

Assessment of biochemical composition and antioxidant activity in a cherry (*Prunus avium* L.) genotype from Yahyalı, Türkiye

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Abstract

This study investigated the biochemical characteristics of cherry (*Prunus avium* L.) fruits of a genotype in terms of phenolic compounds, flavonoids, antioxidant activity, and organic acid profiles. The results of the correlation analysis revealed strong positive relationships between total phenolic content and specific phenolic acids, as well as between total flavonoid content and DPPH antioxidant activity. Principal component analysis (PCA) demonstrated that phenolic compounds were decisive in explaining the total variance and that cherry fruits exhibited a structure characterized by the co-variation of biochemical components. The findings contribute to a better understanding of biochemical interactions in cherry fruits and provide important insights into the evaluation of relationships between phenolic compound profiles and antioxidant capacity.

Keywords: Cherry, Phenolic Compounds, Flavonoids, Antioxidant Activity, Organic Acids, PCA

INTRODUCTION

Cherry (*Prunus avium* L.) belongs to the Rosaceae family and is a stone fruit species widely cultivated in temperate climates with high economic value; the genotype studied represents a valuable genetic resource for biochemical characterization. Türkiye is considered one of the important genetic diversity centers for cherry, and the Central Anatolia Region is particularly rich in wild cherry genotypes. The region hosts numerous wild cherry trees exhibiting diverse morphological characteristics, which make a significant contribution to biological diversity (İlhan, 2023). The Rosaceae family, widely distributed worldwide, comprises approximately 120 genera and nearly 6.000 species and has significant ecological and economic importance (Reim et al., 2023). It includes many economically valuable fruit species such as apple, pear, quince, peach, plum, and cherry, most of which are cultivated in temperate regions. Members of the Rosaceae family play a major role in fruit production for both fresh consumption and processed products (Sevindik et al., 2024). In addition to its distinctive color, taste, and aroma characteristics, cherry fruit is among the plant materials that attract considerable interest from researchers due to its rich biochemical composition (McCune et al., 2011; Serradilla et al., 2011). Cherry (*Prunus avium* L.) is an important fruit species distinguished by its ability to adapt to diverse ecological conditions, its high economic value, and its rich nutritional profile, being abundant in phenolic compounds, anthocyanins, vitamins, and minerals (Yılmaz & Yılmaz, 2025). Phenolic compounds, flavonoids, and organic acids present in the fruit constitute the main components of the chemical structure of cherries (İlhan & Artık 2021).

Phenolic compounds are among the most important bioactive constituents synthesized in plants in association with defense mechanisms and physiological processes, and they stand out due to their strong antioxidant properties. It has been reported that cherry fruits contain various phenolic compounds such as protocatechuic acid, gentisic acid, caffeic acid, coumaric acid, and ellagic acid (Kim et al., 2003; Ferretti et al., 2010). The amounts and distribution of these compounds vary depending on species, cultivar, environmental conditions, and cultivation practices (Usenik et al., 2008; İlhan & Artık, 2021).

Total phenolic content and total flavonoid content are fundamental parameters widely used to determine the antioxidant capacity of fruits. Among the methods used to assess antioxidant activity, the DPPH assay is frequently preferred due to its rapid and reproducible results (Brand-Williams et al., 1995). Previous studies have demonstrated that the antioxidant activity measured in cherry fruits is closely associated with their phenolic compound content (Gonçalves et al., 2004; İlhan & Artık, 2021).

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Organic acids constitute another important group within the chemical composition of cherry fruits. Organic acids such as oxalic acid, tartaric acid, acetic acid, and citric acid play a decisive role in the acidity level and chemical balance of the fruit (Belitz et al., 2009). Evaluating these compounds together with phenolic substances enables a more comprehensive characterization of the biochemical structure of cherry fruits.

Statistical analyses play a crucial role in elucidating the relationships among biochemical components. Pearson correlation analysis allows the determination of linear relationships between variables, while Principal Component Analysis (PCA) contributes to a clearer understanding of data structure by summarizing a large number of variables into a smaller number of components (Jolliffe & Cadima, 2016). These methods enable a holistic evaluation of the relationships among phenolic compounds, organic acids, and antioxidant activity.

This study was conducted to determine the biochemical characteristics and antioxidant capacity of fruits from a cherry (*Prunus avium* L.) genotype grown in the Yahyalı district of Kayseri province. Within this framework, total phenolic content, total flavonoid content, and antioxidant capacity of cherry fruits were investigated, with the aim of identifying the main chemical constituents present in the fruit and evaluating their distribution within the overall chemical structure. The findings were interpreted in light of statistical analyses, with the objective of supporting the existing literature on the biochemical composition of cherry fruits and contributing to the presentation of current data within a clearer and more comprehensive framework.

