International Journal of Horticultural Science and Technology (2024) Vol. 11, No. 2, pp. 201-216

International Journal of Horticultural Science and Technology
Journal homepage: http://ijhst.ut.ac.ir

Comparison of Eleven Commercial Grape (*Vitis vinifera* L.) Cultivars in Terms of Phenolic Profile and Antioxidant Properties

Maryam Rahimi[1,2]*, Narges Pakravan[3], Rouhollah Karimi[1,4]*

1 Grape Production and Genetic Improvement Department, Iranian Grape and Raisin Institute, Malayer University, Iran
2 Department of Biology, Faculty of Science, Malayer University, Malayer, Iran
3 Department of Chemistry, Faculty of Science, Malayer University, Malayer, Iran
4 Department of Horticulture and Landscape Engineering, Faculty of Agriculture, Malayer University, Iran

ARTICLE INFO

Article history:

Received: 18 May 2023,
Received in revised form: 12 August 2023,
Accepted: 13 August 2023

Article type:

Research paper

Keywords:

Anthocyanidins,
Benzoic acids,
Flavanols,
Flavonols,
Grape,
Resveratrol

ABSTRACT

Grapes are a rich source of phenolic compounds with high antioxidant, antibacterial, and nutritional properties among fruits. The aim of this study was to investigate different classes of phenolic compounds in the berry skin of eleven *Vitis vinifera* cultivars. The phenolic compounds were flavonols, flavanols, flavone, anthocyanins, stilbenes, and phenolic acids. The highest amounts of catechin, epicatechin, ferulic acid, and chlorogenic acid were observed in 'Yaghooti' grape cultivar ($P \leq 0.05$). However, the amounts of catechin gallat, kaempferol, myricetin, and p-coumaric acid in 'Bidaneh Ghermez' berries were higher ($P \leq 0.05$) compared to other cultivars. Quercetin was the main flavonol and was highest (9.48 µg g^{-1}; $P \leq 0.05$) in 'Yaghooti' berries. Luteolin content, as a flavone, ranged from 0.49 µmol g-1 in 'Rishbaba' berry skin to 0.88 µmol g^{-1} in 'Bidaneh Ghermez'. Delphinidin-3-glucoside and malvidin-3-glucoside were highest in 'Yaghooti'. Cyanidin-3-glucoside and peonidin -3-glucoside were highest in 'Angoor Siah.' Petunidin 3-glucoside was highest in 'Bidaneh Ghermez' ($P \leq 0.05$). Berry skin resveratrol varied from 22.7 µg g^{-1} in 'Monaqa and Fakhri' cultivars to 54.8 µg g^{-1} FW in 'Bidaneh Ghermez,' with an overall average of 36.9 µg g^{-1} FW. Among different cultivars, the antioxidant capacity of 'Angoor Siah' was highest (71.3%; $P \leq 0.05$) and 'Monaqa' was lowest. The 'Angoor Siah' cultivar had more antibacterial activity compared to other cultivars. In sum, the berry skin of 'Yaghooti,' 'Angoor Siah,' and 'Bidaneh Ghermez' showed the highest health-promoting bioactive compounds, potentially important for future studies.

Introduction

Grapes belong to a group of temperate fruits, which have high nutritional qualities, and many by-products are produced from different parts of their berries. Grape berry skin and seeds are a rich source of phenolic compounds. The grape berry phenolic compounds are divided into two main groups, including flavonoids (i.e. flavonols, flavanols, flavone, and anthocyanins). They also include non-flavonoids (i.e. stilbenes and phenolic acids) which are synthesized through the phenylpropanoid pathway by phenylalanine ammonia-lyase (Dixon and Paiva, 1995; Castellarin et al., 2012; Gouot et al., 2019; Asgarian et al., 2023). Due to their role in color, aroma, taste, and flavor properties, phenolic compounds are strongly associated with fruit sensory properties (Asgarian et al., 2022). Due to the antimicrobial, anti-carcinogenic, and anti-inflammatory role of various phenolic compounds, these secondary metabolites have been the subject of many research cases related to human health (Ferrandino and Guidoni, 2010; Del Rio et al., 2013; Karimi et al., 2019).

Different grape cultivars are different in terms of fruit color, sugar percentage, water content,

* Corresponding author's email: rahimimaryam61@gmail.com, R.Karimi@malayeru.ac.ir

concentration of elements, phenolic compounds, and antioxidant capacity (Ferrandino and Guidoni, 2010; Gil-Muñoz et al., 2010). This difference in qualitative properties of cultivars is an opportunity to screen grapes based on their desirable characteristics and nutritional value (Karimi et al., 2017). The berry internal compositions of grapes usually vary depending on the cultivar, vineyard climate, light, temperature, viticultural operations, nutrition, irrigation management, pests, disease control, pruning, training practices, crop load, and berry development stages (Keller, 2015; Karimi et al., 2019).

The antioxidant activity of grape cultivars is related to phenolic compounds and carotenoids (Bunea et al., 2012; Castellarin et al., 2012). Phenolic compounds include flavonoids, flavonols, anthocyanins, and phenolic acids (Rockenbach et al., 2011). In contrast to pulp, the berry skin color is determined mainly by anthocyanins concentration in grape cultivars. In red grape cultivars, flavonoids and anthocyanidins are the two main phenolics, and catechin is their predominant flavonoid (Rockenbach et al., 2011; Castellarin et al., 2012). Due to their redox properties, phenolic compounds can act as hydrogen donors, reducing agents, and scavengers of reactive oxygen species (Mathew et al., 2015). In grape berry skin extract, phenolic compounds have antioxidant and antibacterial activity against different bacteria species (Xu et al., 2016). However, there are noteworthy differences in the content and type of phenolic compounds among different grape cultivars, which can affect the antioxidant capacity and antibacterial activity of the extract obtained from the skin of their berries (Teixeira et al., 2014). In previous research, the antioxidant activity, total phenol, anthocyanins, and polyphenol oxidase activity of several red grape cultivars were evaluated, and their antioxidant activities were determined (Orak, 2007). Previous research considered the phenolic content and antioxidant capacity of 14 *Vitis vinifera* cultivars, including seven white and seven red grape cultivars in Croatia.

Based on their findings, total phenol and antioxidant capacity in red cultivars were more than in white cultivars (Katalinic et al., 2010). Recently, Farhadi et al. (2016) reported the antioxidant capacity and phenolic profiles in five grape cultivars. Their study showed a noteworthy variance in flavonoids, phenolic acids, and antioxidant capacity among berry skin and seeds of different cultivars. In the mentioned study, the berry skin extract of 'Ghara Shani' presented the highest total anthocyanin, total phenolic, and antioxidant activity (Farhadi et al., 2016). Moreover, the highest concentrations of gallic acid, catechin, epicatechin, and resveratrol were identified in the berry skin of GharaShani and also rutin in the berry skin of 'Ghara Shira' (Farhadi et al., 2016). In another work, the antioxidant capacity and phenolic profiles of 18 Chinese cultivars and several European and Muscadine grape cultivars were measured with HPLC (Xu, 2010). Based on the results, a considerable difference was observed regarding the total phenols and total flavonoid content in the berry skin of all grape cultivars. Among them, the highest antioxidant capacity and total phenol content were found in 'Cabernet Sauvignon' and 'Muscadine' berry seeds, while the highest phenolic contents were found in 'Sangye' and 'Black Pearl' berry skin (Xu, 2010). Kedage et al. (2007) evaluated the phenolic compounds of 11 Asian grape cultivars and reported that the amount of phenolic compounds correlated closely with berry color.

Screening grape cultivars based on their bioactive molecule content is an important subject. To the best of our knowledge, this is the first study to consider the antioxidant capacities, antibacterial activity, and phenolic profile in individual commercial grape (*Vitis vinifera* L.) cultivars from Iran. Therefore, the objective of this work was to study non-flavonoids (phenolic acids and stilbene), flavonoids (flavanols, flavonols, flavone, and anthocyanidins), and antibacterial activity in eleven grape cultivars from Iran.

