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Antioxidant Activity, Total Phenolic Compounds and Anthocyanin Contents in 35 Different Grapevine (*Vitis vinifera* L.) Cultivars Grown in Fars Province

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Abstract
Grapes are significant sources of nutritional antioxidants as well as biologically active dietary components. This study was carried out to determine the amount of total phenols, anthocyanins and antioxidant activity of 35 grapevine (*Vitis vinifera* L.) cultivars grown in Fars province (Iran). Ripened bunches were randomly harvested from grapevine collection in Zarghan (Fars province, Iran) Agricultural Research Center, and then were transferred to the laboratory. Berry size (length, diameter, and weight), skin weight, acidity, vitamin C, total soluble solids (TSS), pH, phenols, anthocyanins and antioxidant activity were evaluated. The results showed that total phenols, anthocyanin and antioxidant activity in the berries varied among the investigated cultivars. 'Gandome Uromia' (Red, 64) and 'Rishbaba Uromia' (Red, 75) cultivars had the highest values of antioxidant activity and total phenols. The lowest amount of phenol was obtained from 'Divaneh Kashmar' (White, 135) cultivar. Anthocyanin and antioxidant activity were the lowest in 'Jeshnion Bavanat' (White, 105) cultivar. Antioxidant activity had a positive significant correlation with amount of phenols and anthocyanin. In general, it was found that different cultivars in this study had a vast range of antioxidant activity from 14.55 to 66.47%.

Keywords: grape cultivars, nutritional value, vitamin C.

Introduction

Grapevines are one of the most important fruit commodities as economic plants with good agricultural characteristics. Grape berries are consumed as table fruits, wine, juice and raisins. Grapevines and their products have been important elements in human life, foods and religions (Lavee, 2000). Grapes are becoming increasingly popular as a fruit and are a significant source of nutritional antioxidants, such as polyphenols, anthocyanins and biologically active dietary components. Antioxidants are our first line of defence against free radical damage, and are critical for maintaining optimum health and wellbeing. The need for antioxidants becomes even more critical with increasing exposure to free radicals (Palomino *et al*., 2000).

The consumption of grape berries plays an important role in the maintenance of health and in disease prevention, such as inflammation, cardiovascular disease, cancer and ageing-related disorders (Ziegler, 1991; Rimm *et al*., 1996; Terry *et al*., 2001; Xu *et al*., 2010).

Products made from grape berries such as grape seed oil, wine and grape juice are all known to contain a diverse array of potent antioxidants in the form of phenolic

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compounds, which include phenolic acids (e.g., gallic acid), anthocyanins, and simple and complex flavonoids (e.g., proanthocyanidins). These compounds could effectively retard or inhibit lipid autoxidation by acting as scavengers of radicals and, consequently, as essential antioxidants that counter the propagation of the oxidative chain and, when taken daily in adequate amounts, offer protection from a number of diseases including cancer and cardiovascular diseases (Leifert and Abeywardena, 2008; Makris *et al*., 2008). In addition, phenolic compounds play a critical role in determining the quality of berries (Chamkha *et al*., 2003).

Xu *et al*. (2010) reported that the total phenolic compounds and the antioxidant activities in grape seeds and skins varied significantly among the grape cultivars grown in China. Poudel *et al*. (2008) evaluated the phenolic compounds and antioxidant activities of skins and seeds of five wild grapes and two hybrids native to Japan, and then reported that wild grapes are a potential source of neutraceutical phenolics. Furthermore, accumulating evidence exists that suggests that different conditions such as genotype, climate and soil properties may have a profound influence on the content of bioactive compounds in grape berries (Anttonen and Karjalainen, 2005).

However, to the best of our knowledge, limited information exists regarding the antioxidant properties of grape cultivars grown in Iran (Fars province). Therefore in this study we analysed 35 grape cultivars grown in Iran (Fars), for their total anthocyanin, total phenolic content and the antioxidant activity of berries and their correlations.