MATERIALS AND METHODS

Plant Material

The plant material used in this study was obtained from fruits of a cherry (*Prunus avium* L.) genotype naturally growing in a wild population in the Yahyalı district of Kayseri province (38°06'N, 35°22'E; approx. 1150 m a.s.l.) during the 2024 harvest season. Harvesting was carried out at the commercial maturity stage, based on skin color and soluble solids content typical for commercial maturity and samples exhibiting uniform characteristics and free from physical damage were selected. The experiment was conducted with three replications, and 50 cherry fruits randomly selected were used for each replication.

Although a continental climate generally prevails in the region, Mediterranean climatic conditions dominate in the southern parts of the district, characterized by lower altitudes and forested areas. The average temperature is approximately 20 °C during the summer months and 18 °C in winter, while the annual maximum average precipitation is around 500 mm. The harvested fruits were transported to the laboratory prior to analysis and subjected to preliminary sample preparation.

Sample Preparation

After being transported to the laboratory, the cherry fruits were washed with distilled water to remove any foreign materials from their surfaces, and surface moisture was eliminated using paper towels. The fruits were separated from their pits and homogenized using a laboratory blender until a uniform consistency was obtained, resulting in fruit juice.

For the determination of phenolic compounds and antioxidant activity, 20 g of the obtained juice was mixed with 100 mL of 80% methanol and extracted at room temperature for 3 h in darkness with intermittent shaking. Following the extraction process, the mixture was centrifuged at 4000 rpm for 20 min at 4 °C, and the supernatant was filtered through Whatman No. 1 filter paper. The resulting extracts were stored in amber vials at +4 °C until analysis, and all procedures were performed in triplicate (Singleton et al., 1999).

Determination of Total Phenolic Content

The total phenolic content of the fruit juice samples was determined using the Folin–Ciocalteu colorimetric method (Gamez-Meza et al., 1999). Prior to analysis, the samples were clarified by passing them through an appropriate membrane filter. For the assay, 0.5 mL of extract was mixed with 2.5 mL of 10% (v/v) Folin–Ciocalteu reagent. After 5 min, 2.0 mL of 7.5% (w/v) sodium carbonate solution was added, and the mixture was incubated at room temperature in the dark for 30 min. Gallic acid was used as the reference phenolic compound for the construction of the standard curve. Methanolic gallic acid solutions (0–200 mg L⁻¹) were prepared for calibration. Absorbance measurements were carried out at a wavelength of 765 nm using a UV–Vis spectrophotometer. The results were expressed as mg gallic acid equivalents per liter (mg GAE L⁻¹).

Determination of Total Flavonoid Content

The total flavonoid content of the samples was determined using a colorimetric method based on aluminum chloride (AlCl₃) (Woisky & Salatino, 1998). Prior to analysis, the samples were diluted with distilled water to a final concentration of 500 ppm. For the assay, 0.5 mL of diluted sample was mixed with 1.5 mL of methanol, 0.1 mL of 10% AlCl₃ solution, 0.1 mL of 1 M potassium acetate, and 2.8 mL of distilled water. The reaction mixture was incubated at room temperature for 30 min in the dark. For the construction of the standard curve, methanolic quercetin solutions (0–100 mg L⁻¹) were prepared, and absorbance measurements were performed at a wavelength of 415 nm using a UV–Vis spectrophotometer. The results were expressed as µg QE mL⁻¹.

Analysis of Phenolic Compounds by HPLC

Phenolic compounds in the fruit juice samples were determined using an Agilent 1260 HPLC system. Chromatographic separation was carried out on an ACE-C18 column (4.6 mm × 150 mm, 5 µm), with ultrapure water containing 0.02%

trifluoroacetic acid (TFA) used as mobile phase A and methanol containing 0.02% TFA used as mobile phase B. The flow rate was maintained at 0.5 mL min⁻¹. The column temperature was kept constant at 25 °C and the injection volume was 10 µL.

The gradient elution program was applied as follows: the run started with 25% B, increased to 30% B between 5–10 min, raised to 45% B between 10–16 min, held at 45% B between 16–18 min, increased to 80% B between 18–25 min, held at 80% B between 25–30 min, and finally returned to 25% B between 30–40 min (Wen et al., 2005). Detection was performed using a Diode Array Detector (DAD) at multiple wavelengths (225, 254, 280, 305, and 330 nm) to ensure accurate identification of the target phenolic compounds. Syringic acid, protocatechuic acid, and gallic acid were monitored at 280 nm; vanillic acid at 225 nm; p-coumaric acid at 305 nm; and caffeic acid and chlorogenic acid at 330 nm.

Quantitative Analysis of Organic Acids and Phenolic Compounds (HPLC-UV)

Organic acids and phenolic compounds in the fruit juice samples were quantitatively analyzed using an Agilent 1260 HPLC system (Agilent Technologies, CA, USA), equipped with ChemStation software, a quaternary pump, an autosampler and a DAD detector. Separation was achieved using an ACE-C18 column (4 mm × 150 mm, 5 µm; Hichrom Ltd.). An isocratic elution method was applied with 10 mM potassium phosphate buffer adjusted to pH 2.2 as the mobile phase. The flow rate was set at 1 mL min⁻¹, and the injection volume was 20 µL. Quantification was performed at a wavelength of 245 nm for ascorbic acid and 210 nm for the other organic acids, while phenolic compounds were detected at their respective UV absorption maxima (Fu et al., 2015).