Material and Methods

Grape material

In this research, eleven grape (*Vitis vinifera* L.) cultivars were considered. The plants were 5-year-old own-rooted vines that grew in an experimental vineyard at Malayer University (lat. 34° 28′ N, long. 48° 84′ E, alt. 1766 m), Iran. The vines were evaluated for phenolic compounds, antioxidant capacity, and antibacterial activity in 2019 and 2020. The cultivars included 'Angoor Siah', 'Yaghooti Ghermez', 'Fakhri Ghermez', 'Bidaneh Ghermez', 'Sahebi Ghermez', 'Mirzaei Ghermez', 'Fakhri Sefid', 'Rishbaba Sefid', 'Monaqa Sefid', 'Lael Sefid', and 'Bidaneh Sefid'. These cultivars are commercially grown in different regions of Iran. Characteristics related to berry and ripening time differed per cultivar (Table 1). Vines were trained under a T-shaped trellis system, with a planting density of 2 × 3 m. Other viticulture operations such as irrigation, fertilization, pest and disease control, weed control, leaf pruning and cluster thinning were similarly applied on all cultivars. Grapes were harvested at the commercial maturity stage with TSS=17 °Brix and transferred to a laboratory for further phytochemical analysis. All chemicals in the current work were of analytical grade (>99%).

Cultivar	Berry skin color	Berry skin thickness	Seed in berry	Berry shape	Berry size	Time of ripening
Lael	White	low	Seedy	Circular	Medium	Medium
Sahebi	Red	low	Seedy	Elliptic	Medium	Late
Fakhri	White	Medium	Seedy	Elliptic	Medium	Late
Rishbaba	White	Medium	Seedy	Elliptic	Large	Medium
Mirzaei	Red	low	Seedy	Ovate	Medium	Late
Bidaneh Sefid	White	low	Seedless	Elliptic	Small	Medium
Monaqa	White	Medium	Seedy	Ovate	Medium	Medium
Bidaneh Ghermez	Red	low	Seedless	Elliptic	Small	Medium
Yaghooti	Red	low	Seedless	Circular	Small	Early
Fakhri Ghermez	Red	Medium	Seedy	Elliptic	Medium	Medium
Angoor Siah	Black	Medium	Seedy	Circular	Medium	Medium

Table 1. Several berry characteristics and ripening time of the 11 grape (*Vitis vinifera* L.) cultivars in the current study.

Phenolic compounds (non-flavonoids and flavonoids)

The following phenolic compounds were analyzed in all grape cultivars: 1. non-flavonoids (1.1. phenolic acids: i. hydroxycinnamic acids i.e. caffeic acid, p-coumaric acid, ferulic acid, and chlorogenic acid; ii. benzoic acids i.e. gallic acid, vanillic acid and syringic acid and also dimethoxybenzoic acid i.e. veratric acid; 1.2. stilbene i.e. resveratrol) and 2. flavonoids (2.1. flavonoids: i. flavanols i.e. catechin, catechin gallat, epicatechin; ii. flavonols i.e. quercetin, myricetin and kaempferol; iii. flavone i.e. luteolin and iiii. anthocyanidins (delphinidin-3-O-glucoside, cyanidin-3-O-glucoside, peonidin-3-O-glucoside and petunidin-3-O-glucoside, malvidin-3-O-glucoside).

To measure anthocyanidins, 3 g of deep freeze-stored berry skin were ground in liquid nitrogen and the obtained powders were boiled in hydrochloric acid (0.1 N) for 28 min, filtrated and then separated with ethyl acetate. The solution part was dissolved in water but the non-soluble portion was dissolved in 80% methanol (Koponen et al., 2007). The solution was filtered through a Millex HA 0.45 µm filter (Milipore Crop.) before injection to a high performance liquid chromatography (HPLC; Crystal 200 series, Unicam, Cambridge, UK) pump at 518 nm wavelength.

Regarding other phenolic compounds, berry skin powder (1 g) was mixed with methanol (30 mL). The mixture was shaken (30 min) and sonicated in a water bath (20 min). The solutions were separated with ethyl acetate after filtration under room temperature. The remaining insoluble and soluble portions of homogenate were dissolved in 80% methanol and water. They were filtered again through a Millex HA 0.45 µm filter (Millipore Crop.; Vekiari et al., 2008) before injection to a HPLC pump under room temperature (Koponen et al., 2007). The samples were subjected to ingredient separation in an HPLC pump with a UV-Vis detector and ODS column (4.6 × 250 mm; HiChrom, USA) at 254 nm wavelength, with potassium di-hydrogen phosphate and ulterapure acetonitrile (80:20, v:v) at a flow rate of 1 mL min^{-1} as mobile phase. Methanolic stock solutions of the different phenolic acids and anthocyanidine standards (E. Merck) were prepared at concentrations of 0, 20, 40, 60, 80, and 100 μg^{-1} mL.

Total phenol

To measure the amount of total phenol, 0.5 g of berry skin tissue was ground in 4 mL of methanol to obtain a homogeneous solution. After 20 min of centrifuge at 6000 rpm, 300 µL of a clear methanolic supernatant extract was mixed with 1000 μL of tenfold-diluted Folin–Ciocalteu reagent solution (Velioglu et al., 1998). Five minutes later, 1000 μL of 7% sodium carbonate was also added to it. After 20 min storage in a dark cabinet, the absorbance of each sample was read with a spectrophotometer (Spekol 2000, Australia) at 765 nm.

Total flavonoids

To measure the amount of total flavonoids, the aluminum chloride colorimetric method was used (Chang et al., 2002). In this method, 0.1 mL of 10% aluminum chloride was poured into a test tube, and 0.1 mL of potassium acetate (1 M) was added. Then, 2.8 mL of distilled water was added to each tube. In the last step, 0.5 mL of the berry skin extract solution was added to the mixture. The samples were placed in a dark environment for 30 min, and finally, the absorption of the samples were read at 415 nm by a spectrophotometer. The amount of total flavonoids for each extract was calculated as mg of quercetin per g of fresh weight (FW).

Total anthocyanin

To measure total anthocyanin content, 0.1 g of berry skin was ground in 10 ml of acidic methanol (methanol:hydrochloric acid, 99:1). The resultant berry extract was placed in a dark place for 24 h (Giusti and Wrolstad, 2001). Then, the spectrophotometric absorption of the samples was measured at 550 nm. Total anthocyanin quantification was calculated in relation to cyanidin-3-glucoside equivalents, calculated per FW (equation 1):

$$[\text{Total anthocyanin}](\text{mg g}^{-1}) = (A_{520} - A_{700}) \times \text{MW} \times \text{DF} \times 1000/\mathcal{E} \times 1 \qquad (1)$$

where MW is the molecular weight of cyanidin-3-glucoside (449.2 g mol-1), DF is the dilution factor and ε is the molar extinction coefficient of cyanidin-3-glucoside (26900 M cm^{-1}).

Antioxidant capacity

Antioxidant capacity was measured using the DPPH (2, 2-Diphenyl-1-Picrylhydrazyl) method (Sanchez-Moreno et al., 1998). In this method, 0.5 g of berry skin was homogenized with 4 mL of 80% methanol and the resultant mixture was centrifuged at 6000 rpm for 15 min. Then, 100 μL of the supernatant solution was mixed with 3400 μL of 0.5 mM DPPH solution and the resultant mixture was kept in the dark for 30 min. Their light absorption value was read at 517 nm. Radical scavenging capacity (RSC) was calculated via the following equation (2). In this regard, Ablank and Asample were the absorbance values of the control (DPPH solution) and sample, respectively.

$$\text{DPPH RSC (\%)} = [(A_{blank} - A_{sample})/A_{blank}] \times 100 \qquad (2)$$

Measurement of minimum inhibitory concentration (MIC)

Berry skin extract MIC was measured according to the agar dilution method (Tantaoui-Elaraki et al., 1994). A gradient of berry skin extract concentration (0.05 to 10 mg mL-1) was prepared and mixed with Muller Hinton agar (MHA). Permeable millipore membranes (0.45 μm) were placed into the MHA and inoculated with 20 μL of each bacterial suspension (contained 100 CFU/spot). The agar plates were incubated at 38 °C for 20-40 h and evaluated for consequent bacterial growth on the millipore membranes.

Experimental design and statistical analysis

Data were analyzed using GLM procedures of SAS (9.2), and mean comparisons were calculated based on Duncan's multiple range test (1% probability level). It should be noted that the present study was conducted in two consecutive years (2019 and 2020), but due to the non-significance of the year effect in data analysis, the average of two years appears in the tables and figures.

Results

Flavanols content

A significant difference (P≤0.05) was found among the different grape cultivars regarding berry skin flavanols, i.e., catechin, catechin-gallate, and epicatechin (Table 2). The highest catechin content (P≤0.05) was related to 'Yaghooti' cultivar, which was not significantly different from the 'Bidaneh Ghermez' cultivar in this respect (Table 2). Among the different cultivars, the lowest catechin content (P≤0.05) was measured in the skin of 'Lael' cultivar. The catechin-gallate content in the berry skin of 'Bidaneh Ghermez' cultivar was more than in other cultivars, without a significant difference from 'Angoor Siah' cultivar. The lowest catechin-gallate content (P≤0.05) was related to the 'Lael' cultivar, which did not show a significant difference with the 'Bidaneh Sefid' cultivar in this regard (Table 2). Among the different cultivars, the highest and lowest epicatechin content (P≤0.05) was related to the berry skin of 'Yaghooti' and 'Fakhri' cultivars, respectively (Table 2). The average of all cultivars in terms of catechin, catechin-gallate, and epicatechin content was 1.7, 2.4, and 2.6 μg g^{-1} berry FW, respectively (Table 2).