Materials and Methods

Harvesting of grape samples

Ripened bunches were randomly harvested from vineyard collection at the Agricultural Research Center located in Fars province (Zarghan). Thirty five grape cultivars including ‘Khalili Ghochan’, ‘Yaghoti Sefid Zarghan’, ‘Ghezel Uzom’, ‘Rotabi Sefid Zarghan’, ‘108 Zarghan, Siahe Ghochan’, ‘Golabi Lotef Abadi Dareghaz’, ‘Gandoem Uromia’, ‘Rishbaba Ghomesh Uromia’, ‘Jeshnion Bavanat’, ‘Rotabi Zarghan’, ‘Rjabi Sefid Zarghan’, ‘Askari Zarghan’, ‘Siah Samarghandi’, Code 148, ‘Neishabori Ghochan’, ‘Rishbaba Uromia’, ‘107 Zarghan’, ‘Piche Kashmar’, ‘Neishabori Birjand’, ‘Gazne Uromia’, ‘Lali Uromia’, ‘Gharehchin Uromia’, ‘Bidaneh Uromia’, ‘Sahebi Uromia’, ‘Elghi Siah Najaf Abad’, ‘Mesghali Najafabad Abade’, ‘Keshmeshi Ghermez Ghochan’, ‘Askari Najafabad Abade’, ‘Kalei Zarghan, Rishbaba Siah Dodaj’, ‘Divane Kashmar’, ‘Siah Khorjan Bavanat’, ‘Sahebi Siah Mazaijan Bavanat’, and ‘Rishbaba Siah Zarghan’ were selected from Zarghan Grapevine Collection (Table 1). These cultivars were tagged with special codes.

The bunch samples were randomly collected from the 15-year old vines grown in experimental vineyards. The vineyards soil type was clayish loam. Vines were trained as a head system. Approximately 500 g of ripened grapes per vine were randomly harvested manually. The harvested bunches were immediately transferred to the horticultural laboratory. Berry size (length, diameter, length: diameter ratio and weight), and berry skin weight, acidity by titration method, total soluble solids (TSS), by manual refractometer and pH were measured. Vitamin C was measured by method titration, which is a commonly used procedure for determining ascorbic acid. When the grapes were transferred to the laboratory, one group from each cultivar was immediately frozen at -25^{o}C for further analysis.

Table 1. The characteristics of 35 grapevine (*Vitis vinifera* L.) cultivars used in this experiment.

Cultivar	Code	Color	Vigor	Bunch density
'Khalili Ghochan'	89	White	Intermediate	Intermediate
'Yaghoti Sefid Zarghan'	149	White	High	Intermediate
'Ghezel Uzom'	72	Red-purple	High	Intermediate
'Rotabi Sefid Zarghan'	8	White	Intermediate	Intermediate
'108 Zarghan'	20	White	High	Low
'Siahe Ghochan'	36	Red	Intermediate	Intermediate
'Golabi LotefAbadi Daregaz'	63	White	High	Intermediate
'Gandome Uromia'	64	Red	High	Intermediate
'Rish Baba Ghomesh Uromia'	76	Red- purple	Intermediate	Intermediate
'Jeshnion Bavanat'	105	White	Intermediate	Intermediate
'Rotabi Zarghan'	116	White	High	Intermediate
'Rajabi Sefid Zarghan'	120	White	High	Intermediate
'Askari Zarghan'	123	White	Low	Intermediate
'Siah Samarghandi'	200	Red-purple	Intermediate	Intermediate
Code 148	148	Red-purple	High	Low
'Neishabori Ghochan'	43	White	High	Low
'Rish Baba Uromia'	75	Red	Intermediate	Low
'107 Zarghan'	19	Red- purple	High	High
'Piche Kashmar'	46	Red-purple	Intermediate	High
'Neishabori Birjand'	62	Red	Intermediate	Intermediate
'Gazne Uromia'	65	Red	Low	Intermediate
'Lali Uromia'	67	Red- black	Intermediate	Intermediate
'Gharechin Uromia'	70	Red-purple	Intermediate	Intermediate
'Bidaneh Uromia'	71	White	Intermediate	Intermediate
'Sahebi Uromia'	77	Red-purple	Low	Intermediate
'Elghi Siah Najafabad Abade'	103	Red	High	Intermediate
'Mesghali Najafabad Abade'	95	Red-purple	Intermediate	Intermediate
'Keshmeshi Ghermez Ghochan'	136	Red black	Intermediate	Low
'Askari Najafabad Abade'	93	Red-purple	Low	High
'Kalei Zarghan'	111	Red- purple	High	Intermediate
'Rishbaba Siah Dodaj'	124	Red-purple	High	Intermediate
'Divane Kashmar'	135	White	High	Intermediate
'Siah Khorjan Bavanat'	162	Red	Intermediate	Intermediate
'Sahebi Siah Mazaijan' 'Bavanat'	158	Red-purple	High	Intermediate
'Rish Baba Siah Zarghan'	119	Red-purple	High	Intermediate

