



Biochemical and Mineral Profiling of ‘Karaevrek’ Grape from the Perspective of Sustainability and Waste Management

Fatma Ergün¹ · Hikmet Bayam¹

Received: 9 May 2025 / Accepted: 6 October 2025 / Published online: 21 October 2025
© The author(s), exclusively licensed to Springer-Verlag GmbH Germany, a part of Springer Nature 2025

Abstract

Recent increases in population density, environmental pollution, and global warming necessitate more efficient use of food resources. Research into the utilisation and economic recovery of waste materials from food processing has gained momentum. This study investigates the health benefits of the ‘Karaevrek’ grape variety, cultivated in the Kayseri/İncesu region, by examining its antioxidant capacity, phenolic and flavonoid content, and mineral and bioactive compound profiles in the fruit flesh, grapeseeds, leaves, and pedicels. Notably, grapeseeds exhibited the highest total phenolic content (176.11 ± 3.15 mg gallic acid equivalents/g) and strongest antioxidant activity ($95.20 \pm 0.21\%$ radical scavenging; $352.00 \mu\text{g}$ trolox equivalents/mL Copper (II) Reducing Capacity), alongside the highest concentrations of all analysed minerals, particularly potassium (296.81 ppm), magnesium (122.22 ppm), and iron (8.96 ppm). Leaves (KL) displayed the highest flavonoid content (301.98 ± 6.44 mg quercetin equivalents/g), indicating complementary bioactive potential. Phosphorus was most abundant in the stem (2.73 ppm), while magnesium was prominent in fruit flesh (13.36 ppm). Gas Chromatography/Mass Spectrometry (GC-MS) analyses identified 54 compounds, including antioxidant hexadecanoic acid methyl ester and cardioprotective Vitamin E. The findings suggest that ‘Karaevrek’ grapes, particularly their grapeseeds, leaves, and pedicels, could be valuable natural additives in the food industry, emphasising the need for further studies on local varieties’ biochemical properties.

Keywords Karaevrek grape · *Vitis vinifera* L. · Mineral · Bioactive component · Inductively Coupled Plasma Mass Spectrometry (ICP-MS) · Sustainability

Introduction

Grapes (*Vitis vinifera* L.) are a fruit of significant importance for both table and industrial use, boasting a rich history of thousands of years and being abundant in taste and nutritional value. Known for their positive effects on human health due to the bioactive compounds they contain, grapes are widely consumed around the world (Averilla et al. 2019; Zhou et al. 2022). With an annual production of approximately 75 million tonnes, Europe is the continent where grapes are predominantly produced, and Türkiye is one of the key players in this production (Bashimov 2017). A substantial portion of grape production is allocated for fresh consumption, while the remaining part is processed or

dried for use in the food industry. However, during the processing of grapes, approximately 20–30% of the resulting waste materials are often discarded without utilisation, presenting a significant issue from a sustainability perspective (Kurćubić et al. 2024).

Türkiye is located between the continents of Asia and Europe, and its diverse climatic conditions provide a favourable geography for grape cultivation. The long-standing grape production in our country has contributed to an increase in local diversity, resulting in the emergence of over a thousand grape varieties (Güler et al. 2023). The ‘Karaevrek’ grape, cultivated in the İncesu district of Kayseri and registered with a geographical indication, holds a significant place among these local varieties. The ‘Karaevrek’ grape is distinguished by its unique morphological characteristics, flavour profile, and adaptability. The grape clusters are conical in shape, with short stems, and the flesh is colourless and sweet, typically containing 2–3 seeds. This variety is characterised by morphological features such as the structure of shoots and leaves, hairiness,

✉ Fatma Ergün
fatma.ergun@ahievran.edu.tr

¹ Department of Nutrition and Dietetics, Faculty of Health Sciences, Kırşehir Ahi Evran University, Kırşehir, Turkey

and anthocyanin density, and it has the potential to thrive in the volcanic tuff soils of the Kayseri region (İncesu Municipality, 2016). However, the majority of studies in the literature have focused on widely cultivated grape varieties, while the functional constituents, antioxidant profiles, and industrial utilisation potential of local varieties such as ‘Karaevrek’ have been largely overlooked. In recent years, particular emphasis has been placed on grape by-products, including seeds, skins, leaves, and stems, as rich sources of phenolic compounds, antioxidants, and dietary fibre with potential applications in the food, pharmaceutical, and cosmetic industries (Gülcü et al. 2020). In this context, the selection of the ‘Karaevrek’ grape variety is expected to contribute scientifically by promoting both the sustainable management of food waste and the valorisation of local biodiversity through the identification of its functional compound profile. The primary aim of this study is to analyse the biochemical compositions of the fruit flesh, grapeseed, leaves, and pedicel of the ‘Karaevrek’ grape, thereby evaluating these components in terms of their nutritional content and functional properties. The data obtained is intended to contribute to sustainable food production and to elucidate the potential for the reuse of grape components that are often considered waste. In light of increasing environmental concerns and in alignment with the United Nations Sustainable Development Goals for 2030, any scientific efforts directed towards the efficient use of natural resources and the reduction of food waste are of enormous significance (Sustainable Development Goals 2015; Goyeneche et al. 2022). This study aims to contribute to sustainable food systems by revealing the contents of various components of a local, geographically indicated grape variety in accordance with these objectives.

Materials and Methods

Sample Collection and Preparation of Methanol Extract

In this study, the plant sample used was the geographical indication product, ‘Karaevrek’ grape (*Vitis vinifera* L.). Plant samples were collected during the harvest season from grape clusters and leaves located on the same shoot, obtained from a private property in the İncesu district of Kayseri province, Türkiye (38°36′45.55″N, 35°11′16.66″E, 1130m elevation). The collected plant samples were separated into four groups: fruit flesh (KF), grapeseed (KG), leaf (KL), and pedicel (KP). The plant samples were then dried in the shade (Fig. 1). A total of 10g of the ground plant samples, processed into a homogeneous powder using a mechanical grinder, were weighed and placed into bottles. For each gram of sample, 20mL of methanol was



Fig. 1 Samples used in the study: (1: ‘Karaevrek’ grapefruit flesh, 2: ‘Karaevrek’ grape seed, 3: ‘Karaevrek’ grape pedicel, 4: ‘Karaevrek’ grape leaf)

added, resulting in a total of 200mL, and the mixture was stirred on a magnetic stirrer overnight. The extracts were filtered through Whatman filter paper. Subsequently, 50mL of methanol was added to the filtrate, stirred for 2h, and filtered again, with this process being repeated three times. The resulting methanol extracts were combined, and the methanol was evaporated using a rotary evaporator at 45 °C. The extracts were stored in the dark at +4 °C until further testing.

