; 5: chlorogenic acid; 6: caffeic acid; 7: epicatechin; 8: syringic acid; 9: vanillin; 10: p-coumaric acid; 11: ferulic acid; 12: sinapinic acid; 13: benzoic acid; 14: o-coumaric acid; 15: rutin; 16: hesperidin; 17: rosmarinic acid; 18: eriodictiol; 19: cinnamic acid; 20: quercetin; 21: luteolin; 22: kaempferol; 23: apigenin.

kg FW, 20.4-43.5 g/kg FW, and 8.73-24.5 g/kg FW, respectively (Begić-Akagić et al., 2014). Veberič & Stampar (2005) determined the fructose (47.9-103.3 g/kg FW), glucose (7.87-38.0 g/kg FW), and sucrose (16.9-77.3 g/kg FW) content of 12 different apple cultivars. Compared to other apple cultivars, our study showed deer apple has relatively high fructose content and low sucrose content. On the other hand, the glucose content of the deer apple was in agreement with the other studies.

3.5 Aroma profile

Analyses were performed using GC-MS to determine the aroma components of the deer apple, and the result of the analysis is given in Table 3. Forty-five volatile aroma compounds were identified in the deer apple. Acetic acid, nonanal, hexanal, acetoin, acetaldehyde, n-octanal, and hept-2(E)-enal were the most abundant aroma compounds in the deer apple fruits with the percentages of 37.70, 15.13, 6.03, 5.09, 3.79, 3.36, and 2.45, respectively.

Aroma components give sensory properties to the foodstuffs, such as taste and odor. In the present study, it is shown that major volatile components of the deer apple were acetic acid, nonanal, hexanal, acetoin, acetaldehyde, n-octanal, and hept-2(E)-enal. Acetic acid is one of the main compositions of the citrus and has sharp vinegar, pomegranate flavor, and sharp, sour, and ripe fruit taste. Nonanal has citrus, cucumber, and melon peel taste, as well as a waxy, citrus, and light green lemon-peel flavor. Hexanal has a green, leafy, woody scent and a green grass and apple flavor. Acetoin gives a sweet, buttery, creamy, milky odor and taste. Acetaldehyde has a pungent, ethereal, fruity, and moldy odor and a sharp, fresh green taste. Octanal has a waxy, strong, orange smell and taste. Hept-2(E)-enal has an intense green, oily fruity scent and dense green, sweet apple peel flavor

(Fan & Qian, 2005; Arena et al., 2006; Conceicao et al., 2007; Cheng, 2010; Wen et al., 2014). In a study determining the volatile aromatic components of different varieties of wild apples, the highest valued compounds were 2-hexenal (21.98%-45.88%), benzaldehyde (5.74%-17.05%), diethyl phthalate (4.19%-12.34%), hexanal (2.52%-12.26%), and 2,4-hexadienal (4.15%-11.70%) (Li et al., 2008). The unripe deer apple fruit has a sharp sour taste, and this may be due to its abundant malic acid and acetic acid content. Malic acid, acetic acid, and nonanal may also be responsible for specific apple flavors of deep apple.