Determination of Antioxidant Capacity

The antioxidant capacity of the fruit juice samples was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay (Ebrahimzadeh et al., 2008). The stock reagent solution (6×10^{-5} M) was prepared by dissolving 0.0024 g of DPPH in 100 mL of methanol. A working DPPH solution (40 mg 100g⁻¹) was then obtained by diluting the stock solution with methanol. In the assay, 300 µL of the extract was mixed with 5700 µL of the DPPH working solution in a 10 mL test tube. The reaction mixture was vortexed thoroughly and incubated in the dark at room temperature for 60 minutes. All measurements were performed in triplicate (n = 3) and results were expressed as mean ± standard deviation (SD). After incubation, the absorbance of the reaction mixture was measured at 517 nm using a UV-Vis spectrophotometer (Shimadzu UV-1800). A control solution without extract was also prepared and its absorbance was measured at the same wavelength. The antioxidant activity was calculated using the following equation:

$$\text{Antioxidant activity (\%)} = [(AC(O)_{517} - AA(t)_{517}) / AC(O)_{517}] \times 100$$

Here, AC₅₁₇ represents the initial absorbance of the control solution, while AA₅₁₇(t) denotes the absorbance of the sample solution measured after 1 hour.

Statistical Analysis

Statistical evaluation of the obtained data was performed using IBM SPSS Statistics 21 software (IBM Corp. (2012)). All experiments were conducted in triplicate, and the results were expressed as mean ± standard deviation (SD) and coefficient of variation (%CV). Relationships among the parameters were examined using Pearson correlation analysis, while the main relationships between variables and the sources of variation within the data set were evaluated using Principal Component Analysis (PCA).

RESULTS AND DISCUSSION

Biochemical and Antioxidant Properties of Cherry Fruits

In this study, descriptive statistics of total phenolic content, total flavonoid content, antioxidant activity, as well as phenolic compound and organic acid compositions of fruits from a cherry (*Prunus avium* L.) genotype are presented in Table 1.

As shown in Table 1, the total phenolic content (TPC) of cherry fruits ranged from 617.00 to 622.00 mg GAE L⁻¹, with a mean value of 619.67 ± 2.52 mg GAE L⁻¹. The low coefficients of variation indicate that the biochemical parameters examined exhibited limited variability among the samples. This finding suggests that the measurements obtained for the cherry fruits analyzed in this study were closely clustered and demonstrated a certain level of consistency. In particular, the low %CV values for total phenolic and total flavonoid contents support the reliability of the measurements. However, it should be noted that this consistency may be associated with the fact that the samples were obtained from the same cultivation area and harvested during the same period.

Indeed, García-Villegas et al. (2024) and Boskov et al. (2023) reported that total phenolic content in cherry fruits varies between 550 and 850 mg GAE L⁻¹ depending on cultivation conditions. Studies conducted under Turkish ecological conditions have also indicated that TPC values may show significant differences depending on genotype and harvest period (Kazazic et al., 2024; Oçkun et al., 2022). In this context, the TPC values obtained in the present study fall within the ranges reported in the literature and are consistent with results obtained under similar ecological conditions.

Table 1. Descriptive statistics of biochemical parameters in fruits of a cherry (*Prunus avium* L.) genotype

Variable	Abbreviation	Unit	Minimum	Maximum	Mean±SD	%CV
Total Phenolic	TPC	mg GAE L ⁻¹	617.00	622.00	619.67±2.52	0.41
Total Flavonoids	TFC	µg QE mL ⁻¹	399.00	404.00	401.67±2.52	0.63
Antioxidant Activity	DPPH	%	77.00	81.00	79.00±2.00	2.53
Phenolic Compounds						
Protocatechuic Acid	ProA	mg 100g ⁻¹	2.37	2.74	2.50±0.21	8.40
Gentisic Acid	GenA	mg 100g ⁻¹	31.60	34.21	32.97±1.31	3.97
Caffeic Acid	CafA	mg 100g ⁻¹	1.30	1.53	1.40±0.12	8.57
Coumaric Acid	CoumA	mg 100g ⁻¹	1.35	1.75	1.53±0.20	13.07
Ellagic Acid	EllA	mg 100g ⁻¹	8.87	9.24	9.00±0.21	2.33
Organic Acid						
Oxalic Acid	OxaA	mg 100g ⁻¹	162	166	164.33±2.08	1.27
Tartaric Acid	TartA	mg 100g ⁻¹	618	638	626.67±10.26	1.64
Acetic Acid	AceA	mg 100g ⁻¹	276	293	286.67±9.29	3.24
Citric Acid	CitA	mg 100g ⁻¹	1.00	2.00	1.43±0.51	35.66

*SD: Standard Deviation; CV: Coefficient of Variation

Total flavonoid content (TFC) ranged between 399.00 and 404.00 µg QE mL⁻¹, with an average value of 401.67 ± 2.52 µg QE mL⁻¹. Considering the substantial contribution of flavonoids to the pool of phenolic compounds, these results highlight the richness of the phytochemical composition of cherry fruit juice. Comparable flavonoid levels have been reported in recent studies, emphasizing that flavonoids particularly anthocyanins and flavonols play a decisive role in the antioxidant and anti-inflammatory effects of cherries (Correia et al., 2017; Afonso et al., 2020). The low %CV value (0.63%) indicates that flavonoid distribution remained relatively stable under the conditions of this study.