Table 2. Berry flavanols concentration of 11 Iranian grape (*Vitis vinifera* L.) cultivars.

Cultivars	Flavanols ($\mu g\ g^{-1}$ berry)		
	Catechin	Catechin gallate	Epicatechin
Lael	0.63± 0.23f	1.50 ± 0.00e	1.69 ± 0.24f
Sahebi	1.49± 0.36d	2.39 ± 0.06cd	3.37 ± 0.10c
Fakhri	1.20± 0.25de	1.90 ± 0.01d	2.49 ± 0.19de
Rishbaba	1.93± 0.27bc	1.55 ± 0.01e	1.55 ± 0.17f
Mirzaei	1.66± 0.35c	2.75 ± 0.09bc	2.79 ± 0.11d
Bidaneh Sefid	1.70± 0.20c	2.19 ± 0.01d	2.19 ± 0.12e
Monaqa	0.96± 0.18ef	1.64 ± 0.10e	1.39 ± 0.29f
Bidaneh Ghermez	2.39± 0.19ab	3.54 ± 0.07a	3.48 ± 0.21c
Yaghooti	2.62± 0.22a	3.03 ± 0.04b	3.68 ± 0.09a
Fakhri Ghermez	2.21± 0.28b	2.58 ± 0.01c	2.75 ± 0.13d
Angoor Siah	2.07± 0.17bc	3.40 ± 0.03a	3.54 ± 0.14a
Mean	1.72	2.41	2.631

Columns with similar letters are not statistically different (based on Duncan's multiple-range test). Data are mean values of three replications ± SE.

Flavonols content

The quercetin content is an important indicator of flavonols in the berry skin. The 'Yaghooti' cultivar had the highest quercetin content (9.48 $\mu g\ g^{-1}$ berry FW) ($P \leq 0.05$) among other cultivars (Table 3). The lowest quercetin content ($P \leq 0.05$) was observed in the berry skin of the 'Fakhri' cultivar (3.73 $\mu g\ g^{-1}$ berry FW). The amount of kaempferol accumulation in 'Bidaneh Ghermez' cultivar showed a higher content ($P \leq 0.05$) compared to other cultivars, although it did not have a statistically significant difference with the 'Angoor Siah' cultivar (Table 3). In the case of myricetin, it was found that 'Bidaneh Ghermez' cultivar accumulated more flavonols ($P \leq 0.05$) in its berry skin compared to other cultivars. The lowest amounts ($P \leq 0.05$) of kaempferol and myricetin were related to the 'Lael' cultivar. The average values of all cultivars in terms of flavonols, quercetin, kaempferol, and myricetin in the berry skin was equal to 6.71, 1.77, and 1.50 $\mu g\ g^{-1}$ berry FW, respectively (Table 3).

Flavone

Luteolin content as an indicator of flavone (a type of flavonoid) was identified and measured in different grape cultivars using HPLC. As can be seen in Fig. 1, a significant difference ($P<0.01$) was observed among different grape cultivars in terms of luteolin content in the berry skin. The amount of this flavone ranged from 0.49 $\mu mol\ g^{-1}$ FW ('Rishbaba' cultivar) to 0.88 $\mu mol\ g^{-1}$ FW ('Bidaneh Ghermez' cultivar), with an overall average of 0.64 $\mu mol\ g^{-1}$ FW in the berry skin (Fig.

1).

Table 3. Berry flavonols concentration in 11 Iranian grape (*Vitis vinifera* L.) cultivars.

Cultivars	Flavonols ($\mu g\ g^{-1}$ berry)		
	Quercetin	**Kaempferol**	**Myricetin**
Lael	4.42 ± 0.35fg	0.96± 0.20g	0.88± 0.14f
Sahebi	7.82 ± 0.12c	1.69± 0.15d	0.63± 0.17f
Fakhri	3.73± 0.44g	1.20± 0.15f	1.17± 0.11e
Rishbaba	5.92± 0.11e	1.58± 0.19de	1.45± 0.10de
Mirzaei	7.59± 0.10cd	1.89± 0.23cd	1.31± 0.09de
Bidaneh Sefid	6.65± 0.09cd	1.36± 0.12ef	1.66± 0.13cd
Monaqa	4.80± 0.34f	1.27± 0.13f	0.97± 0.08a
Bidaneh Ghermez	7.37± 0.22d	2.69± 0.13a	2.50± 0.12a
Yaghooti	9.48± 0.20a	2.31± 0.15b	1.96± 0.14bc
Fakhri Ghermez	7.76± 0.08c	2.03± 0.20bc	1.80± 0.15c
Angoor Siah	8.30± 0.18b	2.44± 0.17ab	2.19± 0.11b
Mean	6.71	1.77	1.50

Column with similar letters are not statistically different (based on Duncan's multiple-range significance test, 1% level). Data are mean of three replications ± SE.

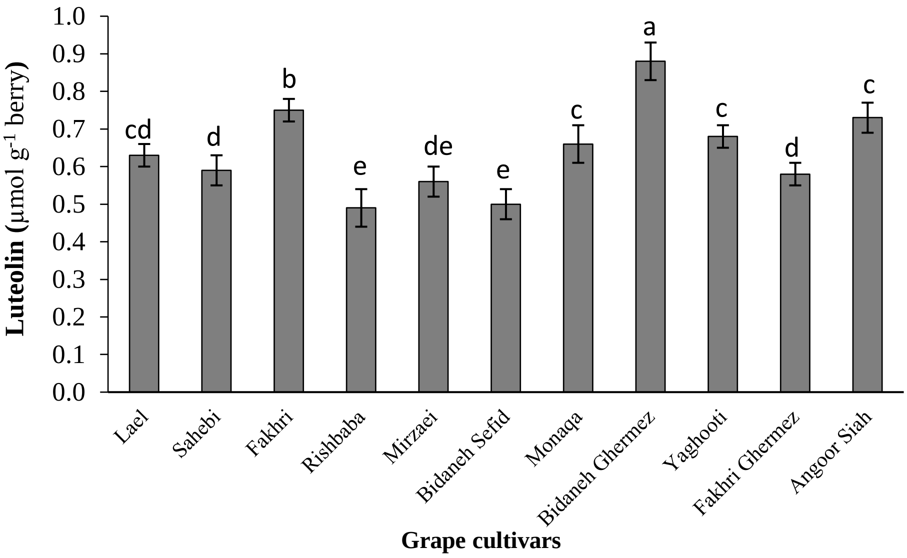

Fig. 1. Berry luteolin concentration (as a flavone group of flavonoids) among different Iranian grape (*Vitis vinifera* L.) cultivars. Columns with similar letters are not statistically different (based

on Duncan's multiple-range significance test, 1% level). Data are mean values of three replications ± SE.

Anthocyanidin content

Malvidin-3-glucoside and delphinidin-3-glucoside contents in the berry skin of 'Yaghooti' were higher than in other grape cultivars. The lowest amounts of these two anthocyanidin (P≤0.05) monoglucosides were measured in the berry skin of the 'Lael' cultivar (Table 4). Among the different grape cultivars, the 'Angoor Siah' cultivar showed higher amounts of cyanidin-3-glucoside and peonidin-3-glucoside (P≤0.05) in its berry skin. The lowest cyanidin-3-glucoside content (P≤0.05) was observed in the 'Lael' cultivar and the lowest peonidin-3-glucoside content (P≤0.05) was observed in the 'Monaqa' cultivar (Table 4). On the other hand, the highest and lowest petunidin 3-glucoside content (P≤0.05) was observed in 'Bidaneh Ghermez' and 'Lael' cultivars, respectively. The average values of delphinidin-3-glucoside, malvidin-3-glucoside, cyanidin-3-glucoside, petonidin-3-glucoside, and peonidin-3-glucoside in the berry skin of different grape cultivars were 414, 204, 340, 501, and 901 µg g-1 berry FW, respectively (Table 4).

Table 4. Berry anthocyanidins concentration of 11 Iranian grape (*Vitis vinifera* L.) cultivars.

