Turkish Journal of Agriculture and Forestry

Volume 47 | Number 6 Article 5

12-1-2023

Determination of the phytochemical contents and pomological properties of chokeberry(Aronia melanocarpa L.) fruit in different harvesting periods

SELMA BOYACI

ŞULE POLAT

NESİBE EBU KAFKAS

TÜBİTAK

Turkish Journal of Agriculture and Forestry

http://journals.tubitak.gov.tr/agriculture/

Research Article

Turk J Agric For
(2023) 47: 842-850

doi:10.55730/1300-011X.3132

Determination of the phytochemical contents and pomological properties of chokeberry (*Aronia melanocarpa* L.) fruit in different harvesting periods

Selma BOYACI[1,*], Şule POLAT[2], Nesibe Ebru KAFKAS[2]

[1]Department of Horticulture, Faculty of Agriculture, Kırşehir Ahi Evran University Kırşehir, Turkiye
[2]Department of Horticulture, Faculty of Agriculture, Çukurova University, Adana, Turkiye

Received: 12.05.2023 • **Accepted/Published Online:** 10.08.2023 • **Final Version:** 01.12.2023

Abstract: This study was conducted to determine some pomological properties and phytochemical contents such as total monomeric anthocyanin, total phenol, antioxidant activity, sugar, and organic acid of the chokeberry cultivars Nero and Viking, which are being cultivated in Türkiye, in 3 different harvest periods (the last week of August, the first week of September, and the second week of September). The highest total monomeric anthocyanin (794.63 mg/100 g), total phenol (5006.60 mgGAE/100 g), and antioxidant activity (79.33%) were obtained in the first harvest period of Nero. Glucose is the main sugar in chokeberry cultivars, and the highest glucose content (6.90%) was recorded in the first harvest period of Nero. The highest malic acid (2302.83 mg/100 g), which is an organic acid, was found in Nero in the first harvest period. The highest vitamin C content (36.92 mg/100 g) was obtained in Nero in the first harvest period. The optimum harvest time or period for yielding of both cultivars was the first week of September (second harvest period). The optimum harvest time was the last week of August (the first harvest period) considering total monomeric anthocyanin, total phenol and antioxidant capacity, organic acids, and sugars.

Key words: Phytochemical contents, chokeberry, harvesting time

1. Introduction

Colorful fruit, which are rich in biochemical content, are very beneficial for human health. Many horticultural plants are rich in bioactive compounds such as phenols, flavonoids, sugars, organic acids, and anthocyanins within their colorful fruit (Poyraz Engin and Mert, 2020). The fruit of *Aronia melanocarpa* (Michx.), which originated in North America and is known as the black chokeberry, has been consumed since the middle of the last century, and *Aronia* is named *Pomae* in the subfamily *Maloideae* of the family *Rosaceae* (Evans, 1999).

The genus *Aronia* has three species: *Aronia melanocarpa* (Michx.) Elliot (black chokeberry), *Aronia arbutifolia* (L.) Elliot (red chokeberry), and *Aronia prunifolia* (Marshall) Rehder (purple chokeberry) (Jeppsson, 2000). *Aronia melanocarpa* is rich in bioactive compounds that have beneficial biological and nutritional effects in animals and humans (Horszwald et al., 2013). The fruit is a good source of vitamins, carotene, dietary fiber, minerals, sugars, and organic acids (Kulling and Rawel, 2008). The chokeberry is particularly rich with respect to anthocyanins and proanthocyanidins. The polyphenolic components of *Aronia melanocarpa* have high antioxidant capacities and healing properties for humans such as anticancer, antimicrobial, antiviral, and antidiabetic (Giampieri et al., 2015; Caruso et al., 2016). The various phytochemicals in the chokeberry play a role in the treatment of diseases caused by xenobiotic agents (Shahin et al., 2019). The chokeberry is called a super/miracle fruit because of these superior properties (Yılmaz et al., 2021).

Phenolic content significantly affects the quality of grown fruit. It also contributes to the nutritional content as well as the sensory properties of fruit. Phenolic compounds affect the taste of fruit, for example, creating a sour taste, depending upon the maturation. Anthocyanins are the most important polyphenols and are responsible for the red coloring in fruit. The concentrations of anthocyanins are very important for the sensory quality of fruit. In addition to the health benefits of fruit, recent studies have focused on identifying the bioactive compounds of different fruit cultivars and determining the factors affecting the composition of bioactive compounds (Williner et al., 2003).

Carbohydrates (sugars) and organic acids are the main components affecting the organoleptic properties of fruit. The ratio of organic acid to sugar is used to characterize

* Correspondence: selma.boyaci@ahievran.edu.tr

fruit flavor and taste. Organic acids have antioxidant properties and thus are widely used for pharmacological purposes. The organic acid content of fruit varies according to the genotypic structure of plants (Ikegaya et al., 2019)

The planting of *Aronia* and consumption of chokeberries in Türkiye have been increased to obtain nutraceutical fresh, dried, juice, different colored, and functional food products (Poyraz Engin and Boz, 2019). The fruit are harvested for 2 months and the physicochemical components of the fruit change during the ripening period (Kulling and Rawel, 2008). Therefore, determining the optimum harvesting time of fruit is very important for different usage purposes (Poyraz Engin and Boz, 2019). Like other fruit species, the fruit quality of the chokeberry depends on cultivar, fertilization, ripening of fruit, harvesting time, location, etc. (Jeppsson and Johansson, 2000; Kulling and Rawel, 2008; Tolić et al., 2017). Fruit quality for the black chokeberry is defined according to anthocyanin (Acy) content, browning tendency, soluble solids content, and total acidity (Jeppsson and Johansson, 2000). In addition, the harvest time varies according to the geographical location, cultivar, climatic conditions, agricultural practices during the growing season, and the aim of fruit processing (Poyraz Engin and Mert, 2020).