Determination of Total Phenolic Content

The total phenolic content of the methanol extracts obtained from plant samples was determined using the method described in the literature with the Folin-Ciocalteu reagent (Slinkard and Singleton 1977). From the extract solution prepared at a concentration of 1000 ppm (1 mg/mL), 100 µL was taken and mixed with 100 µL of Folin-Ciocalteu reagent (FCR) and 4.5 mL of distilled water. After 3 min, 300 µL of a 2% Na₂CO₃ solution was added. The mixture was allowed to stand at room temperature for 2h with intermittent stirring. The absorbance of the samples was measured at 760 nm. The concentrations of phenolic compounds were calculated according to the equation obtained from the standard gallic acid graph ($y=0.0012x-0.079$). The results were expressed as mg gallic acid equivalents (mg GAE/g).

Determination of Total Flavonoid Content

Total flavonoid content determination was performed on the methanol extract of plant samples according to the aluminium nitrate method described in the literature (Moreno et al. 2000). From the prepared extract solution at a concentration of 1000 ppm, 0.5 mL was pipetted into a tube, along with 0.1 mL of 1 M potassium acetate. After one minute, 0.1 mL of 10% aluminium nitrate was added, and

the mixture was shaken. The total volume was then adjusted to 5 mL with 96% ethanol. After an incubation period of 40 min, the absorbance value was measured at a wavelength of 415 nm. Quercetin was used as the standard. The concentrations of flavonoid compounds were calculated based on the equation obtained from the standard quercetin graph ($y = 0.0035x - 0.352$). The results were expressed as mg quercetin equivalents (mg QE/g).

Free Radical Scavenging Analysis

The 1,1-Diphenyl-2-picrylhydrazyl (DPPH) free radical was used to evaluate the hydrogen or electron-donating potential of the extracts and standard compounds (Blois 1958). Standard and extract solutions were prepared in methanol at various concentrations (20–80 µg/mL). 1.5 mL of DPPH solution (0.1 mM) was added to 0.5 mL of these solutions. The mixture was vigorously shaken and incubated at room temperature in the dark for 30 min. The absorbance of the solution was measured at 517 nm against methanol. 2,6-di-*t*-butyl-1-hydroxytoluene (BHT) was used as the standard. The percentage inhibition of free radicals (%I) was calculated using the following formula:

$$\%I = [(A_{\text{blank}} - A_{\text{sample}}) / A_{\text{blank}}] \times 100$$

Where: A_{blank} : Absorbance of the control reaction (solution containing all reagents except the standard or extract), A_{sample} : Absorbance of the reaction containing extract or standard substance.

The IC_{50} value is the effective concentration at which 50% of the DPPH radical is scavenged. IC_{50} values were calculated using the slope equation of the %I-concentration graphs drawn separately for each sample.

Cu²⁺ Reducing Antioxidant Capacity (CUPRAC)

The cupric reducing antioxidant capacity was determined according to the method of Apak et al. (2004). Firstly, solutions with different concentrations ranging from 50 to 500 µg/mL were prepared using Trolox. Subsequently, 1 mL of CuCl₂ (10 mM), 1 mL of Neocuproine (7.5 mM), and 1 mL of NH₄CH₃COO (1 M) solution were added to a tube. Then, 0.5 mL of the solution at different concentrations was added, and the total volume was adjusted to 4 mL with distilled water. After thorough mixing, the mixture was incubated at room temperature for 30 min with the cap closed, and the absorbance was measured at 450 nm against a blank. The same procedures were repeated for solutions prepared from plant extracts at a concentration of 1000 ppm. Each extract was measured in triplicate. The results were expressed as Trolox equivalents.

Gas Chromatography/Mass Spectrometry (GC/MS) Analysis

The GC-MS analysis of the plant samples was performed using the Shimadzu GCMS-QP2010 Ultra device. The GC was equipped with a fused silica capillary Rtx-5MS column (30 m × 0.25 mm i. d., film thickness 0.25 µm).

The ion source temperature was set to 300 °C. The interface temperature was determined to be 280 °C. The solvent exit was closed for 0.5 min. The total analysis time was set to 121 min. The gas chromatography (GC) analysis started at an initial temperature of 40.0 °C, held for 2 min, and then heated to 270 °C at a rate of 10 °C/min. Finally, it was held isothermally for 20 min. Helium was used as the carrier gas, with a flow rate set to 2 mL/min. For GC-MS detection, an electron ionisation system with ionisation energy of 70 eV was used. One microlitre of diluted samples (1/100 v/v in methanol) was injected into the device's heated section in splitless mode (Mothana et al. 2013).

Mineral Matter Determination by Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

The quantitative analysis of the elements Na, Mg, P, K, Ca, Mn, Fe, Cu, Zn, and Se that may be present in plant samples was conducted using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Öztürk et al. 2023). The measurement principle of the instrument is based on the ionisation of metals, their separation, and the detection of ions according to their mass-to-charge ratio (m/z). Initially, 0.1–0.2 g of the sample was taken, and 2 mL of concentrated HNO₃ and 3 mL of H₂O₂ were added. A specific temperature and pressure programme was applied in a microwave digestion system (closed system). The resulting clear solutions were collected and diluted to 10 mL with distilled water (Milestone brand). Prior to analysis, a series of calibration standards containing known concentrations of the elements to be analysed (0.1, 5, 10, 20, 30, 40, 50 ppb in HNO₃) were prepared. To verify the measurement parameters of the instrument, a calibration solution (200 ppb Li, Yb, Cs) was passed through the instrument for performance adjustment. Subsequently, a method containing the elements to be analysed was selected, and the standards were introduced to the instrument first. Thereafter, the analysis of the dissolved and diluted samples commenced. In addition to the elements to be determined, a solution containing a 200 ppb internal standard element (Sc, In) was introduced to the instrument. The dissolved samples were analysed using the Agilent 7900 ICP-MS device.