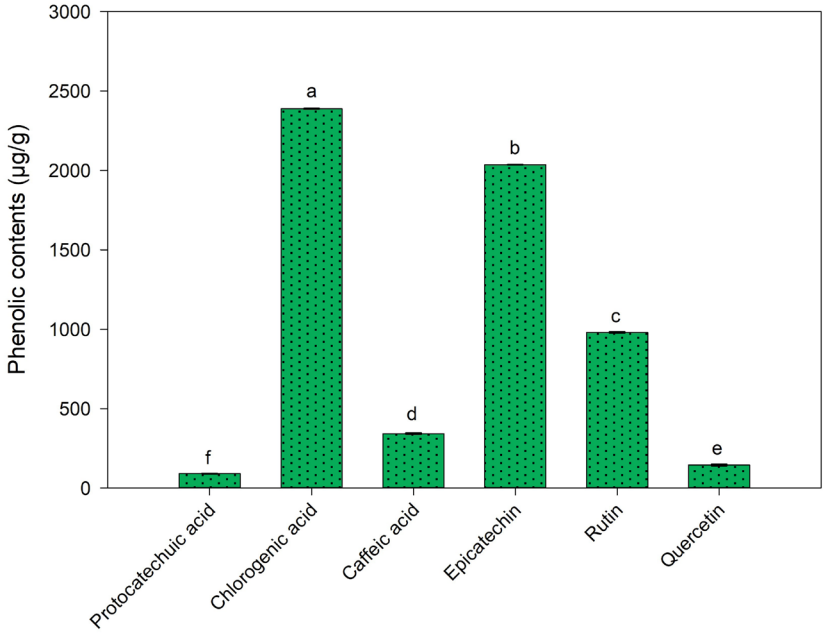

Figure 3. The phenolic compound content of the deer apple (μg/g DW). Different letters (a-f) indicate significant difference at $p < 0.05$.

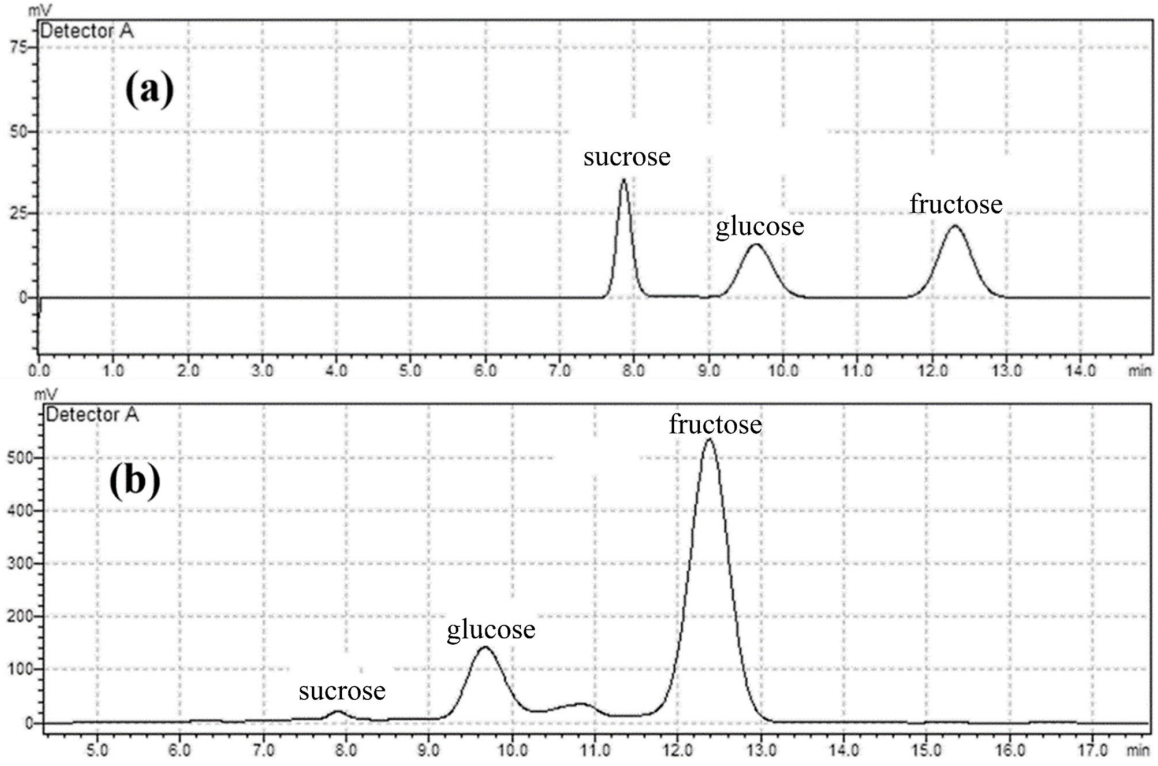

Figure 4. The standard chromatogram (a) and the sample of deer apple chromatogram (b) for sugar content.