The farming of chokeberries, a new and alternative product, has recently started to become widespread in Türkiye, in the form of closed orchards. However, insufficient studies on product quality mean that farmers do have enough information regarding the effects of different harvesting times on the nutrient content of fruit. Therefore, there has been a lack of information about the optimum harvest time. Studies on chokeberries in Türkiye are generally on the pomological and biochemical properties of the fruit. However, studies on organic acid, phenolic compound, sugar, and antioxidant content in the fruit are limited in Türkiye (Poyraz Engin and Mert, 2020). The fact that chokeberry growers receive their products within a wide harvesting season causes great variations in the phytochemical contents of the fruit and limitations in obtaining a uniform product in terms of product quality. Therefore, with the right choice of harvesting time, it may be possible to obtain phytochemically qualified products and, thus, to increase fruit quality. Industrially, determination of the optimal harvesting period can contribute to the production of high quality chokeberry fruit and its juice in Türkiye. In addition, there have the limited scientific studies investigating the effects of different harvesting times on yield and product quality of different *Aronia* cultivars in Türkiye's ecological conditions. Therefore, in the present study, it was aimed to determine the pomological and phytochemical contents of the *Aronia* cultivars Nero and Viking in 3 different harvesting periods to give suggestions to farmers for sustainable and high quality fruit production.

2. Materials and methods

2.1. Material

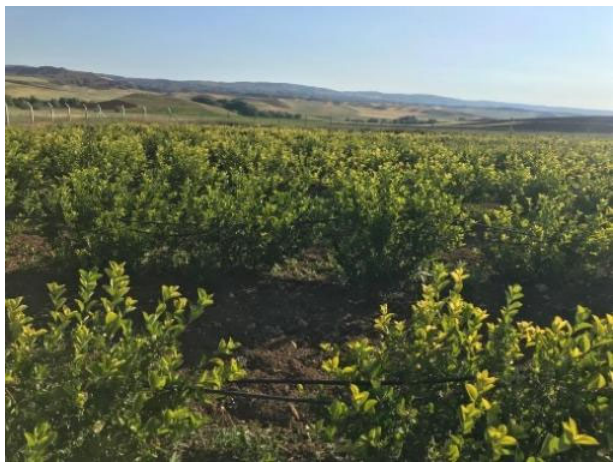
The first studies on chokeberry growing in Türkiye started in Yalova in 2012. In the present study, the cultivars Nero (origin Czech Republic) and Viking (origin Finland), which are the ones grown most commonly in Türkiye, were used. Viking and Nero (*Aronia melanocarpa* L.), planted in a private orchard established in Kırşehir Province in Türkiye (39°08′02″N 34°07′08″E, 1082 m above sea level), were used in the study. This *Aronia* orchard was established in 2019 with a distance of 1 × 4 m intrarow and interrow spacing, and all necessary maintenance operations (irrigation and fertilization) were carried out regularly. A general view of the research orchard is given in Figure.

2.2. Harvest method

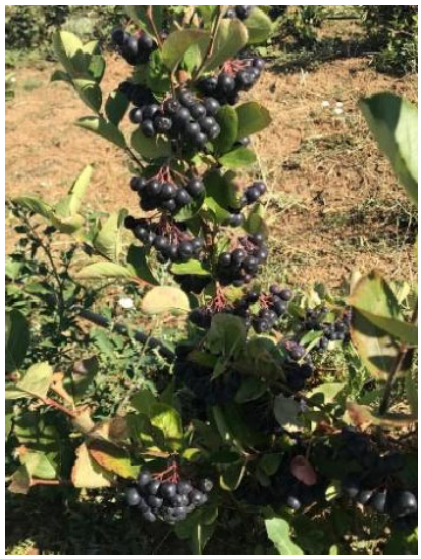
The harvesting periods were determined by characterization of fruit. According to Jeppsson and Johansson (2000) and Poyraz Engin and Mert (2020), harvesting times were established according to fruit coloring and tasting results in two following years and in the time period when fruit color increased from purple to black as maturity progressed in both cultivars. According to these criteria, the harvesting periods in 2021 for both cultivars were August 27 (first harvest period) and September 6 and 16 (second and third harvest periods), while these periods for 2022 were August 28 (first harvest period) and September 7 and 17 (second and third harvest periods).

2.3. Pomological properties of fruit at harvest

Ripe fruit was hand-harvested during the specified maturity period. It was collected in transparent and perforated boxes of 500 g (18.85 × 23.97 × 58 cm) and immediately brought to the laboratory in a thermos bag. Pomological properties were determined in a total of 100 berries for each cultivar with 3 replications. In the pomological analysis, the weight of 100 berries, the number of berries in a cluster (pieces), fruit weight (g), fruit width (mm), and fruit length (mm) were measured immediately after each harvesting time. The stalks of the berries were removed and the berries were washed. For all analyses, the fruit was firstly homogenized in a blender (King Kkb976 Hilde). Then, it was filtered for chemical analysis and made ready for analysis. The soluble solids content (SSC), pH, and titratable acidity (TA) values were determined in juice extracts. The SSC was measured with a digital refractometer (Hanna HI 96801) and the pH value was determined with a digital pH meter (Hanna, HI 9321). Titratable acidity was determined by titration with 0.1 N NaOH up to an endpoint of pH 8.1, and given as a percentage of malic acid in 100 mL of juice.