Determination of total anthocyanin content (TA)

Total anthocyanin content of the grapes was determined using the pH-differential method described by Wrolstad (1976). The obtained grape extracts in methanol were diluted with buffer to give an absorbance reading between 0.4 and 0.6 U. The pH values of the diluted grape extracts were 1.0 (0.025 M potassium chloride buffer) and 4.5 (0.4 M sodium acetate buffer), respectively. Absorbance was measured using a Hitachi U-2000 spectrophotometer at 520 and 700 nm (Carreno *et al*., 1995).

The absorbance values of the diluted samples (A) were calculated as follows:

$$A = (A520\ nm - A700\ nm)PH_{1} - (A520\ nm - A700\ nm)PH_{4.5} \quad (1)$$

The total anthocyanin (TA) pigment (mg kg^{-1}) was calculated as follows:

$$TA = \frac{A \times MW \times DF \times 10\ \hat{}\ 3}{\varepsilon \times 1} \quad (2)$$

The result, considered as the total anthocyanins content, was calculated as milligram of malvidin-3-O-glucoside per 1000 g fruit by using a molar absorptivity (ε) of 28,000 and a molecular weight (MW) of 493.5 according to Wrolstad (1976).

Determination of total antioxidant activity (AA)

The total antioxidant activity of the grape extracts was evaluated by free radical 2, 2-diphenyl-1-picrylhydrazyl (DPPH) method (Moon and Terao 1998). 0.1 mL of the grape extracts was added to 0.9 mL of 100 mM TRIS- HCl buffer (pH=7.4) to which 1 mL of the DPPH (free radical, 95%, Sigma–Aldrich Chemie GmbH, Steinheim, Germany, 0.500 µM in ethanol) was added. The control sample was prepared in a similar way by adding 0.1 mL of water instead of grape extract. The mixture was shacked and left at room temperature for 30 min. Absorbance was measured spectrophotometrically at 517nm by a UV-vis spectrophotometer. The percentage reduction of DPPH was calculated according to the following equation:

$$Antioxidant\ activity\ (\%) = \left[1 - \frac{Asample\ (517\ nm)}{Acontrol\ (517\ nm)}\right] \times 100 \quad (3)$$

Determination of total phenolic compounds content (TP)

Total phenolic content in the grape extracts were determined with Folin-Ciocalteu reagent using Catechol as a standard phenolic compound. Between 0.5 to 1.0 g of the sample was weighed and ground with a pestle and mortar in 10x volume 80% ethanol. The homogenate samples were centrifuged at 10,000 rpm for 20 min and the supernatant saved. The residue was re-extracted with five times the value of 80% ethanol, and supernatant was pooled. The supernatant was evaporated to dryness and the residue dissolved in a known volume of distilled water (5mL). Different aliquots (0.2 to 3 mL) were pipetted into test tubes. The volume in each tube was made up to 3 mL with distilled water and 0.5 mL of Folin-Ciocalteau reagent added. After 3 min 2 mL of 20% sodium carbonate solution was added to each tube. They were thoroughly mixed and the tubes were placed in boiling water for exactly 1 min, were then cooled and absorbance measured at 650 nm against a reagent blank. Ultimately standard curve was prepared using different concentration of catechol.

Statistical analysis

The experiment was as a completely randomized design with three replications. Statistical analyses were made using the SAS 9.1 program. Data were subjected to analysis of variance and means were separated using LSD test at P< 0.01 significance level (Software Version 9.1 SAS).

Results and Discussion

The differences in berry size (length, diameter, length: diameter ratio and weight), berry skin weight and pH, acidity, vitamin C, total phenolic contents, total anthocyanins and antioxidant activity of berries among different grapevine cultivars were statistically significant (P < 0.01, Tables 2 and 3).

The greatest berry diameter (19 mm), berry length (27 mm), berry weight (4.40 g), ratio of length:diameter (1.96), weight of skin (0.47 g) and seed number per berry (3.6) were in ‘Jeshnion Bavanat’, ‘Menghaye Shiraz’, ‘Neishabori Ghochan’, ‘Ghermez Gandome Uromia’ , ‘Sahebi Urormia’, ‘Khalili Ghochan’ cultivars, respectively (Table 2).