Cultivars	Anthocyanidins ($\mu g\ g^{-1}$ berry)				
	Delphinidin-3-glucoside	Cyanidin-3-glucoside	Petunidin-3-glucoside	Peonidin-3-glucoside	Malvidin-3-glucoside
Lael	160± 12g	101± 12f	169± 32f	351± 23fg	633± 37g
Sahebi	301± 28e	214± 14c	276± 36de	430± 35d	824± 32e
Fakhri	188± 25fg	112± 17f	143± 37f	362± 19f	704± 20f
Rishbaba	257± 29ef	146± 23de	252± 35e	441± 24d	892± 29d
Mirzaei	404± 37d	200± 15cd	316± 22d	402± 20de	775± 32ef
Bidaneh Sefid	288± 25e	186± 17d	230± 23e	386± 22ef	721± 30f
Monaqa	204± 28f	123± 19ef	214± 38ef	320± 21g	661± 25a
Bidaneh Ghermez	680± 33b	302± 24ab	626± 37a	751± 38ab	114± 47b
Yaghooti	797± 29a	285± 20b	501± 57b	686± 37b	131± 42a
Fakhri Ghermez	552± 16c	231± 32c	444± 48c	573± 45c	982± 39c
Angoor Siah	726± 43ab	341± 23a	572± 42ab	804± 37a	1272± 52a
Mean	414	204	340	501	901

Columns with similar letters are not statistically different (based on Duncan's multiple-range test, 1% level). Data are mean values of three replications ± SE.

Hydroxycinnamic acids

In this study, four hydroxycinnamic acids were studied, including caffeic acid, p-coumaric acid, ferulic acid, and chlorogenic acid. The acids were identified and quantified using HPLC in grape berry skin. The hydroxycinnamic acid content, as an important group of phenolic acids in the berry skin, showed a significant difference (P≤0.05) among different grape cultivars (Table 5). The highest caffeic acid (P≤0.05) was related to the 'Monaqa' cultivar, while in the berry skin of 'Bidaneh Ghermez', the amount of this phenolic acid was lower (P≤0.05) compared to other cultivars (Table 5). Also, the p-coumaric acid content in 'Bidaneh Ghermez' was higher (P≤0.05) than in other cultivars, while the

'Sahebi' cultivar showed lower p-coumaric acid content (P≤0.05) compared to the other cultivars (Table 5).

The amounts of other hydroxycinnamic acids, including ferulic acid and chlorogenic acid, were highest (P≤0.05) in the berry skin of the 'Yaghooti' cultivar, but were lowest (P≤0.05) in the 'Monaqa' cultivar. The average values of caffeic acid, p-coumaric acid, ferulic acid, and chlorogenic acid in the berry skin of all cultivars were 1.00, 1.31, 1.34, and 1.16 µg g^{-1} berry FW, respectively (Table 5).

Table 5. Hydroxycinnamic acid concentrations in the berry skin of 11 Iranian grape (*Vitis vinifera* L.) cultivars.

Cultivars	Hydroxycinnamic acids (µg g^{-1} berry)			
	Caffeic acid	**P-coumaric acid**	**Ferulic acid**	**Chlorogenic acid**
Lael	1.13± 0.08b	0.95± 0.06d	0.69± 0.05fg	0.60± 0.04g
Sahebi	0.95± 0.07c	1.17± 0.08c	1.10± 0.05d	0.98± 0.07e
Fakhri	0.84± 0.07c	1.20± 0.07c	0.91± 0.06e	0.92± 0.08e
Rishbaba	1.20± 0.06b	1.66± 0.08c	1.17± 0.07d	1.19± 0.08d
Mirzaei	1.26± 0.06b	0.44± 0.06f	0.75± 0.05af	0.74± 0.09f
Bidaneh Sefid	1.34± 0.08ab	0.72± 0.06e	0.88± 0.06e	0.88± 0.08ef
Monaqa	1.45± 0.07a	0.61± 0.07e	0.60± 0.06g	0.56± 0.05g
Bidaneh Ghermez	0.54± 0.08d	2.46± 0.12a	2.44± 0.07a	1.52± 0.13c
Yaghooti	0.69± 0.09cd	1.96± 0.09b	2.36± 0.05a	2.17± 0.10a
Fakhri Ghermez	0.88± 0.05c	1.31± 0.09c	2.07± 0.09b	1.40± 0.11c
Angoor Siah	0.77± 0.06c	1.92± 0.09b	1.80± 0.09c	1.79± 0.12b
Mean	1.00	1.31	1.34	1.16

Columns with similar letters are not statistically different (based on Duncan's multiple-range test, 1% level). Data are mean values of three replications ± SE.

Benzoic acids

Another group of phenolic acids, including benzoic acids (hydroxybenzoic acid and dimethoxy benzoic acid), was measured in the berry skin of different grape cultivars. Based on the results (Table 6), a significant difference (P≤0.05) was observed among different cultivars in terms of the content of hydroxybenzoic acids, such as gallic acid, vanillic acid, and syringic acid in the berry skin. The gallic acid content was higher in the 'Yaghooti' cultivar (P≤0.05) compared to other cultivars. However, 'Rishbaba' had the highest vanillic acid and syringic acid in its berry skin (P≤0.05) (Table 6). The lowest gallic acid and vanillic acid contents (P≤0.05) were observed in the berry skin of the 'Lael' cultivar. The lowest synergic acid content (P≤0.05) was observed in the berry skin of the 'Monaqa' cultivar (Table 6).

There are few reports on veratric acid as a dimethoxybenzoic acid found in grape berry skins. However, in the present study, the amount of this dimethoxybenzoic acid in 'Angoor Siah' cultivar was higher compared to other grape cultivars (Table 6). However, the 'Monaqa' cultivar showed lower veratric acid content in its berry skin (Table 6).

Resveratrol

Resveratrol is the most important stilbene compound in grape berry skin, which can affect cultivar and environmental factors. In the current study, the amount of resveratrol in the berry skin of different grape cultivars varied from 22.7 µg g-1 FW of berry skin in the 'Monaqa' and 'Fakhri' cultivars to 54.8 µg g-1 FW of berry skin in the 'Bidaneh Ghermez' cultivar. It had an overall average of 36.9 µg g-1 FW of berry skin (Fig. 2). In general, the amount of stilbene in red grape cultivars, including 'Bidaneh Ghermez', 'Yaghooti', 'Angoor Siah', 'Fakhri Ghermez', 'Mirzaei', and 'Sahebi', was more than in cultivars with green or yellow skins, such as 'Bidaneh Sefid', 'Rishbaba', 'Lael', 'Fakhri', and 'Monaqa' (Fig. 2).

Table 6. Benzoic acid concentrations in the berry skin of 11 Iranian grape (*Vitis vinifera* L.) cultivars.

Cultivars	Benzoic acids ($\mu g\ g^{-1}$ berry)			
	Hydroxybenzoic acids			Dimethoxy-benzoic acid
	Gallic acid	Vanillic acid	Syringic acid	Veratric acid
Lael	0.47 ± 0.06d	0.22± 0.05g	0.96± 0.08g	0.55± 0.05d
Sahebi	0.80± 0.05c	0.48± 0.03d	1.77± 0.08c	nd*
Fakhri	0.44± 0.06d	0.39± 0.03e	1.24± 0.06e	0.38± 0.04e
Rishbaba	0.87± 0.07c	0.97± 0.02a	2.11± 0.05a	0.56± 0.06cd
Mirzaei	nd*	nd*	1.07± 0.04f	0.47± 0.05d
Bidaneh Sefid	nd*	0.33± 0.04f	0.86± 0.07g	0.42± 0.05e
Monaqa	0.35± 0.05e	nd*	0.46± 0.07h	0.30± 0.03f
Bidaneh Sefid	1.03± 0.07b	0.88± 0.03b	1.90± 0.05b	0.59± 0.07c
Yaghooti	1.20± 0.04a	0.41± 0.03e	1.12± 0.06f	0.69± 0.07c
Fakhri Ghermez	1.08± 0.05b	0.73± 0.04c	1.40± 0.04d	0.88± 0.06b
Angoor Siah	1.12± 0.05ab	0.69± 0.03c	1.23± 0.05e	0.97± 0.04a
Mean	0.82	0.57	1.28	0.58

Columns with similar letters are not statistically different (based on Duncan's multiple-range test, 1% level). Data are mean values of three replications ± SE.