(a)



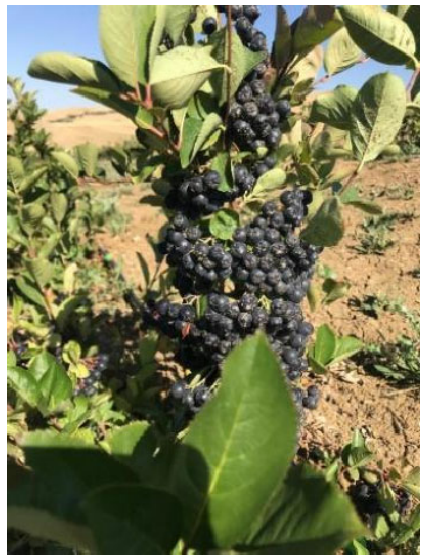


Figure. General view of the research orchard (a), Nero (b), Viking (c).

2.4. Phytochemical parameters

For phytochemical analyses, the berries were packed in polyethylene bags, frozen at –20 °C, and preserved until the analyses. Fruit samples were brought to the Çukurova University Department of Horticulture phytochemical analysis laboratory (Adana, Türkiye) in the ice box and analyses were performed.

2.4.1. Total phenol Folin–Ciocalteu assay

Total phenolic content was determined with Folin–Ciocalteu reagent using the modified method described by Spanos and Wrolstad (1990). Briefly, 4000 µL of 80% methanol extract was added to 1 g of chokeberry juice sample. Water, Folin–Ciocalteu reagent, and 20% sodium carbonate were added to the samples taken from the supernatant of this extract, followed by storage in the dark for 2 h. The absorbance at 760 nm was measured using a Thermo Scientific Multiscan GO microplate spectrophotometer (Thermo Scientific Multiscan GO). The amount of total phenol was calculated through a calibration curve daily prepared with known concentrations of gallic acid (GA) standards. The results were expressed as milligrams of GA equivalents per 100 g fresh weight (FW) of chokeberry.

2.4.2. Sugar content

Changes in glucose, fructose, sucrose, xylose, and total sugar contents of homogenized chokeberry juice samples were determined by a high-performance liquid chromatography (HPLC) technique developed by Crisosto (1997). Frozen juice samples were thawed at 25 °C, and 1 g of chokeberry fruit homogenate was added to 4 mL

of ultrapure water (Millipore Corp., Bedford, MA, USA). The reaction mixture was placed in an ultrasonic bath and sonicated at room temperature for 15 min, then centrifuged at 5500 rpm for 15 min, and filtered before analysis in the HPLC system (Whatman nylon syringe filters, 0.45 µm, 13 mm diameter). Sugar contents were determined with 3 replicates using an HPLC (Shimadzu, Prominence LC-20A) refractive index detector and Coregel-87C (7.8 × 300 mm). Separation was performed at 70 °C at a flow rate of 0.6 mL min^{-1}. Elution was achieved using isocratic ultrapure water. The individual sugars were calculated using the standards and expressed as percent fresh weight (FW). Calibration curves of the references were prepared and sugar contents (%) were determined using the reference calibration curves.

2.4.3. Organic acids

The organic acid contents of chokeberry juice samples were determined using the HPLC analysis developed by Bozan et al. (1997). Changes in malic, citric, and L-ascorbic contents were determined in chokeberry juice samples. The organic acid contents of the chokeberry juice were determined in three replications. For each sample, 1 g of homogenized fruit sample and 4 mL of ultrapure water were mixed for organic acid extraction. The mixture was placed in an ultrasonic water bath for 15 min at room temperature, sonicated, and centrifuged at 5500 rpm for 15 min. The mixture was then filtered using Whatman nylon syringe filters (0.45 µm, 13 mm diameter). Organic acids were analyzed using an HPLC instrument (Shimadzu LC 20A vp, Kyoto, Japan) equipped with a UV detector (Shimadzu SPD 20A vp). An 87 H column (5 µm, 300 × 7.8 mm, Transgenomic) was used in the HPLC device and 0.05 mM sulfuric acid was used as the solvent. The operating conditions for the HPLC were as follows: (a) column temperature was 40 °C, (b) the injection volume was 20 µL, (c) the detection wavelength was 210 nm, and (d) the flow rate was 0.8 mL/min. Identification of organic acids and determination of the peaks were done by taking into account the retention times of the peaks and the comparison of the spectral data with the standards. The number of determined acids was corrected using the corresponding standard calibration curves (mg/100 g).

2.4.4. Total antioxidant capacity

A 1000 mg chokeberry fruit juice sample was weighed, 4000 µL of 80% methanol was added, and a 50 µL sample of the upper phase of the mixture was taken. Next 1950 µL of 0.06 µM DPPH solution was added in preparation for analysis. The absorbance value was read at 515 nm DPPH stock preparation. A weighed 0.0238 g sample was added to 100 mL of DPPH Complement solution with pure Methanol Mix and kept for at least 2 h until all DPPH solution dissolved for analyses. The mixture was prepared using 100 mL of 80% ethanol.

The free radical scavenging activity of chokeberry fruit juice was measured with slight modification of the 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Trolox Equivalent) assay reported by Brand-Williams et al. (1995). The decrease in absorbance of DPPH at 515 nm was measured at 5-min intervals using a Multiscan GO microplate spectrophotometer. Solvent was used as blank and the total antioxidant capacity was calculated as follows:

DPPH(%) = (Control absorbance – (sample absorbance – blank absorbance))/control absorbance) × 100

2.4.5. Total monomeric anthocyanin content (TAC)

A 500 mg sample of fruit juice was added to 2500 µL of 80% methanol solution and mixed by vortex. The upper phase of the mixture was placed into two different 2-mL Eppendorf tubes of 100 µL in a centrifuge at 5500 rpm for 10 min. From each sample 3 replicates were made. After adding 1900 µL of buffer 1 (to one tube) and 1900 µL of buffer 2 (to the other tube), absorbance was read at 515 nm.