DPPH antioxidant activity ranged from 77.00% to 81.00%, with a mean value of 79.00 ± 2.00%. These values indicate that cherry fruits possess a high antioxidant capacity. The strong relationship between phenolic compounds and antioxidant activity has been widely reported in both stone fruits and berry species (Prvulovic et al., 2012; Vangdal et al., 2007). In the literature, hydroxybenzoic and hydroxycinnamic acid derivatives have been shown to make significant contributions to DPPH radical scavenging activity. In the present study, the high DPPH values were associated with the presence of phenolic compounds such as ellagic acid, gentisic acid, and caffeic acid, which is consistent with previous reports (García-Villegas et al., 2024; Dulyanska et al., 2022).

Evaluation of the phenolic compound profile revealed that gentisic acid (32.97 ± 1.31 mg 100 g⁻¹) and ellagic acid (9.00 ± 0.21 mg 100 g⁻¹) were the predominant compounds. The presence of these compounds at high levels has been reported to support the beneficial health effects of cherries. Numerous studies have documented the antioxidant and neuroprotective effects of gentisic acid, as well as the anticancer and antimicrobial properties of ellagic acid (Sánchez-Bravo & Noguera-Artiaga, 2024; Raya-Morquecho et al., 2025; García-Villegas et al., 2024). The lower concentrations of protocatechuic, caffeic, and coumaric acids suggest that these compounds may be more sensitive to genotype and environmental factors (Oçkun et al., 2022; Akšić et al., 2007).

Analysis of the organic acid profile indicated that tartaric acid (626.67 ± 10.26 mg 100 g⁻¹) and acetic acid (286.67 ± 9.29 mg 100 g⁻¹) were the major organic acids. Previous studies have reported that tartaric acid contributes to the characteristic acidic taste of cherries, while acetic acid plays a role in aroma formation (Famiani et al., 2015; Sánchez-Bravo & Noguera-Artiaga, 2024). The high coefficient of variation for citric acid (35.66%) suggests that this compound is sensitive to maturity stage and environmental conditions, and similar findings have been reported in studies on stone fruits (Ockun et al., 2022).

Correlations Among Biochemical Parameters

As shown in Table 2, positive relationships were observed among total phenolic content (TPC), total flavonoid content (TFC), and DPPH antioxidant activity of cherry fruits.

In particular, strong positive correlations were found between total phenolic content (TPC) and gentisic acid (GenA) and protocatechuic acid (ProA) ($r = 1.00^*$ and $r = 0.84$, respectively). This finding supports the direct contribution of phenolic compounds to antioxidant activity. Similarly, a strong positive correlation ($r = 0.99$) was detected between total flavonoid content (TFC) and DPPH antioxidant activity. These results are consistent with previous studies demonstrating the relationship between phenolic compound content and antioxidant capacity in different cherry genotypes; Usenik et al. (2008) and Nunes et al. (2021) reported positive correlations between TPC and DPPH activity. In this context, the present findings are in line with trends reported in the existing literature.

Significant correlations were also observed among individual phenolic compounds. For instance, protocatechuic acid showed strong correlations with caffeic acid (CafA) and ellagic acid (EllA) ($r = 0.95$ and $r = 1.00^{**}$, respectively), whereas coumaric acid (CoumA) exhibited negative relationships with these compounds ($r = -0.83$). These results indicate that phenolic compounds in cherry fruits exhibit a co-varying metabolic profile. Similar metabolic relationships have been reported by Lee et al. (2007) and İlhan (2023) in studies examining the associations between hydroxycinnamic acid derivatives,

flavonoids, phenolic profiles, and antioxidant activity in different cherry cultivars. The correlation values reported in those studies are consistent with the findings of the present study.