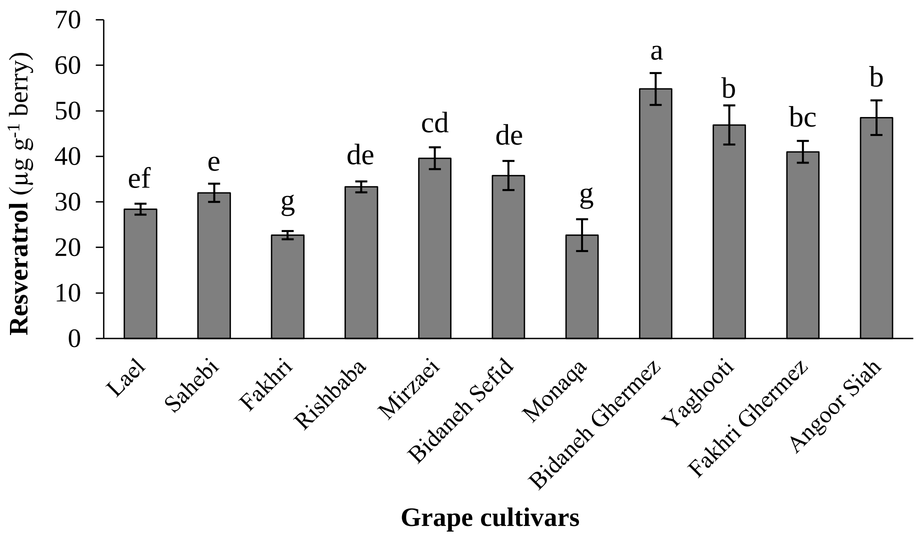

Fig. 2. Resveratrol concentrations in the berry skin of different Iranian grape (*Vitis vinifera* L.) cultivars. Columns with similar letters are not statistically different (based on Duncan's multiple-

range test, 1% level). Data are mean values of three replications ± SE.

Total phenol, total flavonoid and total anthocyanin

Based on the results (Table 7), a significant difference (P≤0.05) was observed among different cultivars in terms of total phenol, total flavonoid and total anthocyanin content of grape skin. The total phenolic content of cultivars varied from 5.57 mg g^{-1} berry FW in 'Lael' cultivar to 11.4 mg g^{-1} berry FW in 'Bidaneh Ghermez' cultivar with a total average of 8.10 mg g-1 berry FW. Regarding the total flavonoid, the lowest and highest content (P≤0.05) was related to 'Bidaneh Ghermez' and 'Rishbaba' cultivars, respectively (Table 7). The average of total flavonoid was equal to 0.65 mg g^{-1} berry FW that varied from 0.41 to 0.94 mg g-1 berry FW in different cultivars (Table 7). The total anthocyanin content of the cultivars varied from 0.28 mg g^{-1} berry FW in the 'Lael' cultivar to 0.75 mg g^{-1} berry FW in the 'Angoor Siah' cultivar, with a total average of 0.47 mg g^{-1} berry FW (Table 7).

Table 7. Berry skin total phenol, total flavonoid and total anthocyanin of 11 Iranian grape (*Vitis vinifera* L.) cultivars.

Cultivars	Total phenol (mg g^{-1} FW)	Total flavonoid (mg g^{-1} FW)	Total anthocyanin (mg g^{-1} FW)
Lael	5.57± 0.14f	0.47± 0.03g	0.28± 0.02f
Sahebi	7.95± 0.14d	0.63± 0.02e	0.41± 0.01d
Fakhri	6.32± 0.18e	0.47± 0.02g	0.30± 0.02f
Rishbaba	6.39± 0.17e	0.41± 0.02h	0.40± 0.03d
Mirzaei	9.73± 0.15c	0.71± 0.01d	0.42± 0.03d
Bidaneh Sefid	6.22± 0.17e	0.54± 0.02f	0.36± 0.02de
Monaqa	4.96± 0.13g	0.43± 0.03gh	0.30± 0.01f
Bidaneh Ghermez	11.36± 0.14a	0.94± 0.01a	0.70± 0.02b
Yaghooti	10.60± 0.18b	0.89± 0.02b	0.72± 0.02b
Fakhri Ghermez	9.75± 0.15c	0.79± 0.16c	0.56± 0.02c
Angoor Siah	10.29± 0.25b	0.89± 0.19b	0.75± 0.01a
Mean	8.10	0.65	0.47

Columns with similar letters are not statistically different (based on Duncan's multiple-range test, 1% level). Data are mean values of three replications ± SE.

Antioxidant capacity

The antioxidant capacity of berry skin extract of different grape cultivars was measured using the DPPH method. Based on the results, different cultivars were significantly different (P≤0.05) in terms of antioxidant capacity (Fig. 3). The radical scavenging capacity of 'Angoor Siah' was higher (71.3%; P≤0.05) than in other cultivars, although statistically, it did not show a significant difference with 'Yaghooti'. The lowest antioxidant capacity (30.4%; P≤0.05) was related to the berry skin of 'Monaqa' cultivar (Fig. 3). The average antioxidant capacity of different cultivars was 50.51%.

Antibacterial activity

In the current study, the antibacterial activity of 11 grape cultivars was investigated based on their response to four bacterial strains, including *Escherichia coli, Bacillus subtilis, Pseudomonas aeruginosa,* and *Staphylococcus aureus* (Table 8). Based on the results, a significant difference was observed among different grape cultivars in terms of antibacterial activity. In response to the Gram-negative bacteria *E. coli*, the highest minimum inhibitory concentration (MIC) index was related to the extract prepared from the berry skin of the 'Angoor Siah' cultivar. Other cultivars, including 'Yaghooti', 'Fakhri Ghermez', 'Bidaneh Ghermez', 'Sahebi', 'Fakhri', and 'Mirzaei', had MIC values ≤

10 μg mL^{-1} and ranked lower in terms of antibacterial activity (Table 8).

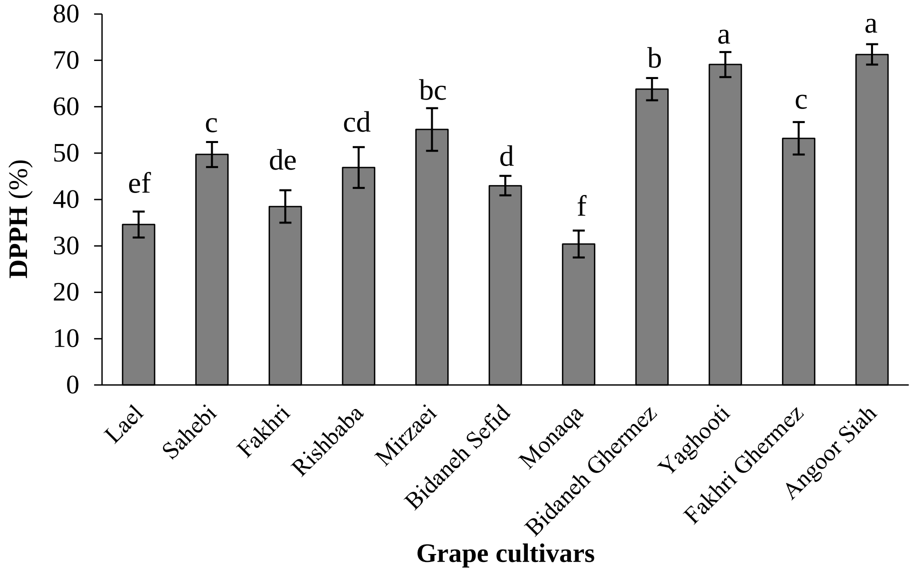

Fig. 3. Berry antioxidant capacity (based on DPPH method) concentration among different Iranian grape (*Vitis vinifera* L.) cultivars. Columns with similar letters are not statistically different (based on Duncan's multiple-range test, 1% level). Data are mean values of three replications ± SE.

Regarding the gram positive bacteria *B. subtilis*, it was found that 'Fakhri Ghermez', 'Angoor Siah', Sahebi', 'Yaghooti', and Bidaneh Ghermez' cultivars had MIC values < 7μg mL^{-1} in the first group. Other cultivars were in the second group in terms of antibacterial activity. The highest and lowest antibacterial activity in response to this bacterial strain was related to 'Fakhri Ghermez' and 'Fakhri', respectively (Table 8).

The antibacterial activity of the extract in different grape cultivars was measured based on their response to the gram-negative bacteria *P. aeruginosa*. A significant difference occurred among the cultivars in terms of antibacterial activity. Based on this strain, the highest antibacterial activity (MIC=1.25 μg mL^{-1}) was related to the berry skin extract of the 'Angoor Siah' cultivar and the lowest antibacterial activity (MIC=32.2 μg mL^{-1}) was related to the 'Rishbaba' cultivar (Table 8).