Total monomeric anthocyanin content (TAC) was estimated by the pH differential method with slight modifications as described by Giusti and Wrolstad (2001). Two extracts were prepared, one containing potassium chloride buffer (pH 1.0) and the other sodium acetate buffer (pH 4.5). The pH 1.0 extract was prepared with 125 mL of potassium chloride and hydrochloric acid, while the pH 4.5 extract was prepared with 400 mL of sodium acetate and hydrochloric acid. The absorbance of the extracts was measured at 510 and 700 nm (Thermo Multi Scan Go brand Spectrophotometer, USA). Total monomeric anthocyanin content was determined from the molar absorptivity of cyanidin 3-glucoside and expressed as the 3-glucoside equivalent of cyanidin. Total monomeric anthocyanin content of the fruit was calculated using the molar absorption coefficient as follows:

Total Monomeric Anthocyanins (mg/100 g) = (A × MW × DF × 10,000)/ε × l

In the equation, A: absorbance difference, MW: molecular weight (MW: 449.2), DF: dilution factor, and ε: molar extinction coefficient (ε: 26,900, l = path length (1 cm)).

2.5. Statistical analysis

The experiment was conducted in 3 replications according to the randomized plot design. The differences in fruit properties between the harvesting times were analyzed using SPSS 22.0. When the differences between the means were statistically significant ($p < 0.05$), the mean values of traits were compared using Duncan's multiple range test.

3. Results and discussion

3.1. Pomological properties of fruit at harvest

The first harvest was carried out when the fruit color turned to black. The average pomological properties of fruit samples are given in Tables 1 and 2.

The highest 100-berry weight (100.22–123.41 g), average fruit weight (1.13–1.41 g), fruit width (12.34–13.74 mm), and fruit length (11.56–12.42 mm) in Nero were obtained in the second harvest period of both experimental years. All values tended to decrease in the third harvest period. Jeppsson and Johansson (2000) reported that the weight of 100 berries in Nero and Viking between August 14 and 22 increased from 75 g to 99 g and fluctuated slightly until September 8. Poyraz Engin and Mert (2020) showed that the weight of 100 berries in Nero increased up to the third harvest (112 g) during 6 harvests and decreased in the sixth harvest (102 g). Similarly, fruit weight increased (103 g) in the third harvest in Viking and decreased in the sixth harvest (101 g). Similarly, in the present study, the weight of 100 berries in Nero and Viking increased in the second harvest period in both years and decreased in the third harvest period. The reasons for this are thought to be the decrease in temperatures in September and the decrease in the amount of irrigation towards the end of the harvest.

The highest 100-berry weight (95.10–130.38 g) in Viking was obtained in the second harvest period in both years, while average fruit weight, width, and length values differed between the studied years. Maximum fruit weight, width, and length data were found in the third harvest period of the 2021 season (1.11 g, 11.70 mm, 11.40 mm) of the 2021 season, while the highest values (1.58 g, 14.16 mm, 13.30 mm) in the 2022 season were recorded in the first harvesting period. The mean fruit size and 100-berry weight recorded in the present study were slightly higher than the findings of previous studies. Ochmian et al. (2012) reported average chokeberry fruit size between 12 and 17 mm and 100-berry weight between 32 and 112 g. Poyraz Engin and Mert (2020) reported that the average fruit size

Table 1. Pomological properties of Nero at different harvesting periods in 2021 and 2022.

Parameters	**Harvest periods (2021)**			**Harvest periods (2022)**		
	1	2	3	1	2	3
Fruit weight (g)	1.02 ± 0.02b	1.13 ± 0.04a	0.80 ± 0.03c	1.32 ± 0.04b	1.41 ± 0.03a	1.25 ± 0.03b
Fruit width (mm)	11.77 ± 0.11b	12.34 ± 0.19a	10.30 ± 0.15c	13.15 ± 0.19b	13.74 ± 0.12a	13.13 ± 0.13b
Fruit length (mm)	11.30 ± 0.16a	11.56 ± 0.14a	9.97 ± 0.17b	12.04 ± 0.15b	12.42 ± 0.13a	11.70 ± 0.11b
Hundred-berry weight (g)	92.70 ± 0.23b	100.22 ± 0.38a	63.78 ± 0.09c	110.10 ± 0.54b	123.41 ± 0.31a	106.40 ± 0.50c
pH	3.59 ± 0.01c	3.70 ± 0.01b	3.77 ± 0.01a	3.59 ± 0.03b	3.69 ± 0.02a	3.72 ± 0.01a
TA (%)	0.60 ± 0.00a	0.57 ± 0.00b	0.55 ± 0.01c	0.66 ± 0.00a	0.54 ± 0.01b	0.45 ± 0.00c
Number of berries per cluster	16.33 ± 1.71ab	18.56 ± 1.11a	14.33 ± 1.03b	28.22 ± 1.42a	26.00 ± 0.76a	25.56 ± 1.43a

a–c: Different letters within the same line show significant differences ($p < 0.05$) between harvesting times

Table 2. Pomological properties of Viking at different harvesting periods in 2021 and 2022.