Table 2. Pearson correlation coefficients among biochemical parameters fruits from a cherry (*Prunus avium* L.) genotype

		TPC	TFC	DPPH	ProA	GenA	CafA	CoumA	EllA	OxaA	TartA	AceA	CitA
TPC	r	1	0.68	0.60	0.84	1.00*	0.63	-1.00*	0.84	-0.64	0.40	-0.73	0.94
	Sig.		0.52	0.59	0.36	0.02	0.57	0.02	0.36	0.56	0.74	0.48	0.22
TFC	r	0.68	1	0.99	0.19	0.66	-0.14	-0.71	0.19	0.13	0.94	-0.00	0.40
	Sig.	0.52		0.07	0.88	0.54	0.91	0.50	0.88	0.92	0.22	0.99	0.74
DPPH	r	0.60	0.99	1	0.07	0.57	-0.25	-0.62	0.07	0.24	0.97	0.11	0.29
	Sig.	0.59	0.07		0.95	0.61	0.84	0.58	0.95	0.85	0.14	0.93	0.81
ProA	r	0.84	0.19	0.07	1	0.86	0.95	-0.83	1.00**	-0.95	-0.15	-0.98	0.98
	Sig.	0.36	0.88	0.95		0.34	0.21	0.38	0.00	0.20	0.90	0.12	0.14
GenA	r	1.00*	0.66	0.57	0.86	1	0.65	-0.99*	0.86	-0.66	0.37	-0.75	0.95
	Sig.	0.02	0.54	0.61	0.34		0.55	0.04	0.34	0.54	0.76	0.46	0.20
CafA	r	0.63	-0.14	-0.25	0.95	0.65	1	-0.61	0.95	-1.00**	-0.46	-0.99	0.85
	Sig.	0.57	0.91	0.84	0.21	0.55		0.59	0.21	0.01	0.69	0.09	0.35
CoumA	r	-1.00*	-0.71	-0.62	-0.83	-0.10*	-0.61	1	-0.83	0.61	-0.43	0.72	-0.93
	Sig.	0.02	0.50	0.58	0.38	0.00	0.59		0.38	0.58	0.72	0.49	0.24
EllA	r	0.84	0.19	0.07	1.00**	0.86	0.95	-0.83	1	-0.95	-0.15	-0.98	0.98
	Sig.	0.36	0.88	0.95	0.00	0.34	0.21	0.38		0.20	0.90	0.12	0.14
OxaA	r	-0.64	0.13	0.24	-0.95	-0.66	-1.00**	0.61	-0.95	1	0.45	0.99	-0.86
	Sig.	0.56	0.92	0.85	0.20	0.54	0.01	0.58	0.20		0.70	0.09	0.34
TartA	r	0.40	0.94	0.97	-0.15	0.37	-0.46	-0.43	-0.15	0.45	1	0.33	0.07
	Sig.	0.74	0.22	0.14	0.90	0.76	0.69	0.72	0.90	0.70		0.79	0.96
AceA	r	-0.73	-0.00	0.11	-0.98	-0.75	-0.99	0.72	-0.98	0.99	0.33	1	-0.92
	Sig.	0.48	0.10	0.93	0.12	0.46	0.09	0.49	0.12	0.09	0.79		0.26
CitA	r	0.94	0.40	0.29	0.98	0.95	0.85	-0.93	0.98	-0.86	0.07	-0.92	1
	Sig.	0.22	0.74	0.81	0.14	0.20	0.35	0.24	0.14	0.34	0.96	0.26	

*.Correlation is significant at the 0.05 level; **.Correlation is significant at the 0.01 level.

With respect to organic acids, tartaric acid (TartA) and acetic acid (AceA) showed both positive and negative correlations with certain phenolic compounds. A strong negative relationship was observed between oxalic acid (OxaA) and caffeic acid (CafA) ($r = -1.00^{**}$), indicating that organic acid metabolism interacts in a complex manner with the phenolic compound profile. Similar trends have been reported by Dulyanska et al. (2022) in different cherry genotypes and by Brand-Williams et al. (1995) in wild fruit species, where organic acid phenolic compound interactions exhibited both positive and negative correlations. In this respect, the results obtained in the present study support the observations of previous research.

Overall, the correlation analyses revealed interactions among phenolic compounds, flavonoids, antioxidant activity, and organic acids in cherry fruits and showed consistency with previous studies. In particular, the contribution of TPC and TFC to antioxidant capacity, as well as the reciprocal relationships between phenolic compound profiles and organic acid metabolism, were found to be in agreement with trends reported in the literature (Usenik et al., 2008; Nunes et al., 2021; Dulyanska et al., 2022). These findings demonstrate that phenolic compounds and organic acids in cherry fruits not only interact with each other but also confirm the phenolic–antioxidant relationships previously reported in the literature.

Principal Component Analysis (PCA) of Biochemical Components

To better understand the variance of the biochemical components of fruits from a cherry (*Prunus avium* L.) genotype and their interrelationships, principal component analysis (PCA) was performed, and the results are presented in Table 3. As shown in Table 3, two principal components (PC1 and PC2) accounted for 100% of the total variance, with PC1 contributing 67.68% and PC2 contributing 32.32%.

PC1 exhibited high loading values particularly for protocatechuic acid (ProA, 0.99), ellagic acid (EllA, 0.99), caffeic acid (CafA, 0.97), and citric acid (CitA, 0.96). This indicates that phenolic acids and certain organic acids display a co-varying profile. Similarly, studies conducted on different cherry genotypes by Usenik et al. (2008) and Nunes et al. (2021) reported that phenolic compounds are strongly associated with the antioxidant capacity of fruit juice and that specific phenolic acids occur at high levels simultaneously.