Regarding the gram-positive *S. aureus* bacteria, the results showed that the skin extract of the 'Angoor Siah' cultivar had MIC values < 8 μg mL^{-1} and had the highest antibacterial activity, whereas the 'Fakhri' cultivar had an MIC value of 244 μg mL^{-1} and showed the lowest antibacterial activity among the grape cultivars (Table 8).

The overall average MIC values measured in response to the application of the skin extract of different cultivars in the four bacterial strains of *E. coli, B. subtilis, P. aeruginosa*, and *S. aureus* were 11.4, 28.2, 23.5, and 101.7 μg mL^{-1}, respectively (Table 8).

Discussion

In this study, the profile of individual phenolic components, antioxidant capacities, and antibacterial activity of eleven grape cultivars were investigated. A significant difference was observed among all cultivars in terms of the content of bioactive compounds and antioxidant indices. The content of flavan-3-ols of catechin and epicatechin in the 'Yaghooti' and catechin gallate in 'Bidaneh Ghermez' and 'Angoor Siah' were higher than in other grape cultivars. In a relevant study, the phenolic profile and antioxidant capacities of berry skin and flesh of 11 grape cultivars from a research farm in Southwest University of Chongqing, China, were studied. A significant difference was observed among the cultivars in terms of the content of phenolic compounds of the grape cultivars. According to the results, the highest amounts of kaempferol (541.2 μg g^{-1} FW) and catechin (67.7 μg g^{-1} FW) were related to 'Kyoho'. The highest amounts of total phenol (10.2 mg g^{-1} FW), antioxidant capacity (EC50=11.7 μg mL^{-1} based on DPPH radical scavenging capacity), rutin (262.3 μg g^{-1} FW), and epicatechin (45.5 μg g^{-1} FW) were attributed to the berry skin of 'Muscat Kyoho' grape cultivar (Li et al., 2019). In the skin of grape berries, the amounts of two flavanols, catechin, and epicatechin, were much higher than epigallocatechin and epigallocatechin, although the total flavanols content was influenced by grape variety (Gouot et al., 2019). The content and presence of flavan-3-ols in grapes mainly depends on the cultivar, soil, climate, and other viticultural practices (Sun et al., 2006). Also, in grapes berries the content of catechin, epicatechin, and epigallocatechin as the three main flavonols can be influenced significantly by cultivars and cultivation systems (Mehrpour, 2021). The scenario for the flavonoid biosynthesis regulation through the phenylpropanoid pathway depends on the tree species and its genome structure of origin, which is affected by natural variation and tree domestication episodes (Cavallini et al., 2015).

Table 8. Antimicrobial activity based on minimum inhibitory concentrations (MIC) in berry skins of 11 Iranian grape (*Vitis vinifera* L.) cultivars.

Cultivars	Minimum inhibitory concentrations (MICs) (µg mL^{-1})			
	Escherichia coli	*Bacillus subtilis*	*Pseudomonas aeruginosa*	*Staphylococcus aureus*
Lael	16.8	42.22	16.8	211.1
Sahebi	6. 5	54.8	6.45	64.5
Fakhri	7.8	64.8	15.6	244
Rishbaba	32.2	40.32	32.2	201.6
Mirzaei	10.0	35.0	15	15
Bidaneh Sefid	5.00	25.0	5	50
Monaqa	31.2	31.2	9.7	195
Bidaneh Ghermez	3.60	6.98	4.78	53.7
Yaghooti	2.80	3.76	4.56	45.6
Fakhri Ghermez	3.1	3.12	>312.5	31.2
Angoor Siah	1.25	3.15	125	7.81
Mean	11.38	28.21	23.51	101.77

Different grape cultivars showed different responses in terms of the accumulation of flavonols (quercetin, kaempferol, myricetin) in their berry skin. In the current work, the content of quercetin in 'Yaghooti' and kaempferol and myricetin in 'Bidaneh Ghermez' were found to be highest among all grape cultivars herein. Castillo-Munoz et al. (2007) investigated the profile of individual flavonols in seven varieties of red grapes and concluded that there is a significant difference between the varieties in terms of quercetin, kaempferol, and myricetin content. In a study, Mehrpour (2021) investigated the effect of cultivar and training system on the content of flavonols in two grape cultivars, 'Bidaneh Ghermez' and 'Bidaneh Sefid'. In that study, the highest content of flavonols (quercetin, myricetin, and kaempferol) was related to the 'Bidaneh Ghermez' under the trellised system, and the lowest content of these phenolic compounds was related to the 'Bidaneh Sefid' under the non-trellised system (Mehrpour, 2021).

Quercetin, myricetin, and kaempferol, as three important flavonols (a group of colorless flavonoids), mainly accumulate in the berry skin, especially in colored skin grape cultivars (Gouot et al., 2019). During the ripening stage, flavonols accumulation in berry skin or seed to a great extent depends on the cultivar genetic background (de Silva et al., 2019), however, it can be affected to some extent by crop load (Gutiérrez-Gamboa et al., 2018) and viticultural operations (Liu et al., 2018).

Among all studied grape cultivars, the content of luteolin was found to be highest in the 'Bidaneh Ghermez' berry skin. Luteolin is a 3'-

hydroxyflavonoid compound and a tetrahydroxyflavone. This major flavone has a main role in human health as a bioactive compound with antioxidant, anti-inflammatory, and anti-cancer properties (Tsao, 2010). Flavones, especially in the form of aglycons or glycoside, have been identified and quantified in plants, however, except for luteolin, the amounts of other flavones in grapes are not significant (Fang et al., 2008). This is the first report of luteolin measurement in grape cultivars confirming the effect of cultivar and growing condition on the biosynthesis of this flavone in grapevine.

In the present study, a significant difference ($P \leq 0.05$) was observed between different cultivars in terms of anthocyanidin content. The content of malvidin-3-glucoside and delphinidin-3-glucoside in the skin of 'Yaghooti', cyanidin-3-glucoside and peonidin-3-glucoside in 'Angoor Siah' and petunidin 3-glucoside in Bidaneh Ghermez' were found to be highest among all studied grape cultivars. Recently, cultivars such as 'Cabernet Sauvignon', 'Shiraz' (*V. vinifera*), *Vitis labrusca* ('Bordô'), and hybrids (Niagara Rosada) were evaluated in high-growth rootstocks (Mota et al., 2009). Based on their results, 'IAC 313 Tropical' has a greater ability to improve the concentration of anthocyanins and (poly) phenols in its berries compared to 'IAC 572 Jales' (Mota et al., 2009). Also, it has been reported that the content of anthocyanins (malvidin, delphinidin, pelargonidin, and cyanidin) in the 'Bidaneh Ghermez' cultivar is more than 'Bidaneh Sefid' cultivar (Mehrpour, 2021), which confirms the findings of the present study. The content of anthocyanins in berry skin is affected by several factors. The genetics of the variety and rootstock are one of the most influential factors on the profile of anthocyanidins in grape skin. However, the role of other factors such as degree of maturity and weather conditions, especially light intensity and temperature, training system, and viticultural operations on anthocyanin content is also of particular importance (Ferrandino and Guidoni, 2010). Under the same environmental condition and viticultural management, the profile of anthocyanins for each grape variety is relatively stable, which indicates that the absolute amounts of anthocyanins largely depend on the cultivar-based genetic background (Gil-Muñoz et al., 2010). The phenylpropanoid pathway is strongly controlled and regulated by a series of transcription factors and several protein families. The changes and mutual interaction of these regulatory protein complexes ultimately determine the expression level of genes related to the biosynthesis of phenolic compounds, especially anthocyanins, and proanthocyanidins in grape berries of different cultivars through the phenylpropanoid pathway (Koes et al., 2005; Cavallini et al., 2015).

A significant difference ($p < 0.01$) was observed among different grape cultivars in terms of berry skin hydroxycinnamic acids, including caffeic acid, p-coumaric acid, ferulic acid, and chlorogenic acid. In a study, Mehrpour (2021) investigated the content of phenolic acids in two grape cultivars, 'Bidaneh Ghermez' and 'Bidaneh Sefid'. In that study, the highest content of caffeic acid, p-coumaric acid, and ferulic acid was related to the 'Bidaneh Ghermez', and the lowest content of these phenolic acids was related to the 'Bidaneh Sefid' confirming the result of the current study. Recently, Li et al. (2019) investigated the phenolic acid content of the berry skin of 11 native grape cultivars in Chongqing, China. Their study showed a significant difference in free gallic acid, caftaric acid, 3, 4, dihydroxybenzoic acid, vanillic acid, caffeic acid, syringic acid, and p-coumaric acid content among berry skins of 11 *Vitis vinifera* cultivars. The highest concentrations of gallic acid and 3, 4, dihydroxybenzoic acid, were found in 'White Olympia' berry skin, whereas the highest concentrations of caftaric acid, vanillic acid, caffeic acid, syringic acid, and p-coumaric acid catechin were found in 'Moldova', 'Hutai-8', 'Hakuho', 'Muscat Kyoho', and 'Kyoho' grape cultivars, respectively (Li et al., 2019). These researchers concluded that the content of phenolic acids is strongly influenced by the variety, which confirms the findings of the present study.