Table 3. The aroma profile of the deer apple fruit.

Peak #	Retention time	Aroma component	Rate %
1	1.111	Acetaldehyde (CAS) Ethanal	3.79
2	1.169	Ethanol (CAS) Ethyl alcohol	1.54
3	1.228	2-Propanone (CAS) Acetone	1.72
4	1.306	Acetic acid, methyl ester (CAS) Methyl acetate	1.73
5	1.653	Acetic acid (CAS) Ethylic acid	37.70
6	1.889	2-Butenal (CAS) Crotonaldehyde	0.22
7	2.000	Formate <isobutyl->	0.17
8	2.334	Pentanal (CAS) n-Pentanal	0.75
9	2.457	2-Butanone, 3-hydroxy- (CAS) Acetoin	5.09
10	2.727	1,3-Dioxolane, 2,4,5-trimethyl-	0.38
11	2.942	2-Methyl-1-butanol	0.62
12	3.458	1-Penten-3-one, 2-methyl- (CAS) Isopropenylethylketone	0.63
13	3.768	1,3-Butanediol (CAS) Butane-2,3-diol	0.68
14	3.906	1-Octene	0.22
15	3.978	2,3-Butanediol	0.60
16	4.106	Hexanal	6.03
17	6.059	Hexanol	0.30
18	7.036	Heptanal	0.94
19	7.130	2-Butoxyethanol	0.17
20	8.963	Hept-2(E)-enal	2.45
21	9.089	Benzaldehyde (CAS) Phenylmethanal	0.63
22	9.739	1-Octen-3-one (CAS) Vinyl amyl ketone	0.73
23	9.906	1-Octen-3-ol (CAS) Oct-1-en-3-ol	1.56
24	10.029	6-Methyl-5-hepten-2-one	1.24
25	10.226	Furan, 2-pentyl-	0.60
26	10.724	Octanal (CAS) n-Octanal	3.36
27	11.047	Benzene, 1,4-dichloro- (CAS) p-Dichlorobenzene	0.26
28	11.676	I-Limonene	0.44
29	12.041	Oct-3(E)-en-2-one	0.75
30	12.800	Oct-2(E)-enal	0.95
31	13.226	2-Octen-1-ol, (E)- (CAS) trans-2-Octenol	0.46
32	13.390	Caprylalcohol; Octanol	1.15
33	14.519	6-Methyl-3,5-heptadien-2-one	0.79
34	14.624	Nonanal	15.13
35	16.721	Non-2(E)-enal	0.52
36	17.250	1-Nonanol (CAS) n-Nonylalcohol	0.60
37	17.528	Naphthalene (CAS) White tar	0.94
38	18.495	Capraldehyde; Decanal	1.03
39	18.820	Nona-2(E),4(E)-dienal	0.23
40	19.676	(2-(2-butoxyisopropoxy)-2-isopropanol	0.17
41	20.540	Dec-2(E)-enal	1.08
42	20.673	Octanoicacid, trimethylsilyl ester (CAS)	0.46
43	25.461	Tetradecane (CAS) n-Tetradecane	0.35
44	26.940	5,9-Undecadien-2-one, 6,10-dimethyl- (CAS) Dihydropseudoionone	0.38
45	31.839	Hexadecane	0.44
		Total	100

4 Conclusions

Some pomological properties of the deer apple (*Malus trilobata*), as well as sugar content, organic acid content, phenolic composition, and aroma profile, have been determined for the first time in this study. According to the findings, the deer apple has high nutritional values and functional components. Especially, deer apple is rich in malic acid, chlorogenic acid, epicatechin, rutin, and fructose content. Currently, the deer apple is not widely known and has limited use in many areas locally. With the increase in agriculture, it is thought that its usage area could be expanded with organic products such as vinegar, pies, compotes, pickles, jams, and baby foods. In this

study, we aimed to identify some properties and components of deer apple and to increase its awareness and consumption. In addition, more studies are needed to identify the fruit and increase its usage areas.

Conflict of interest

The authors declare that they have no conflict of interest.

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