PC2, on the other hand, showed high positive loadings for total flavonoid content (TFC, 0.99), DPPH antioxidant activity (1.00), and tartaric acid (TartA, 0.98). These findings reveal that flavonoids and antioxidant activity vary together and that tartaric acid is associated with these components. Previous studies have demonstrated that flavonoids exhibit positive correlations particularly with DPPH and other antioxidant activities (Lee et al., 2007; İlhan, 2023).

Table 3. Principal component analysis (PCA) results and variance contributions of biochemical components in fruits of a cherry (*Prunus avium* L.) genotype

Variable	Abbreviation	PC1	PC2
Total Phenolic	TPC	0.80	0.59
Total Flavonoids	TFC	0.12	0.99
Antioksidan activity	DPPH	0.00	1.00
Protocatechuic Acid	ProA	0.99	0.07
Gentisic Acid	GenA	0.82	0.57
Cafeic Acid	CafA	0.97	-0.25
Coumaric Acid	CoumA	-0.79	-0.62
Ellagic Acid	EllA	0.99	0.07
Oxalic Acid	OxaA	-0.97	0.24
Tartaric Acid	TartA	-0.22	0.98
Acetic Acid	AceA	-0.99	0.11
Citric Acid	CitA	0.96	0.29
Eigenvalue	EigVal	8.12	3.88
Explained variance (%)	ExpVar	67.68	32.32
Cumulative variance (%)	CumVar	67.68	100.00

The PCA results also indicated that some compounds had negative loadings, with coumaric acid (CoumA, -0.79 and -0.62), oxalic acid (OxaA, -0.97), and acetic acid (AceA, -0.99) showing high negative loadings on PC1 and PC2. This suggests that these compounds vary inversely with other phenolic and organic acids and may play a balancing role in fruit metabolism. Similar metabolic relationships have been reported in PCA studies conducted on cherries and other stone fruit species (Brand-Williams et al., 1995; Dulyanska et al., 2022).

Overall, the PCA results revealed complex interactions among phenolic compounds, flavonoids, antioxidant activity, and organic acids in cherry fruit juice and were consistent with trends reported in the literature. In particular, the loading values of PC1 and PC2 clearly demonstrated the contribution of phenolic components in fruit juice to antioxidant capacity and the organic acid profile (Usenik et al., 2008; Nunes et al., 2021; Lee et al., 2007; İlhan, 2023).

CONCLUSION

This study comprehensively characterized the biochemical composition of cherry (*Prunus avium* L.) genotype fruits and evaluated the relationships among phenolic compounds, flavonoids, antioxidant activity, and organic acids. The strong positive correlations identified between total phenolic content and certain individual phenolic acids, as well as between total flavonoid content and DPPH antioxidant activity, indicate that phenolic compounds make a substantial contribution to the antioxidant capacity of cherry fruits. The results of the principal component analysis revealed that total phenolic content, total flavonoid content, and specific phenolic acids largely explained the variation among samples and that the distribution of these components within the fruit was interrelated. The positive and negative relationships observed between organic acids and phenolic compounds further demonstrate that the biochemical structure of cherry fruits represents a multicomponent and well-balanced system. The findings indicate that cherry fruits are rich in phenolic compounds and organic acids and that these constituents play a decisive role in antioxidant capacity. Overall, this study contributes to a better understanding of the biochemical characteristics of cherry fruits and suggests that the generated data may provide a scientific basis for future studies on cultivar development, cultivation strategies, and value-added product development.

Conflict of Interest

The authors declare no conflicts of interest.

Author Contribution

All authors contributed equally to the study design, data collection, analysis, and manuscript preparation.

REFERENCES

- Afonso, S., Oliveira, I. V., Meyer, A. S., Aires, A., Saavedra, M. J., & Gonçalves, B. (2020). Phenolic Profile and Bioactive Potential of Stems and Seed Kernels of Sweet Cherry Fruit. *Antioxidants*, 9(12), 1295. <https://doi.org/10.3390/antiox9121295>
- Akšić, M. F., Nikolić, D., & Rakonjac, V. (2007). Variability components and heritability of pomological and chemical characteristics in sour cherry clones of cultivar Montmorency. *Genetika*, 39(3), 297-306. <https://doi.org/10.2298/GENSR0703297F>
- Belitz, H.-D., Grosch, W., & Schieberle, P. (2009). Food chemistry (4th ed.). Springer.
- Boskov, D., Milatovic, D., Rakonjac, V., Zec, G., Hudina, M., Veberic, R., & Mikulic-Petkovsek, M. (2023). The Phenolic Profile of Sweet Cherry Fruits Influenced by Cultivar/Rootstock Combination. *Plants*, 12(1), 103. <https://doi.org/10.3390/plants12010103>
- Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT – Food Science and Technology*, 28(1), 25-30. [https://doi.org/10.1016/S0023-6438\(95\)80008-5](https://doi.org/10.1016/S0023-6438(95)80008-5)