In the current work, the amounts of resveratrol in red grape cultivars, including 'Bidaneh Ghermez', 'Yaghooti', 'Angoor Siah', 'Fakhri Ghermez', 'Mirzaei', and 'Sahebi', were more than in cultivars with green or yellow berry skins. The obtained results were comparable with previous findings (Careri et al., 2003; Sun et al., 2006; Karimi et al., 2019). In a relevant study, the resveratrol content of two grape cultivars was investigated, showing that the 'Bidaneh Ghermez' had more resveratrol content compared to the 'Bidaneh Sefid' cultivar (Mehrpour, 2021). According to Sun et al. (2006), there was no significant difference among grape cultivars 'Tinta Roriz', 'Syrah', and 'Castelao' in terms of berry skin resveratrol content (with an average of 20 mg Kg^{-1} of dry skin weight). The highest content of resveratrol was related to the 'Cabernet Sauvignon' cultivar. The amount of resveratrol was highly dependent on the grape variety. However, viticultural operations, such as the use of training systems, can affect the amount of resveratrol biosynthesis (Karimi et al., 2019).

In the current study, the antioxidant capacity of 'Angoor Siah' and 'Yaghooti' were significantly higher than in other grape cultivars. According to de Silva et al. (2019), cultivars and rootstocks strongly influence the antioxidant capacity of grapes and their by-products. Some polyphenols found in the skin and seeds of red grapes, such as catechin and epicatechin (flavan-3-ol), quercetin and its rutin glycoside (flavonols) and trans-resveratrol, have antioxidant activity (Yilmaz and Toledo, 2004). It has been proven that these compounds due to their basic structure and other structural factors have strong antioxidant properties and exhibit important biological, pharmacological, and medical properties (Colombo et al., 2019). Indeed, different phenolic compounds have a high capacity to neutralize reactive oxygen species and chelate some metal ions due to their hydroxyl groups and their position in the phenol ring (Garrido and Borges, 2013).

Regarding the four bacterial strains, *E. coli, B.subtilis, P. aeruginosa*, and *S. aureus*, the highest MICs index was related to the extract prepared from the berry skin of the 'Angoor Siah' cultivar. Our results agree partially with previous studies of whole grape or grape pomace extracts that found antibacterial activity against both Gram-positive and Gram-negative bacteria (Nada et al., 2012; Xu et al., 2016). The antibacterial activities of four grape varieties (Cabernet Franc, Chambourcin, Vidal Blanc, and Viognier) from Virginia were investigated by Xu et al. (2016). Their study showed a significant difference in antibacterial activity against L. monocytogenes and S. aureus, but no antibacterial activity was detected against E. coli and S. typhimurium (Xu et al., 2016). Flavonoids are known to be synthesized in response to microbial infection by plants and can bind to bacterial cell walls (Cowan, 1999). Phenolic compounds bind to extracellular and soluble proteins and form complexes with bacterial cell walls, leading to the inactivation of bacteria (Puupponen-Pimia et al., 2001; Xu et al., 2016). These antibacterial properties in the skin or other parts of the grape demonstrate that these natural compounds can replace synthetic antioxidants and antibacterial compounds to reduce concerns in food consumers and maintain their health.

Conclusion

Significant differences were found among the 11 grape cultivars in terms of berry skin phenolic compounds profile, antioxidant capacity, and antibacterial activity. These findings confirmed that phenolics and their properties can be affected mainly by the cultivar-based genetic background. The highest amounts of catechin, epicatechin, and quercetin were related to the berry skin of 'Yaghooti'. The amounts of catechin gallate, kaempferol, and myricetin in the 'Bidaneh Ghermez' cultivar were higher than in other cultivars. The amounts of delphinidin-3-glucoside and malvidin-3-glucoside in 'Yaghootin', cyanidin-3-glucoside and peonidin-3-glucoside in 'Angoor Siah', and petunidin 3-glucoside in 'Bidaneh Ghermez' were higher compared to the other cultivars. The p-coumaric acid in 'Bidaneh Ghermez' and other hydroxycinnamic acids (ferulic acid and chlorogenic acid) were highest in the skin of the 'Yaghooti cultivar. The amount of gallic acid in the berry skin of 'Yaghooti' was higher than in the other cultivars. 'Rishbaba' showed higher amounts of vanillic acid and syringic acid in the berry skin. Among different cultivars, the antioxidant capacity in 'Angoor Siah' was highest, but was lowest in 'Monaqa'. Based on the MICs index, 'Angoor Siah' had more antibacterial activity compared to the other cultivars. The results of the current work revealed a considerable variation in berry skin phenolic compounds, antioxidant capacity, and antibacterial properties of 11 grape cultivars. The results of this study can be used as a guide for selecting cultivars with different amounts of phenolic compounds and antibacterial activity for fresh consumption and processing with the desirable cultivars.

Acknowledgements
Funding was provided by Vice-Presidency of Research and Technology of Malayer University, Iran (M. Rahimi; Grant no. 84.5–250). The authors gratefully acknowledge Malayer University.

Conflict of Interest
The authors indicate no conflict of interest for this work.

References

Asgarian ZS, Karimi R, Ghabooli M, Maleki M. 2022. Effect of phenylalanine treatment on chilling tolerance and biochemical attributes of grape during postharvest cold storage. Journal of Berry Research 12, 513-529.

Asgarian ZS, Karimi R, Ghabooli M, Maleki M. 2022. Biochemical changes and quality characterization of cold-stored 'Sahebi' grape in response to postharvest application of GABA. Food Chemistry 373, 131401.

Bunea CI, Pop N, Babeş AC, Matea C, Dulf FV, Bunea A. 2012. Carotenoids, total polyphenols and antioxidant activity of grapes (*Vitis vinifera*) cultivated in organic and conventional systems. Chemistry Central Journal 6(1), 1-9.

Careri M, Corradini C, Elviri L, Nicoletti I, Zagnoni I. 2003. Direct HPLC analysis of quercetin and trans-resveratrol in red wine, grape, and winemaking byproducts. Journal of Agriculture and Food Chemistry 51(18), 5226-5231.

Castellarin SD, Bavaresco L, Falginella L, Gonçalves MIVZ, di Gaspero G. 2012. Phenolics in Grape Berry and Key Antioxidants. In The Biochemistry of the grape berry; Gerós H, Chaves M, Delrot S, Eds.; Bentham Science: Bussum, The Netherlands, pp. 89-110.

Castillo-Muñoz N, Gómez-Alonso S, García-Romero E, Hermosín-Gutiérrez I. 2007. Flavonol profiles of *Vitis vinifera* red grapes and their single-cultivar wines. Journal of Agriculture and Food Chemistry 55(3), 992-1002.

Cavallini E, Matus JT, Finezzo L, Zenoni S, Loyola R, Guzzo F, Schlechter R, Ageorges A, Arce-Johnson P, Tornielli GB. 2015. The phenylpropanoid pathway is controlled at different branches by a set of R2R3-MYB C2 repressors in grapevine. Plant Physiology 167(4), 1448-1470.

Chang CC, Yang MH, Wen HM, Chern JC. 2002. Estimation of total flavonoid content in propolis by two complementary colorimetric methods. Journal of Food and Drug Analysis 10(3), 187-182.

Colombo F, Di Lorenzo C, Regazzoni L, Fumagalli M, Sangiovanni E, de Sousa LP, de Bavaresco L, Tomasi D, Bosso A, Aldini G, Restani P, Dell'Agli M. 2019. Phenolic profiles and anti-inflammatory activities of sixteen table grape (*Vitis vinifera* L.) varieties. Food and Function 10(4), 1797-1807.

Cowan MM. 1999. Plant products as antimicrobial agents. Clinical Microbiology Reviews 12(4), 564-582.

da Silva MJR, da Silva Padilha CV, dos Santos Lima M, Pereira GE, Venturini Filho WG, Moura MF, Tecchio MA. 2019. Grape juices produced from new hybrid varieties grown on Brazilian rootstocks–bioactive compounds, organic acids and antioxidant capacity. Food Chemistry 289, 714-722.