Parameters	**Harvest periods (2021)**			**Harvest periods (2022)**		
	1	2	3	1	2	3
Fruit weight (g)	0.90 ± 0.02c	1.01 ± 0.03b	1.11 ± 0.02a	1.58 ± 0.03a	1.49 ± 0.04a	1.48 ± 0.03a
Fruit width (mm)	11.29 ± 0.10b	11.57 ± 0.14ab	11.70 ± 0.14a	14.16 ± 0.11a	13.89 ± 0.14a	13.89 ± 0.15a
Fruit length (mm)	10.92 ± 0.12b	11.00 ± 0.10b	11.40 ± 0.13a	13.30 ± 0.12a	12.81 ± 0.17b	12.56 ± 0.10b
Hundred-berry weight (g)	77.75 ± 0.05c	95.10 ± 0.16a	90.44 ± 0.16b	128.11 ± 1.77a	130.38 ± 1.82a	121.35 ± 0.32b
pH	3.51 ± 0.00c	3.70 ± 0.01b	3.89 ± 0.02a	3.71 ± 0.03b	3.77 ± 0.01ab	3.85 ± 0.04a
TA (g malic acid 100 mL^{-1})	0.60 ± 0.00a	0.56 ± 0.01b	0.53 ± 0.00c	0.54 ± 0.00a	0.48 ± 0.00b	0.37 ± 0.00c
Number of berries per cluster	23.33 ± 2.17b	19.67 ± 1.24b	28.78 ± 1.45a	25.78 ± 2.79a	21.89 ± 0.87a	26.22 ± 0.83a

a–c: Different letters within the same line show significant differences ($p < 0.05$) between harvesting times

of Nero and Viking in Yalova conditions was between 9 and 13 mm, fruit weight was between 0.64 and 1.34 g, and 100-berry weight was between 103 and 112 g. The differences may have resulted from the ecological conditions in the orchards and the agricultural practices used during the growing seasons.

The number of berries per cluster in Nero was 14.33–28.22 and 19.67–28.78 in Viking. Çelik et al. (2022) determined the number of berries per cluster as 21.53 in Nero and 21.45 in Viking, and the results are consistent with our findings. Chokeberry fruit is formed by fleshing and watering the flower bed and therefore the fruit is included in the pseudo fruit class. According to the grain shape, Nero is defined as round and Viking as elliptical. Our findings are in agreement with the definitions of the fruit reported in previous studies (Rohrer et al., 1994; Evans, 1999; Poyraz Engin and Mert, 2020).

3.2. Phytochemical parameters

The total monomeric anthocyanin, total phenol, and antioxidant activity (%DPPH inhibition and %DPPH radical scavenging activity) of Nero and Viking are given in Table 3.

The highest total monomeric anthocyanin value (794.63 mg/100 g) in Nero was obtained in the first harvest period, while the lowest value (426.93 mg/100 g) was recorded in the third harvest period. Contrary to Nero, the highest total monomeric anthocyanin content (597.41 mg/100 g) in Viking was obtained in the third harvest period. Ochmian et al. (2012) reported that the chemical compositions of Nero and Viking fruit are similar. However, the total monomeric anthocyanin content of Nero in our study was higher compared to that recorded in Viking. Our findings (418.78–794.63 mg/100 g) are within the range of total monomeric anthocyanin content reported by Zheng and Wang (2003) and Wu et al. (2004), who showed that the total monomeric anthocyanin content of chokeberry was between 237 and 990 mg/100 g.

The maximum total phenol ingredient of Nero was obtained in the first harvest (5006.60 mgGAE/100 g) and this value decreased regularly in the second and third harvest periods. The highest total phenol content in Viking was 3749.60 mgGAE/100 g in the first harvest period, and this value decreased to 2367.40 mgGAE/100 g in the second harvest period and increased to 3025.00 mgGAE/100 g in the third harvest period. Wangensteen et al. (2014) stated that the total amount of phenolic is equivalent to 1921 mg of gallic acid in 100 g of fresh fruit. Bolling et al. (2015) stated that total amount of phenol in chokeberry fruit increased between August 1 and September 12 in the USA. The total phenol content obtained in our study was higher than the value reported by Bolling et al. (2015). The difference in total phenol content can be attributed to the ecological conditions of the experimental sites.

The antioxidant capacity of chokeberry fruit is higher than that of other fruit species (Kulling and Rawel, 2008). Both %DPPH inhibition and %DPPH radical scavenging in both cultivars reached the highest level with the onset of maturity and decreased with the progression of maturity. Denev et al. (2018) and Yang et al. (2019) also stated that the antioxidant capacity of *Aronia* cultivars decreased with the progress in fruit ripening. The results of our study were parallel to the findings of other researchers.

The sugars (%), total sugar (%), and SSC (°Brix) contents of Nero and Viking in different harvest periods are given in Table 4.

Chokeberries contain carbohydrates, organic acids, amino acids, minerals, vitamins, and polyphenols (Kulling and Rawel, 2008). The composition of the fruit depends on factors such as climatic and soil conditions, ripening

Table 3. Total monomeric anthocyanin (mg cyanidin-3-glucoside/100 g), total phenol (mgGAE/100 g) and antioxidant activity (%DPPH inhibition, %DPPH free radical scavenging activity) in fruit of Nero and Viking in 2022.

Parameters	Nero harvesting periods			Viking harvesting periods		
	1	2	3	1	2	3
Total monomeric anthocyanin (mg/100 g)	794.63 ± 1.66a	441.09 ± 0.14b	426.93 ± 1.18c	441.27 ± 1.44b	418.78 ± 0.66c	597.41 ± 4.90a
Total phenol (mgGAE/100 g)	5006.60 ± 44.73a	3199.10 ± 8.70b	2281.40 ± 7.73c	3749.60 ± 10.17a	2367.40 ± 1.15c	3025.00 ± 7.28b
%DPPH inhibition	79.33 ± 0.24a	78.63 ± 0.12a	65.97 ± 0.49b	80.27 ± 0.63a	78.57 ± 0.41b	78.43 ± 0.21b
%DPPH free radical scavenging activity	61.87 ± 0.24a	61.18 ± 0.12a	48.51 ± 0.49b	62.81 ± 0.63a	61.11 ± 0.41b	60.97 ± 0.21b

a and b: Different letters within the same line show significant differences ($p < 0.05$) between harvesting times

Table 4. Sugars (%), total sugar (%), and SSC (°Brix) in chokeberry cultivars during different harvest periods in 2022.