- Correia, S., Schouten, R., Silva, A. P., & Gonçalves, B. (2017). Factors Affecting Quality and Health Promoting Compounds during Growth and Postharvest Life of Sweet Cherry (*Prunus avium* L.). *Frontiers in plant science*, 8, 2166. <https://doi.org/10.3389/fpls.2017.02166>
- Dulyanska, Y., Cruz-Lopes, L. P., Esteves, B., Ferreira, J. V., Domingos, I., Lima, M. J., Correia, P. M. R., Ferreira, M., Fragata, A., Barroca, M. J., Moreira da Silva, A., & Guiné, R. P. F. (2022). Extraction of Phenolic Compounds from Cherry Seeds: A Preliminary Study. *Agronomy*, 12(5), 1227. <https://doi.org/10.3390/agronomy12051227>
- Ebrahimzadeh, M. A., Hosseini-mehr, S. J., Hamidinia, A., & Jafari, M. (2008). Antioxidant and free radical scavenging activity of Feijoa sellowiana fruits peel and leaves. *Pharmacologyonline*, 1, 7-14
- Famiani, F., Battistelli, A., Moscatello, S., Cruz-Castillo, J. G., & Walker, R. P. (2015). The organic acids that are accumulated in the flesh of fruits: Occurrence, metabolism and factors affecting their contents - A review. *Revista Chapingo Serie Horticultura*, 21(2), 97–128. <https://doi.org/10.5154/r.chsh.2015.01.004>
- Ferretti, G., Bacchetti, T., Belleghia, A., & Neri, D. (2010). Cherry Antioxidants: From Farm to Table. *Molecules*, 15(10), 6993-7005. <https://doi.org/10.3390/molecules15106993>
- Fu, H. X., Zhang, L. L., He, B., Yue, P. X., & Gao, X. L. (2015). Analysis of organic acids in blueberry juice and its fermented wine by high-performance liquid chromatography. *Advance Journal of Food Science and Technology*, 9, 127-134. <https://doi.org/10.19026/ajfst.9.1947>
- Gamez-Meza, N., Noriega-Rodriguez, J. A., Medina-Juarez, L. A., Ortega-Garcia, J., Cazarez-Casanova, R., & Angulo-Guerrero, O. (1999). Antioxidant activity in soybean oil of extracts from Thompson grape bagasse. *JAOCs, Journal of the American Oil Chemists' Society*, 76(12), 1445-1447. <https://doi.org/10.1007/s11746-999-0182-4>
- García-Villegas, A., Fernández-Ochoa, Á., Alañón, M. E., Rojas-García, A., Arráez-Román, D., Cádiz-Gurrea, M. d. I. L., & Segura-Carretero, A. (2024). Bioactive Compounds and Potential Health Benefits through Cosmetic Applications of Cherry Stem Extract. *International Journal of Molecular Sciences*, 25(7), 3723. <https://doi.org/10.3390/ijms25073723>
- Gonçalves, B., Landbo, A. K., Knudsen, D., Silva, A. P., Moutinho-Pereira, J., Rosa, E., & Meyer, A. S. (2004). Effect of ripeness and postharvest storage on the phenolic profiles of Cherries (*Prunus avium* L.). *Journal of agricultural and food chemistry*, 52(3), 523–530. <https://doi.org/10.1021/jf030595s>
- IBM Corp. (2012). *IBM SPSS Statistics for Windows, Version 21.0* [Computer software]. Armonk, NY: IBM Corp.
- İlhan, G. (2023). Wild Sweet Cherry (*Prunus avium* L.) Genotypes: Morphological, Biochemical, and Antioxidant Diversity. *Research in Agricultural Sciences*, 54(3), 124-129. <https://doi.org/10.5152/AUAF.2023.23151>
- İlhan, Ö., & Artık, N. (2021). Determination of some physicochemical properties and aroma components of sweet cherries (*Prunus avium*) grown in different locations. *European Journal of Science and Technology*, 21, 437–443. <https://doi.org/10.31590/ejosat.818911>
- Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: a review and recent developments. *Philosophical transactions. Series A, Mathematical, physical, and engineering sciences*, 374(2065), 20150202. <https://doi.org/10.1098/rsta.2015.0202>
- Kazacic, M., Mehic, E., Aliman, J., & Djapo, M. (2024). The bioactive compounds of sweet cherry fruits influenced by cultivar/rootstock combination. *Horticultural Science*, 51(1), 1–10. <https://doi.org/10.17221/47/2023-HORTSCI>
- Kim, D.O., Jeong, S. W., & Lee, C. Y. (2003). Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. *Food Chemistry*, 81(3), 321-326. [https://doi.org/10.1016/S0308-8146\(02\)00423-5](https://doi.org/10.1016/S0308-8146(02)00423-5)
- Lee, B.-B., Cha, M.-R., Kim, S.Y., Park, E., Park, H.-R., & Lee, S.-C. (2007). Antioxidative and anticancer activity of extracts of cherry (*Prunus serrulata* var. *spontanea*) blossoms. *Plant Foods for Human Nutrition*, 62(2), 79-84. <https://doi.org/10.1007/s11130-007-0045-9>
- McCune, L. M., Kubota, C., Stendell-Hollis, N. R., & Thomson, C. A. (2011). Cherries and health: a review. *Critical reviews in food science and nutrition*, 51(1), 1–12. <https://doi.org/10.1080/10408390903001719>
- Nunes, A. R., Gonçalves, A. C., Falcão, A., Alves, G., & Silva, L. R. (2021). *Prunus avium* L. (Sweet Cherry) By-Products: A Source of Phenolic Compounds with Antioxidant and Anti-Hyperglycemic Properties—A Review. *Applied Sciences*, 11(18), 8516. <https://doi.org/10.3390/app11188516>
- Oekun, M. A., Gercek, Y. C., Demirsoy, H., Demirsoy, L., Macit, I., & Oz, G. C. (2022). Comparative evaluation of phenolic profile and antioxidant activity of new sweet cherry (*Prunus avium* L.) genotypes in Turkey. *Phytochemical analysis : PCA*, 33(4), 564–576. <https://doi.org/10.1002/pca.3110>
- Prvulovic, D., Popovic, M., Malenčić, Đ., Ljubojevic, M., Barac, G., & Ognjanov, V. (2012). Phenolic content and antioxidant capacity of sweet and sour cherries. *Studia Universitatis Babeş-Bolyai. Chemia*, 57(4), 175-181.
- Raya-Morquecho, E. M., Aguilar-Zarate, P., Sepúlveda, L., Michel, M. R., Iliná, A., Aguilar, C. N., & Ascacio-Valdés, J. A. (2025). Ellagitannins and Their Derivatives: A Review on the Metabolization, Absorption, and Some Benefits Related to Intestinal Health. *Microbiology Research*, 16(6), 113. <https://doi.org/10.3390/microbiolres16060113>
- Reim, S., Schiffler, J., Braun-Lüllemann, A., Schuster, M., Flachowsky, H., & Höfer, M. (2023). Genetic and Pomological Determination of the Trueness-to-Type of Sweet Cherry Cultivars in the German National Fruit Genebank. *Plants*, 12(1), 205. <https://doi.org/10.3390/plants12010205>
- Sánchez-Bravo, P., & Noguera-Artiaga, L. (2024). Fruits Quality and Sensory Analysis. *Horticulturae*, 10(12), 1279. <https://doi.org/10.3390/horticulturae10121279>
- Serradilla, M. J., Lozano, M., Bernalte, M. J., Ayuso, M. C., López Corrales, M., & Gonzalez-Gomez, D. (2011). Physicochemical and bioactive properties evolution during ripening of ‘Ambrunés’ sweet cherry cultivar. *LWT – Food Science and Technology*, 44(1), 199-205. <https://doi.org/10.1016/j.lwt.2010.05.036>