Table 1 Total phenolic and flavonoid compound amounts for the groups, along with CUPRAC and IC₅₀ results

Groups	TPC (mg GAE/g)	TFC (mg QE/g)	CUPRAC (μgTE/mL)	IC ₅₀ (μg/mL)
KF	76.66 ± 1.66 ^d	101.52 ± 0.43 ^d	5.70 ± 0.55 ^c	5323.79 ± 27.05 ^a
KG	176.11 ± 3.15 ^a	111.61 ± 1.85 ^c	352.00 ± 0.44 ^a	33.81 ± 2.77 ^c
KL	121.38 ± 0.96 ^c	301.98 ± 6.44 ^a	280.58 ± 15.24 ^b	288.53 ± 2.42 ^b
KP	125.83 ± 0.83 ^b	124.95 ± 0.92 ^b	339.54 ± 1.97 ^a	98.45 ± 1.44 ^{bc}
BHT	–	–	–	104.23 ± 3.86 ^{bc}

*The differences between the means indicated by the same letter are not significant at the $p < 0.05$ level

*KF (fruit flesh extract), KG (grape seed extract), KL (leaf extract), KP (pedicel extract), BHT (2,6-di-*t*-butyl-1-hydroxytoluene)

*TPC (total phenolic activity, GAE-gallic acid equivalent), TFC (total flavonoid activity, QE-quercetin equivalent), and IC₅₀ are the concentrations of the extract that inhibit 50% of the DPPH radical. CUPRAC (Copper (II) Reducing Capacity, TE-Trolox equivalent)

Statistical Analyses

The statistical analysis of the data obtained at the end of the study was conducted using the SPSS 22 statistical software package. One-way analysis of variance (ANOVA) was employed in the study (Genç and Soysal 2018). In cases where significant differences were observed, Duncan's test, a multiple comparison test, was used to determine which specific treatments or applications were responsible for the differences (Duggan et al. 2017). Additionally, a significance level of $p < 0.05$ was accepted for all calculations in the study.

Results

In the study, the phenolic contents of different parts of the 'Karaevrek' grape were determined using the Folin-Ciocalteu reagent, expressed as gallic acid equivalents (GAE). According to the results obtained, the highest phenolic content was found in the KG group at 176.11 ± 3.15 mg GAE/g, while the lowest value was recorded in the KF group at 76.66 ± 1.66 mg GAE/g (Table 1). These findings exhibit similar trends when compared to other studies in the literature. For instance, in a study examining the antioxidant properties and phenolic compound contents of grape seed and skin extracts from 'Cabernet Sauvignon', 'Kalecik Karası', and 'Narince' grape varieties, it was determined that the total phenolic compound content in seed extracts ranged from 522.49 to 546.50 mg GAE/g, while in skin extracts, it varied between 22.73 and 43.75 mg GAE/g (Baydar et al. 2011).

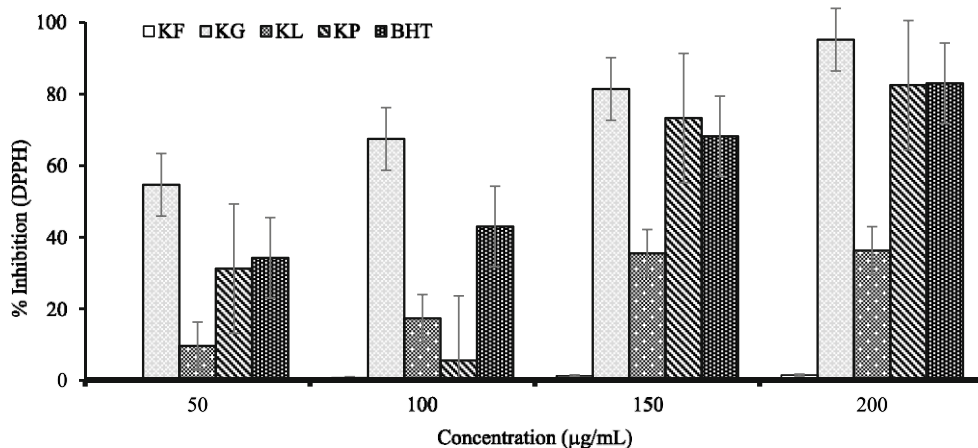
In their study conducted in 2024 with the 'Horoz Karası' grape variety, Koyuncu and Türkmen reported that the dried grapes contained 0.662 mg GAE/g, while the seeds had 1.542 mg GAE/g (Koyuncu and Türkmen 2024). Katalinic et al. (2013) noted differences in the total phenolic compound content of grape leaves collected at various times, reporting values that ranged from 18.8 ± 0.4 to 46.8 ± 0.4 g GAE/L. In their 2020 study on the 'Beltiz Kabarcık' grape variety, Balbaba and Bağcı quantified total phenolic con-

tent, expressing results in mg GAE/100 g. Their findings revealed that the total phenolic content in 'Beltiz Kabarcık' grapes ranged between 44.31 and 313.92 mg GAE/100 g. In a separate study conducted by Gündeşli et al. (2018), which analysed different tissues such as grape seed, skin and pulp of the 'Kabarcık' grape, mean phenolic concentrations were determined as follows: 197.64 mg GAE/100 g in the pulp, 247.41 mg GAE/100 g in the skin, and 227.74 mg GAE/100 g in the seeds.

The total flavonoid amounts for the groups were calculated as follows: 101.52 ± 0.43 mg QE/g for KF, 111.61 ± 1.85 mg QE/g for KG, 301.98 ± 6.44 mg QE/g for KL, and 124.95 ± 0.92 mg QE/g for KP (Table 1). In several studies, flavonoid amounts were reported as 0.01 mg RE/g in dried grapes and 0.15 mg RE/g in seeds (Koyuncu and Türkmen 2024), and 98.07 ± 2.60 g QE/g dw in grape stems (Vázquez-Armenta et al. 2017). In a study conducted on the leaves of 16 different grape varieties, flavonoid content was reported to range between 16.1 ± 0.6 and 35.8 ± 2.1 mg/g, expressed as quercetin equivalents (Murathan et al. 2025). The values obtained show both similarities and differences when compared to the results of other studies. The findings indicate that variations in geography, climate, plant variety, harvest method, and timing influence the amounts of phenolic and flavonoid compounds.

In the present study, the total antioxidant potential method (CUPRAC) using Cu (II) as an oxidant was employed to determine the antioxidant capacities. The reduction capacities of the samples were calculated as Trolox equivalents (TEAC_{CUPRAC}) and are presented in Table 1. The highest activity was measured in the grapeseeds at 339.54 ± 1.97 μg TE/mL, while the lowest activity was found in the fruit flesh at 5.7 ± 0.55 μg TE/mL. The copper reduction capacities of the groups were ranked as follows: KG > KP > KL > KF. Notably, the antioxidant capacity of the stem extracts was higher than that of the fruit flesh. The high antioxidant activity of these waste parts, which are typically discarded after grape harvesting, is significant for their potential utilisation. A study on seeded dried grape varieties indicated a greater reduction capacity in the seed parts (Öz 2018). In another study, the values reported were

Fig. 2 The effect of ‘Karaevrek’ grape study groups and BHT on the scavenging of the DPPH radical. (*: KF (fruit flesh extract), KG (grape seed extract), KL (leaf extract), KP (pedicel extract), BHT (2,6-di-t-butyl-1-hydroxytoluene), DPPH (free radical removal activity))



92.20 mg TE/g in dried grapes and 204.46 mg TE/g in seeds (Koyuncu and Türkmen 2024).