Parameters	Nero harvesting periods			Viking harvesting periods		
	1	2	3	1	2	3
Sucrose	0.46 ± 0.00a	0.39 ± 0.02b	0.36 ± 0.01b	0.45 ± 0.03a	0.35 ± 0.02b	0.47 ± 0.01a
Glucose	6.90 ± 0.34a	4.40 ± 0.38b	4.59 ± 0.27b	5.31 ± 0.04a	4.22 ± 0.05c	5.15 ± 0.03b
Xylose	0.20 ± 0.04a	0.09 ± 0.01b	0.10 ± 0.01b	0.12 ± 0.02a	0.06 ± 0.01a	0.08 ± 0.02a
Fructose	5.31 ± 0.24a	3.57 ± 0.24b	3.67 ± 0.17b	4.26 ± 0.03a	3.51 ± 0.02c	4.15 ± 0.02b
Total sugar	12.87 ± 0.61a	8.44 ± 0.65b	8.73 ± 0.46b	10.14 ± 0.10a	8.15 ± 0.09b	9.85 ± 0.07a
SSC (°Brix)	22.83 ± 0.73a	15.17 ± 1.33b	16.17 ± 1.09b	18.83 ± 0.33a	15.50 ± 0.29b	18.67 ± 0.44a

a and b: Different letters within the same line show significant differences ($p < 0.05$) between harvesting times

time, harvesting methods, and storage conditions (Tolić et al., 2017). The main carbohydrates in the fruit are sugars (Jurendić and Ščetar, 2021) and glucose and fructose are the main sugars in both Nero and Viking (Sosnowska et al., 2016). The amounts of sucrose and xylose were relatively low in both cultivars. The sucrose content in the berries was reported by Denev et al. (2018) to be 0.34%, which was similar to the sucrose content in our study. The highest glucose content (6.90% and 5.31%) in Nero and Viking was obtained in the first harvest period. The highest fructose content in both cultivars was also obtained in the first harvest period. Total sugar content varied between 8.44% and 12.87% in Nero and between 8.15% and 10.14% in Viking. The total sugar content of Nero was higher than that of Viking. Ochmian et al. (2012) reported that the total sugar content of Nero in Poland was between 10.25 and 9.16 g/100 g. Poyraz Engin and Mert (2020) found that the highest total sugar content in Nero and Viking was 28.88 and 24.34%, respectively, in Türkiye. Total sugar content in our study was lower than that reported by Poyraz Engin and Mert (2020), while our finding is similar to the total sugar content reported by Ochmian et al. (2012). The differences in total sugar content of chokeberry can be associated with many factors such as ecology, harvesting time, and the cultivar used in the experiments (Jeppsson, 2000; Strik et al., 2003).

The highest soluble solids (°Brix) content in both cultivars (22.83% and 18.83%) was obtained in the first harvest period. The soluble solids content reported by Ristvey and Mathew (2011) was between 15% and 22%, and by Hudec et al. (2006) was between 15% and 24%. The soluble solids content in Aydın Province in Türkiye was between 13.07% and 21.63% (Özder, 2021), which is in parallel with the soluble solids contents reported by other researchers.

The organic acid content of fruit affects the flavor formation and many physiological processes in fruit depending on the cultivar. The sugar to acid ratio and their contents are very important in determining the taste characteristics of fruit. The L-ascorbic acid, citric acid, and malic acid contents in the fruit of Nero and Viking found in the present study are given in Table 5.

The main organic acid of chokeberries is malic acid, followed by citric acid (Strigl et al., 1995; Schafhalter et al., 1998; Kulling and Rawel, 2008). The highest amount of malic acid in Nero (2302 mg/100 g) was recorded in the first harvest, while the amount of malic acid decreased as maturity progressed. Warm seasons may accelerate the breakdown of malic acid during fruit ripening compared to the cooler seasons (Toldham-Andersen and Hansen, 1997). In contrast to the decrease in malic acid content in Nero with the maturation of fruit, the malic acid content of Viking was 1766.58 mg/g in the first harvest period, decreased to 1154.67 mg/g in the second harvest period, and reached the highest level (1871.62 mg/g) in the third harvest period. The highest vitamin C (36.92 mg/100 g) content in Nero was obtained in the first harvest period, while the highest content in Viking was measured in the third harvest period.

4. Conclusion

Simultaneous measurement of several important characteristics in fruit during ripening allows farmers to estimate the optimum harvesting period. In order to determine the most suitable harvesting period for chokeberries in Kırşehir in Türkiye, ecological conditions, the fruit yield, and total monomeric anthocyanin content were chosen as the most important harvesting criteria. When the weight of 100 berries is considered an important parameter for yield, the optimum harvesting time for both cultivars was determined as the second harvest period, the first week of September. If the optimum harvesting time is determined by considering the anthocyanin content, whose health effects are widely known, the total monomeric anthocyanins (794.63 to 441.09 mg/100 g) in Nero in the second har-

Table 5. Organic acid contents in fruit of chokeberry cultivars (mg/100 g) in 2022.