- Sevindik, E., Korkom, Y. & Murathan, Z.T. (2024). Evaluating DNA barcoding using cpDNA *matK* and *rbcL* for species identification and phylogenetic analysis of *Prunus armeniaca* L. (Rosaceae) genotypes. *Genet Resour Crop Evol*, 71, 1825–1835. <https://doi.org/10.1007/s10722-023-01748-9>
- Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin–Ciocalteu reagent. *Methods in Enzymology*, 299, 152-178. [https://doi.org/10.1016/S0076-6879\(99\)99017-1](https://doi.org/10.1016/S0076-6879(99)99017-1)
- Usenik, V., Fabčič, J., & Štampar, F. (2008). Sugars, organic acids, phenolic composition and antioxidant activity of sweet cherry (*Prunus avium* L.). *Food Chemistry*, 107(1), 185–192. <https://doi.org/10.1016/j.foodchem.2007.08.034>
- Vangdal, E., Sekse, L., & Slimestad, R. (2007). Phenolics and other compounds with antioxidative effect in stone fruit- Preliminary results. *Acta Horticulturae*, 734, 331-336. <https://doi.org/10.17660/ActaHortic.2007.734.51>
- Yılmaz, Y., & Yılmaz, C. (2025). Eskişehir Ekolojik Koşullarında Bazı Kiraz Çeşitlerinin Fenolojik, Pomolojik ve Bazı Kimyasal Özelliklerinin Belirlenmesi. *Alatarım* , 24(1), 12 - 21.
- Wen, D., Li, C., Di, H., Liao, Y., & Liu, H. (2005). A universal HPLC method for the determination of phenolic acids in compound herbal medicines. *Journal of agricultural and food chemistry*, 53(17), 6624–6629. <https://doi.org/10.1021/jf0511291>
- Woisky, R. G., & Salatino, A. (1998). Analysis of propolis: some parameters and procedures for chemical quality control. *Journal of Apicultural Research*, 37(2), 99–105. <https://doi.org/10.1080/00218839.1998.11100961>