The radical scavenging capacity of methanol extracts obtained from the fruit flesh, grapeseeds, pedicel, and leaves of the ‘Karaevrek’ grape was determined using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical. In this study, where BHT was used as a standard, percentage inhibition values were calculated from the absorbance values obtained from extracts prepared at different concentrations. A graph of the average percentage inhibition values of the groups against concentration was plotted (Fig. 2). Additionally, IC₅₀ values for each sample were calculated using the data obtained from the DPPH radical scavenging capacity studies and are presented in Table 1.

DPPH• is a commonly used free radical for determining the radical scavenging activities of antioxidants. All extracts used in the study demonstrated the ability to reduce the stable DPPH• radical; however, differences were observed in the inhibition values. At the highest concentration tested, 200 µg/mL, the radical scavenging activities (% inhibition) of the groups were determined as follows: KG > BHT > KP > KL > KF. While the inhibition value for BHT at a concentration of 200 µg/mL was 83.03%, the inhibition

value for the KG extract was 95.20%, and for the KP extract, it was 82.5%. The lowest inhibition was calculated for the KF extract at 1.5%.

The IC₅₀ values, determined using the slope equations of the graphs plotted against the % inhibition values calculated from the DPPH• tests, indicated that the highest activity was found in the seeds. The lowest IC₅₀ value was calculated for KG (Table 1). Lower IC₅₀ values indicate greater DPPH• radical scavenging activity, as IC₅₀ values are inversely proportional to activity. The IC₅₀ values for the groups and BHT were ranked as follows: KG > KP > BHT > KL > KF. The findings suggest that the ‘Karaevrek’ grape seeds possess a significantly high DPPH• scavenging activity compared to the positive control. A study that determined the DPPH• antioxidant activity of the fruit flesh, skin, whole grape, and grape seed parts of different grape varieties noted that the seeds exhibited higher activity than the other plant parts (Bayır Yeğin and Uzun 2018). Numerous studies have reported that the high antioxidant capacity of grape seeds affects the overall antioxidant capacity of the entire fruit (Göktürk Baydar et al. 2007; Andjelkovic et al. 2013).

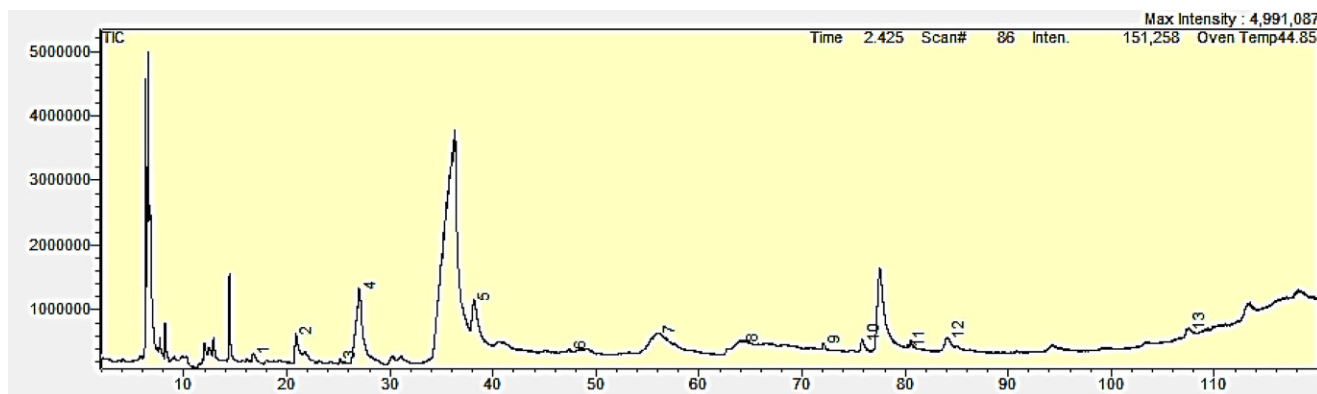


Fig. 3 GC-MS chromatogram of *V. vinifera L.* fruit flesh extract

Table 2 GC/MS analysis table of *V. vinifera* L. plant parts.

No	Name	KF	KG	KL	KP	Areas of use/Activities
1	Phenol, 5-methyl-2-(1-methyl)ethyl)-(CAS)	A	-	5.84	6.65	Nf
2	4-tert-Butylphenyl acetate	A	-	3.22	-	Nf
3	4-Methoxybenzoic acid, 2,3-dichlorophenyl ester	A	-	1.64	-	Nf
4	6-Acetyl-5-methylphenol	A	-	1.19	-	Nf
5	1-Methyladamantane	A	-	0.26	-	Nf
6	FARNESYL ACETONE C	A	-	1.34	-	In the field of cosmetics
7	Hexadecanoic acid, methyl ester (CAS)	A	3.13	3.82	1.45	Pharmacology-bioactivity
8	n-Hexadecanoic acid	A	-	14.13	2.95	Antioxidant, anticancer activity
9	d-Nerolidol	A	-	0.64	-	Used as a food flavoring agent
10	9,12,15-Octadecatrienoic acid, methyl ester, (Z-Z-Z)-	A	-	9.61	-	*Hypocholesterolemic Nematicide Antiarthritic Hepatoprotective Antian-drogenic, Nematicide, Antiacne Hypocholesterolemic, 5-Alpha reductase inhibitor Antihistaminic Anticoronary Insectifuge Antieczemic
11	Hexadecen-1-ol, 3,7,11,15-tetramethyl-, (CAS)	A	-	5.66	-	Nf
12	Octadecatrienoic acid, methyl ester (CAS)	A	-	1.21	-	Nf
13	9,12,15-Octadecatrienoic acid, (Z-Z-Z)-	A	-	15.71	-	*Hypocholesterolemic Nematicide Antiarthritic Hepatoprotective, Antian-drogenic, Hypocholesterolemic, Nematicide, 5-Alpha reductase inhibitor, Antihistaminic, Anticoronary, Insectifuge, Antieczemic, Antiacne
14	Octadecatrienoic acid (CAS)	A	-	2.62	0.82	Nf
15	4,8,12,16-Tetramethylheptadecan-4-olide	A	-	2.54	-	Nf
16	2,6,10,14-Hexadecatetraen-1-ol, 3,7,11,15 tetramethyl-, acetate, (E,E,E)-	A	-	1.13	-	Nf
17	DOCOSANOIC ACID, METHYL ESTER	A	-	1.12	-	Nf
18	Hexadecanoic acid, 2-hydroxy-1(hydrox-ymethyl)ethyl ester	A	-	2.36	-	Nf
19	Octadecatrienoic, 2,3-dihydroxypropyl ester	A	-	5.41	-	Nf
20	2,6,10,14,18,22-Tetracosahexaene, 2,6,10,15,19,23-hexamethyl-, (cas)	A	-	12.66	-	Nf
21	1-Eicosanol (CAS)	A	-	3.46	-	Nf
22	Trans-Geranylgeraniol	A	-	4.43	-	Nf
23	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	A	23.36	5.18	0.59	Nf
24	4-Hydroxy-3-methylacetophenone	A	-	-	0.22	Nf
25	.beta.-D-Glucopyranose,1,6-anhydro-	A	-	-	20.18	Nf
26	1,6-Anhydro-beta-D-glucofuranose	A	11.48	-	15.57	Nf
27	7-Hexadecenoic acid, methyl ester, (Z)-	A	-	-	1.59	Nf