Parameters	Nero harvesting periods			Viking harvesting periods		
	1	2	3	1	2	3
L-ascorbic acid	36.92 ± 2.79a	28.91 ± 2.31b	25.51 ± 1.15b	29.91 ± 1.47b	24.57 ± 1.63c	35.31 ± 0.72a
Citric acid	1035.05 ± 65.35b	800.37 ± 5.77b	1625.75 ± 179.75a	677.63 ± 20.44b	478.97 ± 44.15b	1100.55 ± 119.48a
Malic acid	2302.83 ± 177.37a	1733.01 ± 134.18b	1283.87 ± 57.38b	1766.58 ± 52.49a	1154.67 ± 22.84b	1871.62 ± 45.48a

a and b: Different letters within the same line show significant differences ($p < 0.05$) between harvesting times

vest period were decreased by 44.5% compared to the first harvest period. With respect to total monomeric anthocyanin content, the optimum harvesting time of Nero was determined to be August 27, which is the first harvesting period. However, it was determined that total monomeric anthocyanins (418.78 to 597.41 mg/100 g) were increased by 42.7% in the third harvest period compared to the second harvest period in Viking. In terms of total monomeric anthocyanin content, the optimum harvesting time of Viking was determined to be the third harvest period, namely September 16.

Acknowledgment
This work was funded by the Scientific Research Projects Coordination Unit of Kırşehir Ahi Evran University (Project Number ZRT.A4.22.019).

References

Bolling BW, Taheri R, Pei R, Kranz S, Yu M (2015). Harvest date affects aronia juice polyphenols, sugars and antioxidant activity, but not anthocyanin stability. Food Chemistry 187: 189-196. https://doi.org/10.1016/j.foodchem.2015.04.106

Bozan B, Baser KHC, Kara S (1997). Quantitative determination of naphthaquinones of *Arnebia densiflora* (Nordm.) Ledeb. by an improved high-performance liquid chromatographic method. Journal of Chromatography A 782 (1): 133-136. https://doi.org/10.1016/S0021-9673(97)00460-3

Brand-Williams W, Cuvelier ME, Berset C (1995). Use of a free radical method to evaluate antioxidant activity. Food Science Technology 28: 25-30. https://doi.org/10.1016/S0023-6438(95)80008-5

Caruso MC, Galgano F, Tolve R, Pecora M, Tedesco I et al. (2016). Nutraceutical properties of wild berry fruits from Southern Italy. Journal of Berry Research 6 (3): 321-332. https://doi.org/10.3233/JBR-160140

Çelik H, Karabulut B, Uray Y (2022). Growth-development, yield and quality characteristics of aronia varieties grown in pots. International Journal of Innovative Approaches in Agricultural Research 6 (3): 246-254. https://doi.org/10.29329/ijiaar.2022.475.8

Crisosto CH (1997). Developing maturity indices for full red plum cultivars. California Tree Fruit Agreement 34-48.

Denev P, Kratchanova M, Petrova I, Klisurova D, Georgiev M et al. (2018). Black chokeberry (*Aronia melanocarpa* (Michx.) Elliot) fruits and functional drinks differ significantly in their chemical composition and antioxidant activity. Journal of Chemistry Article ID 9574587. https://doi.org/10.1155/2018/9574587

Evans RC (1999). Molecular morphological and ontogenetic evaluation of relationships and evolution in the Rosaceae. PhD, Philosophy Graduate Department, Botany, University of Toronto, Canada.

Giampieri F, Forbes-Hernandez TY, Gasparrini M, Alvarez-Suarez JM, Afrin S et al. (2015). Strawberry as a health promoter: an evidence based review. Food Function 6: 1386-1398. https://doi.org/10.1039/c5fo00147a

Giusti MM, Wrolstad RE (2001). Anthocyanins characterization and measurement with UV visible spectroscopy. In Wrolstad RE (editor). Current Protocols in Food Analytical Chemistry. New York, NY, USA: Wiley.

Horszwald A, Julien H, Andlauer W (2013). Characterisation of Aronia powders obtained by different drying processes. Food Chemistry 141: 2858-2863. https://doi.org/10.1016/j.foodchem.2013.05.103

Hudec J, Bakos D, Mravec D, Kobida L, Burdova M et al. (2006). Content of phenolic compounds and free polyamines in black chokeberry (*Aronia melanocarpa*) after application of polyamine biosynthesis regulators. Journal of Agricultural and Food Chemistry 54 (10): 3625-3628. https://doi.org/10.1021/jf060299q

Ikegaya A, Toyoizumi T, Ohba S, Nakajima T, Kawata T et al. (2019). Effects of distribution of sugars and organic acids on the taste of strawberries. Food Science Nutrition 7 (7): 2419-2426. https://doi.org/10.1002/fsn3.1109

Jeppsson N (2000). The effect of cultivar and cracking on fruit quality in black chokeberry (*Aronia melanocarpa*) and hybrids between chokeberry and rowan (Sorbus). Gartenbauwissenschaft, 65: 93-98.

Jeppsson N, Johansson R (2000). Changes in fruit quality in black chokeberry (*Aronia melanocarpa*) during maturation. Journal Horticulture Science Biotechnology 75: 340-350. https://doi.org/10.1080/14620316.2000.11511247

Jurendić T, Ščetar M (2021). *Aronia melanocarpa* products and by-products for health and nutrition: a review. Antioxidants 10 (7): 1052. https://doi.org/10.3390/antiox10071052

Kulling SE, Rawel HM (2008). Chokeberry (*Aronia melanocarpa*) - a review on the characteristic components and potential health effects. Planta Medica 74 (13): 1625-1634. https://doi.org/10.1055/s-0028-1088306

Ochmian I, Grajkowski J, Smolik M (2012). Comparison of some morphological features, quality and chemical content of four cultivars of chokeberry fruits (*Aronia melanocarpa*). Notulae Botanicae Horti-Agrobotnici-Cluj-Napoca 40 (1): 253-260. https://doi.org/10.15835/nbha4017181

Özder A (2021). Determination of growth performances some aronia (*Aronia melanocarpa* L.) cultivars. Aydın Adnan Menderes University, Graduate School of Natural and Applied Sciences, Department of Horticulture Aydın, Türkiye.