Del Rio D, Rodriguez-Mateos A, Spencer JP, Tognolini M, Borges G, Crozier A. 2013. Dietary (poly) phenolics in human health: structures, bioavailability, and evidence of protective effects against chronic diseases. Antioxidants and Redox Signaling 18(14), 1818-1892.

Dixon RA, Paiva NL. 1995. Stress-induced phenylpropanoid metabolism. Plant and Cell 7(7), 1085.

Fang F, Li JM, Zhang P, Tang K, Wang W, Pan QH, Huang WD. 2008. Effects of grape variety, harvest date, fermentation vessel and wine ageing on flavonoid concentration in red wines. Food Research International 41(1), 53-60.

Farhadi K, Esmaeilzadeh F, Hatami M, Forough M, Molaie R. 2016. Determination of phenolic compounds content and antioxidant activity in skin, pulp, seed, cane and leaf of five native grape cultivars in west Azerbaijan province, Iran. Food Chemistry 199, 847-855.

Ferrandino A, Guidoni S. 2010. Anthocyanins, flavonols and hydroxycinnamates: an attempt to use them to discriminate *Vitis vinifera* L. cv 'Barbera'clones. Journal of European Food Research and Technology 230(3), 417-427.

Garrido J, Borges F. 2013. Wine and grape polyphenols - a chemical perspective. Food Research International 54(2), 1844-1858.

Gil-Muñoz R, Fernández-Fernández JI, Vila-López R, Martinez-Cutillas A. 2010. Anthocyanin profile in monastrell grapes in six different areas from denomination of origen jumilla during ripening stage. International Journal of Food Science and Technology 45(9), 1870-1877.

Giusti MM, Wrolstad RE. 2001. Characterization and measurement of anthocyanins by UV-visible spectroscopy. Current Protocols in Food Analytical Chemistry (1), F1-2.

Gouot JC, Smith JP, Holzapfel BP, Walker AR, Barril C. 2019. Grape berry flavonoids: a review of their biochemical responses to high and extreme high temperatures. Journal of Experimental Botany 70(2), 397-423.

Gutiérrez-Gamboa G, Carrasco-Quiroz M, Verdugo-Vásquez N, Díaz-Gálvez I, Garde-Cerdán T, Moreno-Simunovic Y. 2018. Characterization of grape phenolic compounds of 'Carignan' grapevines grafted onto 'País' rootstock from Maule Valley (Chile): implications of climate and soil conditions. Chilean Journal of Agricultural Research 78(2), 310-315.

Karimi R, Koulivand M, Ollat N. 2019. Soluble sugars, phenolic acids and antioxidant capacity of grape berries as affected by iron and nitrogen. Acta Physiologiae Plantarum 41(7), 1-11.

Karimi R, Mirzaei F, Rasouli M. 2017. Phenolic acids, flavonoids, antioxidant capacity and minerals content in fruit of five grapevine cultivars. Iranian Journal of Horticiltural Science and Technology 18(1), 89-102.

Katalinić V, Možina SS, Skroza D, Generalić I, Abramovič H, Miloš M, Ljubenkov I, Piskernik S, Pezo I, Terpinc D, Boban M. 2010. Polyphenolic profile, antioxidant properties and antimicrobial activity of grape skin extracts of 14 *Vitis vinifera* varieties grown in dalmatia (Croatia). Food Chemistry 119(2), 715-723.

Kedage VV, Tilak JC, Dixit GB, Devasagayam TP, Mhatre M. 2007. A study of antioxidant properties of some varieties of grapes (*Vitis vinifera* L.). Criticul Review in Food Science and Nutrition 47(2), 175-185.

Keller M. 2015. The science of grapevines: anatomy and physiology. 2rd ed. Academic Press. Burlington, MA, 400 p.

Koes R, Verweij W, Quattrocchio F. 2005. Flavonoids: a colorful model for the regulation and evolution of biochemical pathways. Trends in Plant Science 10(5), 236-242.

Koponen JM, Happonen AM, Mattila PH, Törrönen AR.

2007. Contents of anthocyanins and ellagitannins in selected foods consumed in Finland. Journal of Agriculture and Food Chemistry 55(4), 1612-1619.

Li FX, Li FH, Yang YX, Ran YIN, Jian MING. 2019. Comparison of phenolic profiles and antioxidant activities in skins and pulps of eleven grape cultivars (*Vitis vinifera* L.). Journal of Integrated Agriculture 18(5), 1148-1158.

Mathew S, Abraham TE, Zakaria ZA. 2015. Reactivity of phenolic compounds towards free radicals under *in vitro* conditions. Journal of Food Science and Technology 52(9), 5790-5798.

Mehrpour H. 2021. Comparison of the effect of trellised and non-trellised training systems on fruit and raisin quality indices and cold tolerance of two grapevine cultivars. MSc dissertation, Malayer University 198p.

Mota RVD, Souza CRD, Favero AC, Silva CPC, Carmo ELD, Fonseca AR, Regina MDA. 2009. Produtividade e composição físico-química de bagas de cultivares de uva em distintos porta-enxertos. Brazilian Journal of Agricultural Research 44, 576-582.

Nada El D, Joanna T, Paulette Bou M, James P, Joseph Y, Eugène V, Richard GM. 2012. A comparative study on antiradical and antimicrobial properties of red grapes extracts obtained from different *Vitis vinifera* varieties. Food and Nutrition Sciences 3, 1420-1432.

Orak HH. 2007. Total antioxidant activities, phenolics, anthocyanins, polyphenoloxidase activities of selected red grape cultivars and their correlations. Scientia Horticulturae 111(3), 235-241.

Puupponen-Pimiä R, Nohynek L, Meier C, Kähkönen M, Heinonen M, Hopia A, Oksman-Caldentey KM. 2001. Antimicrobial properties of phenolic compounds from berries. Journal of Applied Microbiology 90(4), 494-507.

Rockenbach II, Gonzaga LV, Rizelio VM, Gonçalves AEDSS, Genovese MI, Fett R. 2011. Phenolic compounds and antioxidant activity of seed and skin extracts of red grape (*Vitis vinifera* and *Vitis labrusca*) pomace from Brazilian winemaking. Food Research International 44(4), 897-901.

Sánchez-Moreno C, Larrauri JA, Saura-Calixto F. 1998. A procedure to measure the antiradical efficiency of polyphenols. Journal of the Science of Food and Agriculture 76(2), 270-276.

Shrestha B, Theerathavaj MS, Thaweboon S, Thaweboon B. 2012. *In vitro* antimicrobial effects of grape seed extract on peri-implantitis microflora in craniofacial implants. Asian Pacific Journal of Tropical Biomedicine 2(10), 822-825.

Sun B, Ribes AM, Leandro MC, Belchior AP, Spranger MI. 2006. Stilbenes: quantitative extraction from grape skins, contribution of grape solids to wine and variation during wine maturation. Analytica Chimica Acta 563(1-2), 382-390.

Tantaoui-Elaraki A, Beraoud L. 1994. Inhibition of growth and aflatoxin production in Aspergillus parasiticus by essential oils of selected plant materials. Journal of Environmental Pathology, Toxicology, and Oncology 13(1), 67-72.

Teixeira A, Baenas N, Dominguez-Perles R, Barros A, Rosa E, Moreno DA, Garcia-Viguera C. 2014. Natural bioactive compounds from winery by-products as health promoters: a review. International Journal of Molecular Sciences 15(9), 15638-15678.

Tsao R. 2010. Chemistry and biochemistry of dietary polyphenols. Nutrients 2(12), 1231-1246.

Vekiari SA, Gordon MH, Garcia-Macias PA, Labrinea H. 2008. Extraction and determination of ellagic acid content in chestnut bark and fruit. Food Chemistry 110(4), 1007-1011.

Velioglu Y, Mazza G, Gao L, Oomah BD. 1998. Antioxidant activity and total phenolics in selected fruits, vegetables, and grain products. Journal of Agriculture and Food Chemistry 46(10), 4113-4117.

Xu C, Zhang Y, Cao L, Lu J. 2010. Phenolic compounds and antioxidant properties of different grape cultivars grown in China. Food Chemistry 119(4), 1557-1565.

Xu Y, Burton S, Kim C, Sismour E. 2016. Phenolic compounds, antioxidant, and antibacterial properties of pomace extracts from four Virginia-grown grape varieties. Food Science and Nutrition 4(1), 125-133.

Yilmaz Y, Toledo RT. 2004. Major flavonoids in grape seeds and skins: antioxidant capacity of catechin, epicatechin, and gallic acid. Journal of Agriculture and Food Chemistry 52(2), 255-260.