Table 2 (Continued)

No	Name	KF	KG	KL	KP	Areas of use/Activities
28	7-Tetradecenal, (Z)-	A	-	-	1.68	Nf
29	Vitamin E	A	-	-	3.84	*Antileukemic, Antitumor, Anticancer, Hepatoprotective, Hypocholesterolemic Antiulcerogenic, Vasodilator, Antispasmodic, Antifibronchitic, Anticoronary
30	Gamma.-Sitosterol	A	-	-	14.54	Antihyperglycemic activity
31	Lupeol	A	-	-	26.87	Anti-inflammatory and cardiovascular protective
32	2H-Pyran-2,6(3H)-dione	A	1.27	-	-	Nf
33	Bicyclo[2.2.1]heptane-2-carboxylic acid isobutyl-amide	A	4.46	-	-	Nf
34	Hepta-2,4-dienoic acid, methyl ester	A	0.40	-	-	Nf
35	Phenol, 2-methyl-5-(1-methylethyl)-(CAS)	A	20.48	-	-	Nf
36	Citric acid, trimethyl ester	A	0.65	-	-	Nf
37	1,6-anhydro-beta-d-glucopyranose (lev-oglucosan)	A	19.97	-	-	Nf
38	Tridecanoic acid, methyl ester	A	3.57	-	-	Nf
39	1,E-11,Z-13-Octadecatriene	A	3.98	-	-	Nf
40	9-Octadecenoic acid (Z)-(CAS)	A	5.46	-	-	Nf
41	Octadecanoic acid, 2,3-dihydroxypropyl ester	A	1.79	-	14.55	Nf
42	Hexanal	A	-	-	0.36	*Antibacterial, Antisalmonella, Antiseptic, Pesticide
43	2-Heptanal, (E)-(CAS)	A	-	-	2.84	Nf
44	1-pyrrolidmeacetamide.alpha.-ethyl-2-oxo-(.alpha.-Is)-	A	-	-	7.47	Nf
45	2,4-Decadienal	A	-	-	8.39	Nf
46	Thymol	A	-	-	2.25	*Acaricide, Antiatherosclerotic, Antibacterial, Anticartogenic, Antiinflammatory, Antineuritic, Antioxidant (LDL), Antisalmonella, Antispasmodic, Candidicide, Insecticide, Pesticide
47	1-Octanol, 2-ro-	A	-	-	1.50	Nf
48	1,2,4-Benzenetriol	A	-	-	7.99	Nf
49	Pentadecanoic acid, 14-methyl-, methyl ester	A	-	-	1.19	Nf
50	9,12-Octadecadienoic acid, methyl ester, (E,E)-	A	-	-	1.26	*Hypocholesterolemic Nematicide Antiarthritic Hepatoprotective Antiandrogenic, Antieczemic, Antiacne Hypocholesterolemic, Nematicide, Anticoronary5-Alpha reductase inhibitor, Anthistaminic, Insecticide
51	9-Octadecenoic acid (Z)-, methyl ester	A	-	-	2.35	Bioactivity
52	Dodecanoic acid, methyl ester (CAS)	A	-	-	0.32	Nf
53	Octadecanoic acid (CAS)	A	-	-	3.83	In the field of pharmaceuticals, cosmetics and industry
54	Hexadecanoic acid (CAS)	A	-	-	11.40	Antioxidant, anticancer activity