Poyraz Engin S, Boz Y (2019). Aronia (*Aronia melanocarpa* (Michx) Elliot) cultivation in Turkey and in the world. Bahçe (special issue 1): 247-252.

Poyraz Engin S, Mert C (2020). The effects of harvesting time on the physicochemical components of aronia berry. Turkish Journal of Agriculture and Forestry 44 (4): 371-370. https://doi.org/10.3906/tar-1903-130

Ristvey A, Mathew S (2011). Aronia: cultural and production considerations as an alternative crop. International Plant Propagators' Society. Combined Proceedings 61: 463-468.

Rohrer JR, Robertson KR, Phipps JB (1994). Floral morphology of Maloideae (Rosaceae) and its systematic relevance. American Journal of Botany 81 (15): 574-581. https://doi.org/10.1002/j.1537-2197.1994.tb15487.x

Schafhalter AK, Fuchs H, Pfannhauser W (1998). Solid-phase extraction (SPE)—a comparison of 16 materials for the purification of anthocyanins from *Aronia melanocarpa* var Nero. Journal of the Science of Food and Agriculture, 78 (3): 435-440. https://doi.org/10.1002/(SICI)1097-0010(199811)78:3<435::AID-JSFA139>3.0.CO;2-Q

Shahin L, Phaal SS, Vaidya BN, Brown JE, Joshee N (2019). Aronia (chokeberry): an underutilized, highly nutraceutical plant. Journal of Medicinally Active Plants 8 (4): 46-63. https://doi.org/10.7275/q651-2w57

Sosnowska D, Podsędek A, Kucharska AZ, Redzynia M, Opęchowska M (2016). Comparison of in vitro anti-lipase and antioxidant activities, and composition of commercial chokeberry juices. European Food Research and Technology 242: 505-515. https://doi.org/10.1007/s00217-015-2561-4

Spanos GA, Wrolstad RE (1990). Influence of processing and storage on the phenolic composition of Thompson seedless grape juice. Journal of Agricultural and Food Chemistry 38 (7): 1565-1571. https://doi.org/10.1021/jf00097a030

Strik B, Finn C, Wrolstad R (2003). Performance of chokeberry (*Aronia melanocarpa*) in Oregon, USA. Acta Horticulturae 626: 439-443. https://doi.org/10.17660/ActaHortic.2003.626.61

Strigl AW, Leitner E, Pfannhauser W (1995). Qualitative and quantitative analyses of the anthocyans in black chokeberries (*Aronia melanocarpa* Michx. Ell.) by TLC, HPLC and UV/VIS-spectrometry. Zeitschrift für Lebensmittel-Untersuchung und Forschung, 201 (3): 266-268. https://doi.org/10.1007/BF01193001

Toldham-Andersen TB, Hansen P (1997). Growth and development in black currant (*Ribes nigrum*). III. Seasonal changes in sugars, organic acids, chlorophyll and anthocyanins and their possible metabolic background. Journal of Horticultural Science 72 (1): 155-169. https://doi.org/10.1080/14620316.1997.11515502

Tolić MT, Krbavčić IP, Vujević P, Milinović B, Jurčević IL et al. (2017). Effects of weather conditions on phenolic content and antioxidant capacity in juice of chokeberries (*Aronia melanocarpa* L.). Polish Journal of Food and Nutrition Sciences 67 (1): 67-74. http://dx.doi.org/10.1515/pjfns-2016-0009

Wangensteen H, Braunlich M, Nikolic V, Malterud K, Slimesta R (2014). Anthocyanins, proanthocyanidins and total phenolics in four cultivars of aronia: antioxidant and enzyme inhibitory effects. Journal of Functional Foods 7: 746-752. https://doi.org/10.1016/j.jff.2014.02.006

Williner MR, Pirovani ME, Guemes DR (2003). Ellagic acid content in strawberries of different cultivars and ripening stages. Journal of the Science of Food and Agriculture 83 (8): 842-845. https://doi.org/10.1002/jsfa.1422

Wu X, Gu L, Prior RL, McKay S (2004). Characterization of anthocyanins and proanthocyanidins in some cultivars of *Ribes*, *Aronia* and *Sambucus* and their antioxidant capacity. Journal of Agriculture Food Chemistry 52 (26): 7846-7856. https://doi.org/10.1021/jf0486850

Yang H, Kim YJ, Shin Y (2019). Influence of ripening stage and cultivar on physicochemical properties and antioxidant compositions of aronia grown in South Korea. Foods 8 (598): 2-16. https://doi.org/10.3390/foods8120598

Yılmaz A, Güler E, Soydemir HE, Demirel S, Mollahaliloğlu S et al. (2021). Miracle plant: black chokeberry (*Aronia melanocarpa*). MAS Journal of Applied Sciences 6 (1): 83-94. http://dx.doi.org/10.52520/masjaps.20

Zheng W, Wang SY (2003). Oxygen radical absorbing capacity of phenolics in blueberries, cranberries, chokeberries and lingonberries. Journal of Agriculture Food Chemistry 51 (2): 502-509. https://doi.org/10.1021/jf020728u