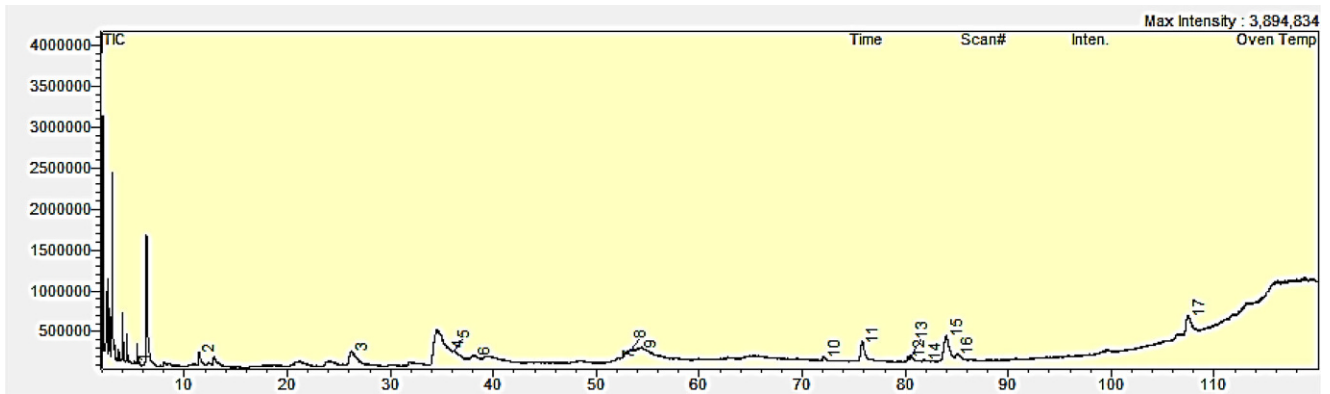


Fig. 4 GC-MS chromatogram of *V. vinifera* L. grapeseed extract

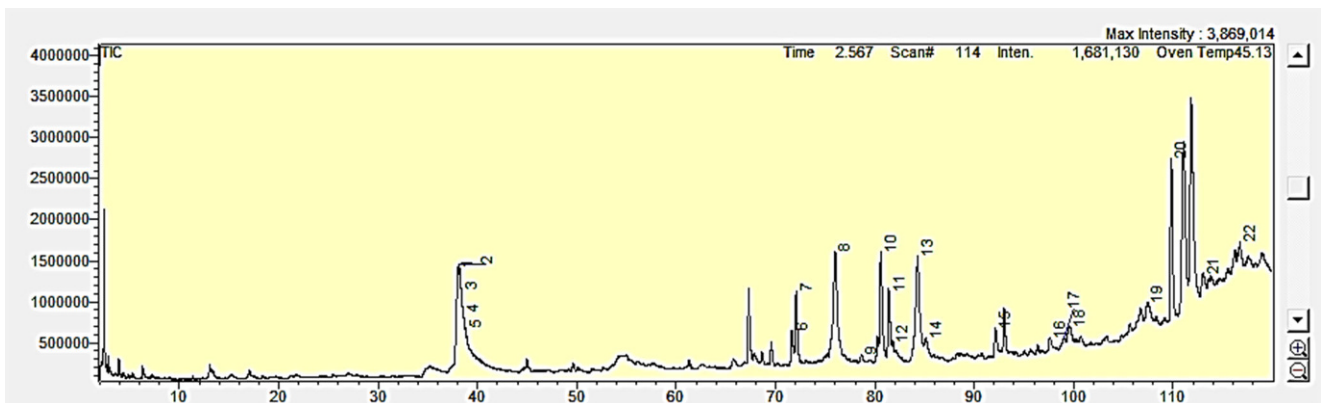


Fig. 5 GC-MS chromatogram of *V. vinifera* L. leaf extract

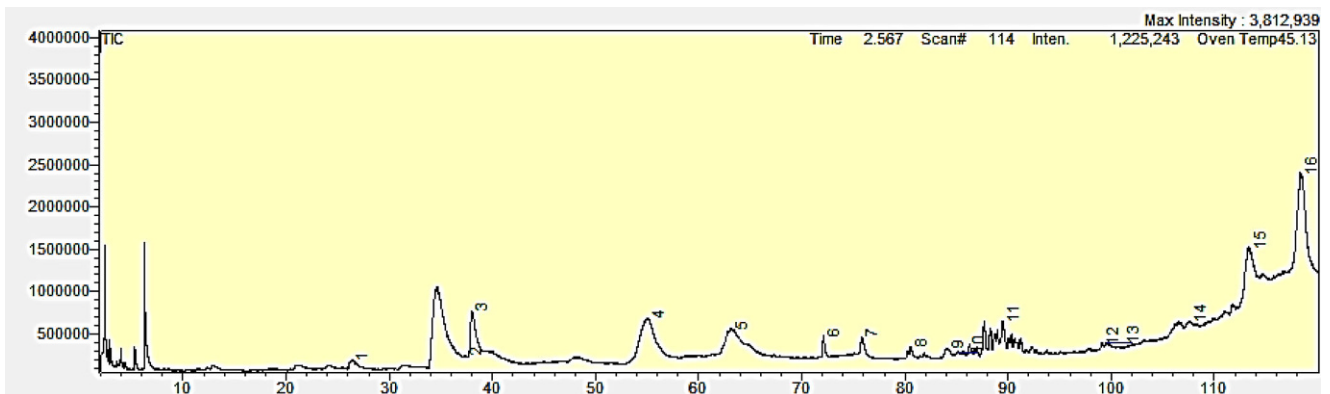


Fig. 6 GC-MS chromatogram of *V. vinifera* L. pedicel extract

In the study, GC/MS analyses were conducted on extracts from the fruit flesh, seeds, leaves, and pedicels of the ‘Karaevrek’ grape (Table 2, Fig. 3 and 4 and 5 and 6). The analysis results revealed that grapes and their by-products contain significant bioactive compounds, which could be utilised in various fields. The GC-MS analysis identified hexadecanoic acid, methyl ester, in the leaves, pedicels, and fruit flesh. Previous studies have demonstrated that this

compound possesses antioxidant and antimicrobial properties (Ghazali et al. 2021). The presence of this compound, which is widely used in the food and cosmetic industries, offers an important opportunity for the conversion of grape by-products into value-added products.

The 1,2,4-benzenetriol identified in grape seeds is known for its strong antioxidant properties. It has been suggested that this compound may combat free radicals, thereby pre-

Table 3 ICP-MS analysis table of *V. vinifera* L. plant parts.

Mineraller	KF	KG	KL	KP
Na ²³	0.92	46.72	34.06	1.41
Mg ²⁴	13.36	122.22	64.45	2.18
P ³¹	2.23	6.71	3.46	2.73
K ³⁹	3.07	296.81	153.49	0.75
Ca ⁴⁰	8.93	67.88	39.15	1.83
Mn ⁵⁵	0.28	4.75	2.40	0.07
Fe ⁵⁶	0.28	8.96	5.07	1.41
Cu ⁶³	0.2	1.94	1.75	0.10
Zn ⁶⁵	0.15	3.63	1.20	0.12
Se ⁷⁹	0.01	0.03	0.02	0.03

venting cellular damage and providing significant health benefits (Dai and Mumper 2010). Additionally, hexadecanoic acid (palmitic acid) was also identified in the seeds, and this fatty acid is utilised in cosmetic and pharmaceutical applications due to its moisturising and anti-inflammatory effects (Rao et al. 2024).

When evaluating the components of the leaves and stems, it is observed that compounds such as 2,6,10,14,18,22-tetra-cosa-hexaene are present in high concentrations. Given the antioxidant capacities and potential immunomodulatory effects of such compounds, there is potential for grape leaves to be utilised as dietary supplements and natural preservatives (Sundari et al. 2023). Additionally, components such as Vitamin E and lupeol found in the stems stand out for their anti-inflammatory and cardiovascular protective properties (Galanakis 2021). Vitamin E is a powerful antioxidant that supports skin health, enhances the immune system, and helps prevent neurodegenerative diseases. Lupeol is noteworthy for its anti-inflammatory, anti-carcinogenic, and hepatoprotective effects. Research has shown that lupeol plays a significant role, particularly in the treatment of skin disorders and the preservation of cardiovascular health (Goufo and Trindade 2014).

Grape cultivation and winemaking generate substantial quantities of by-products, particularly pomace, skins, and seeds, which represent rich sources of potent bioactive compounds, including polyphenols, flavonoids, resveratrol, proanthocyanidins, and anthocyanins. Moreover, lipid-derived bioactives such as unsaturated fatty acids, carotenoids, and lipid-soluble vitamins also exhibit strong antioxidant, anti-inflammatory, and anti-ageing properties. Advances in modern extraction techniques have enabled the more efficient and sustainable recovery of these valuable constituents (Tsiapali et al. 2025). In parallel, grape by-products, including seeds, skins, stems, and leaves, are attracting growing interest for their potential utilisation in food preservation, development of functional ingredients, and applications in the pharmaceutical and cosmetic industries (Bhutani et al. 2025). Notably, Yarovaya et al. (2021) demonstrated in their

study that grape seed extract provides long-term protection against premature skin ageing and effectively mitigates UV-induced skin damage, thereby highlighting its potential as a sustainable natural resource for dermatoprotective and anti-ageing formulations.

In the present study, the mineral contents of Na, Mg, P, K, Ca, Mn, Fe, Cu, Zn, and Se in samples of the ‘Karaevrek’ grapefruit flesh, grapeseed, pedicels, and leaves were determined in ppm ($\mu\text{g/mL}$). The analyses conducted using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) revealed that the highest values were found in the seed part, while the lowest values were observed in the stem part (Table 3).

The four minerals with the highest concentrations in the grapeseed and leaf parts are observed to be K, Mg, Ca, and Na. In the pedicel part, the mineral present in the highest quantity is P (2.73 ppm), while in the fruit flesh, it is Mg (13.36 ppm). The elements Se and Cu, which have safety limits of 0.04 and 2.00 ppm respectively, as recommended by WHO (2022), were found to be below legal limits in all samples (WHO 2022). A study conducted on a different grape variety reported the presence of Ca, K, Mg, and Na in the seed, leaf, and fruit flesh but did not detect Fe and Zn (Öz 2018). According to Akın and Çitil (2011), among the macronutrients in grape seeds, the highest concentration was found for Ca (0.820–0.487%), while the lowest was for Mg (0.123–0.077%). Among the micronutrients, Zn was found in the highest concentration (419.00–345.67 mg/kg) and Cu in the lowest (16.67–8.00 mg/kg). Results from a similar study indicated the following concentrations: P: 0.29–0.44%, K: 0.33–0.50%, Ca: 0.48–0.79%, Mg: 0.13–0.17%, Fe: 33.50–35.00 mg/kg, Cu: 7.27–13.04 mg/kg, and Mn: 11.13–23.86 mg/kg (Gök Tangolar et al. 2009). The differences among grape varieties can be attributed to genetic characteristics, the type of soil in which they are produced, and environmental conditions.

Conclusion

In this study, the phenolic contents, flavonoid levels, antioxidant capacities, and mineral compositions of the fruit flesh, seeds, pedicel, and leaves of the ‘Karaevrek’ grape variety were evaluated. The findings revealed that seed extracts exhibited the highest phenolic content and the strongest antioxidant capacity. In contrast, the fruit flesh demonstrated the lowest levels of bioactive compounds and antioxidant activity. These results indicate that grape seeds represent the most promising by-product for functional food, nutraceutical, and cosmetic applications due to their rich bioactive and mineral profiles. Furthermore, the pedicel and leaves also displayed considerable antioxidant potential and could

be considered for use in natural preservatives or dietary supplement formulations. Although the fruit flesh exhibited relatively lower antioxidant activity, it may still be utilised in flavouring agents or lower value-added products. Overall, this study underscores the importance of valorising grape byproducts and highlights that seed and pedicel fractions possess the greatest potential for industrial utilisation. This approach not only contributes to sustainable waste management but also offers significant opportunities for the development of high-value added products.

Funding This study was supported by the Kırşehir Ahi Evran University Scientific Research Projects Coordination Unit (Project Number: SYO.A3.24.003). We thank Kırşehir Ahi Evran University Scientific Research Projects Coordination Unit.

Author Contribution F.E. planned the study, determination antioxidant capacity, F.E. and H.B. statistical analyses, interpretation of analyses and writing of results. All authors contributed to the preparation of the manuscript.

Data Availability Data will be made available on reasonable request.

Conflict of interest F. Ergün and H. Bayam declare that they have no competing interests.

Consent for publication All authors have agreed to publish the paper.

References

- Akın A, Çitil ÖB (2011) Determination of mineral substance contents in the seed of some grape varieties. *Selcuk J Agric Food Sci* 25(2):39–41
- Andjelkovic M, Radovanović B, Radovanović A, Andjelkovic AM (2013) Changes in polyphenolic content and antioxidant activity of grapes cv vranac during ripening. *SAJEV* 34(2):147–155. <https://doi.org/10.21548/34-2-1090>
- Apak R, Güçlü K, Özyürek M, Karademir SE (2004) A novel total antioxidant capacity index for dietary polyphenols, vitamin c and e, using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method. *J Agric Food Chem* 52:7970–7981. <https://doi.org/10.1021/jf048741x>
- Averilla JN, Oh J, Kim HJ, Kim JS, Kim JS (2019) Potential health benefits of phenolic compounds in grape processing by-products. *Food Sci Biotechnol* 28(6):1607–1615. <https://doi.org/10.1007/s10068-019-00628-2>
- Balbaba N, Bağcı S (2020) Determination of some quality properties and total phenol compounds and antioxidant capacity in ‘Bertiz Kabarcık’ grape. *KSU J Agric Nat* 23(6):1414–1421. <https://doi.org/10.18016/ksutarimdogu.vi.658449>
- Bashimov G (2017) Grape production and export performance in Turkey. *J Agric Fac Uludag Univ* 31(2):57–68
- Baydar N, Babalık Z, Türk F, Çetin E (2011) Phenolic composition and antioxidant activities of wines and extracts of some grape varieties grown in Turkey. *J Agric Sci* 17(1):67–76. https://doi.org/10.1501/Tarimbil_0000001157
- Bayır Yeğın A, Uzun Hİ (2018) Some chemical phenolic content and antioxidant activity variations in different parts of grape berry. *Derim* 35(1):1–10. <https://doi.org/10.16882/derim.2018.298997>
- Bhutani M, Gaur SS, Shams R, Dash KK, Shaikh AM, Béla K (2025) Valorization of grape by-products: Insights into sustainable industrial and nutraceutical applications. *Future Foods* 12:100710. <https://doi.org/10.1016/j.fufo.2025.100710>
- Blois MS (1958) Antioxidant determinations by the use of a stable free radical. *Nature* 181:1199–1200
- Dai J, Mumper RJ (2010) Plant phenolics: extraction, analysis and their antioxidant and anticancer properties. *Molecules* 15(10):7313–7352. <https://doi.org/10.3390/molecules15107313>
- Duggan MR, Lee-Soety JY, Anderson MJ (2017) Personality types in Budgerigars, *Melopsittacus undulates*. *Behav Processes* 138:34–40. <https://doi.org/10.1016/j.beproc.2017.02.003>
- Galanakis CM (2021) Functionality of food components and emerging technologies. *Foods* 10(1):128. <https://doi.org/10.3390/foods10010128>
- Genç S, Soysal MI (2018) Parametric and nonparametric post hoc tests. *Black Sea J Eng Sci* 1(1):18–27
- Ghazali M, Zaki M, Hidayati E (2021) Antibacterial activity of methanol extract of sargassum polycystum on *Escherichia coli* and *Staphylococcus aureus*. *J Biol Trop* 21(1):199–205. <https://doi.org/10.29303/jbt.v21i1.2485>
- Gök Tangolar S, Özoğul Y, Tangolar S, Torun A (2009) Evaluation of fatty acid profiles and mineral content of grape seed oil of some grape genotypes. *Int J Food Sci Nutr*. 60(1):32–9. <https://doi.org/10.1080/09637480701581551>
- Göktürk Baydar N, Ozkan G, Yasar S (2007) Evaluation of the anti-radical and antioxidant potential of grape extracts. *Food Control* 18:1131–1136. <https://doi.org/10.1016/j.foodcont.2006.06.011>
- Goufo P, Trindade H (2014) Rice antioxidants: phenolic acids, flavonoids, anthocyanins, proanthocyanidins, tocopherols, tocotrienols, γ -oryzanol, and phytic acid. *Food Sci Nutr* 2:75–104. <https://doi.org/10.1002/fsn3.86>
- Goyeneche OYR, Ramirez M, Schot J, Arroyave F (2022) Mobilizing the transformative power of research for achieving the sustainable development goals. *Res Policy* 51(10):104589. <https://doi.org/10.1016/j.respol.2022.104589>
- Gülcü M, Ghafoor K, Al Juhaimi F, Özcan M, Uslu N, Babiker E, Mohamed Ahmed I, Azmi I (2020) Effect of grape (*Vitis vinifera* L.) varieties and harvest periods on bioactive compounds, antioxidant activity, phenolic composition, mineral contents and fatty acid compositions of *Vitis* leaves and oils. *J Food Process Preserv* 44:e14890. <https://doi.org/10.1111/jfpp.14890>
- Güler E, Kan E, Ünal MS (2023) The diversity in grapes of *Vitis labrusca* grown in Bolu (Türkiye) assessed by multivariate approaches. *Genes* 14(7):1491. <https://doi.org/10.3390/genes14071491>
- Gundeşli MA, Attar ŞH, Değirmenci İ, Nogay G, Kafkas NE (2018) Total phenol and antioxidant activity of ‘Kabarcık’ grape (*Vitis vinifera* L.) variety. *J Sci Eng Res* 5(11):222–227
- İncesu Municipality (2016) İncesu municipality cultural inventory report. İncesu municipality publications. https://incesu.bel.tr/tema/genel/uploads/faaliyet_raporlari/dosya/2016-FAAL%20%20B0YET-RAPORU.pdf
- Katalinic V, Mozina SS, Generalic I, Skroza D, Ljubenkov I, Klancnik A (2013) Phenolic profile, antioxidant capacity, and antimicrobial activity of leaf extracts from six *Vitis vinifera* L. varieties. *Int J Food Prop* 16(1):45–60. <https://doi.org/10.1080/10942912.2010.526274>
- Koyuncu G, Türkmen FU (2024) Antioxidant properties and phenolic compounds of methanol extracts of raisin and grape seed of Horoz Karası (*Vitis vinifera* L.). *Harran Tarım Ve Gıda Bilimleri Dergisi* 28(2):293–303
- Kurčić VS, Stanišić N, Stajić SB, Dmitrić M, Živković S, Kurčić LV, Živković V, Jakovljević V, Mašković PZ, Mašković J (2024) Valorizing grape pomace: a review of applications, nutritional benefits, and potential in functional food development. *Foods* 13(24):4169. <https://doi.org/10.3390/foods13244169>
- Moreno MI, Isla MI, Sampietro AR, Vattuone MA (2000) Comparison of the free radical-scavenging activity of propolis from several

- regions of Argentina. *J Ethnopharmacol* 71(1-2):109–114. [https://doi.org/10.1016/S0378-8741\(99\)00189-0](https://doi.org/10.1016/S0378-8741(99)00189-0)
- Mothana RA, Al-Said MS, Al-Yahya MA, Al-Rehaily AJ, Khaled JM (2013) GC and GC/MS analysis of essential oil composition of the endemic Soqotraen *Leucas virgata* Balf.f. and its antimicrobial and antioxidant activities. *IJMS* 14:23129–23139. <https://doi.org/10.3390/ijms141123129>
- Murathan ZT, Sevindik E, Arslan M, Erbil N (2025) Genetic diversity and biological characteristics of grape variety (*Vitis vinifera*) leaves. *Appl Fruit Sci* 67:380. <https://doi.org/10.1007/s10341-025-01591-5>
- Öz V (2018) Determination of some phytochemical characteristics of seeded raising of south-east Anatolia region (Master thesis Dicle University, , Diyarbakır, Türkiye)
- Öztürk B, Yolcu Z, Apaydın E, Yolcu M (2023) Determination of mineral matter in some molasses of Giresun region by ICP-MS and IC system. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi* 20(1):117–125. <https://doi.org/10.25308/aduziraat.1231970>
- Rao NN, Kumari MEL, Babu YTR, Padal SB (2024) Evaluation of Phytochemical screening, GC-MS analysis and anti-bacterial potentiality of terminalia chebula fruit. *Ann Plant Sci* 13(7):6451–6462. <https://doi.org/10.21746/aps.2024.13.7.5>
- Slinkard K, Singleton VL (1977) Total phenol analyses: Automation and comparison with manual methods. *Am J Enol Vitic* 28:49–55. <https://doi.org/10.5344/ajev.1977.28.1.49>
- Sundari D, Handayani DS, Suryanti V (2023) Chemical compositions, antioxidant and antibacterial activities of kepel (*Stelechocarpus burahol*) fruit flesh and peel extracts. *Biodiversitas* 24(9):4668–4675. <https://doi.org/10.13057/biodiv/d240907>
- Sustainable Development Goals (2015) Transforming our world: the 2030 agenda for sustainable development. United Nations. <https://sdgs.un.org/2030agenda>
- Tsiapali OI, Ayfantopoulou E, Tzourouni A, Ofrydopoulou A, Letsiou S, Tsoupras A (2025) Unveiling the utilization of grape and winery by-products in cosmetics with health promoting properties. *Appl Sci* 15(3):1007. <https://doi.org/10.3390/app15031007>
- Vázquez-Armenta FJ, Silva-Espinoza BA, Cruz-Valenzuela MR, González Aguilar GA, Nazzaro F, Fratianni F (2017) Antibacterial and antioxidant properties of grape stem extract applied as disinfectant in fresh leafy vegetables. *J Food Sci Technol* 54(10):3192–3200. <https://doi.org/10.1007/s13197-017-2759-5>
- World Health Organization (2022) Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. <https://www.who.int/publications/i/item/9789240045064>
- Yarovaya L, Waranuch N, Wisuitiprot W, Khunkitti W (2021) Effect of grape seed extract on skin fibroblasts exposed to UVA light and its photostability in sunscreen formulation. *J Cosmet Dermatol* 20(4):1271–1282. <https://doi.org/10.1111/jocd.13711>
- Zhou DD, Li J, Xiong RG, Saimaiti A, Huang SY, Wu SX, Yang ZJ, Shang A, Zhao CN, Gan RY, Li HB (2022) Bioactive compounds, health benefits and food applications of grape. *Foods* 11(18):2755. <https://doi.org/10.3390/foods11182755>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.