Table 2. Quantitative traits of berry of 35 grape cultivars used in this study.

Cultivar code	Seed number per berry	Skin weight (g)	Lengt: diameter ratio	Berry weight (g)	Berry length (mm)	Berry diameter (mm)
8	2.76 b-d	0.41cd	1.53 c	2.80 h	23.06 b	15.04 f
19	2.36 h-k	0.34 e-g	0.99 p	1.70 op	14.03 l	14.05 hi
20	2.26 i-n	0.23 m-o	1.19 jk	1.90 m	17.12 i	14.33 h
36	2.60 d-g	0.19 o-q	0.86 q	1.40 q	12.15 n	14.00 hi
46	1.96 pq	0.22 n-p	1.00 p	3.08 g	12.02 n	12.00 k
62	2.03 o-q	0.26 lm	1.00 p	1.24 r	13.03 m	13.00 j
63	2.26 i-n	0.33 f-h	1.20 ij	2.16 k	18.09 h	15.00 f
65	2.06 n-q	0.27 j-l	1.96 a	1.66 p	21.66 d	11.00 l
65	1.96 pq	0.25 lm	1.37 ef	4.10 b	22.00 c	16.01 d
67	2.66 b-e	0.33 f-h	1.21 ij	1.98 l	17.03 i	14.06 hi
70	1.36 r	0.18 p-r	1.14 lm	2.3 j	16.00 j	14.00i
71	2.23 j-o	0.35 e-g	1.42 d	2.13 k	20.03 f	14.03 hi
76	2.4 g-j	0.33 e-g	1.35 f	1.76 no	19.06 g	14.06 hi
77	2.86 b	0.47 a	1.25 gh	1.83mn	20.06 f	16.03 d
89	3.6 a	0.15 rs	1.23 hi	1.36 q	16.13 j	13.10 j
103	2.13 l-p	0.32 g-i	5.15 f	2.75 h	16.00 j	16.00 d
105	2.16j-p	0.36 e	1.15 l	3.6d	23.07 b	19.00 a
111	2.5 e-h	0.42b-d	1.42 d	2.56 i	20.03 f	14.00 hi
116	2.63c-f	0.28 j-l	1.43 d	3.26 f	23.01 b	16.05 d
120	2.86 b	0.44 a-c	1.50 c	2.36 e	23.16 b	15.40 e
123	2.1m-p	0.17 qr	1.23 e	1.90 m	21.00 e	15.06 f
124	2.16 j-p	0.41 d	1.28 g	2.26 j	18.06 h	14.1 hi
135	1.86 q	0.34 e-g	1.11 mn	2.16 k	19.1 g	17.00c
162	2.43 f-j	0.32 f-i	1.06 o	3.83 c	17.03 i	6.03 d
200	2.03 o-q	0.33 f-h	1.00 p	1.99 l	18.00 h	18.00 b
148	2.36 h-k	0.29 i-k	1.91 b	2.80 h	27.00 a	14.10 hi
158	2.00 pq	0.33 e-g	1.16 kl	1.70 op	14.1 l	12.06 k
149	-	0.29 h-j	1.00 p	1.00 s	13.23 m	13.20 j
72	2.16 j-p	0.35 ef	0.85 q	2.16 k	12.03 n	14.03 hi
119	2.23 h-l	0.12 s	1.19 jk	2.80 h	18.03 h	15.10 ef
95	2.83 bc	0.44 a-c	1.06 o	2.16 k	16.10 j	15.13 ef
93	2.46 e-i	0.25 l-n	1.10 n	2.16 k	16.26 j	14.66 g
136	2.30 h-m	0.26 k-m	1.04 o	2.00 l	15.00 k	14.33 h
75	2.23 j-o	0.32 g-i	1.38 e	2.53 i	19.88 f	14.33 h
43	2.10 m-p	0.45 ab	1.05 o	4.40 a	18.00 h	17.00 c

In each column different letters indicate significant differences according to (LSD) test at P<0.01

Vitamin C

There was a significant difference in ascorbic acid content between different grape cultivars (Table 3). 'Neishabori Birjand' (62) cultivar had the highest content of ascorbic acid (9.83 mg 100^{-1} mL), whereas 'Rishbaba Siah Dodaj' (124) (3.46 mg 100^{-1} mL), 'Khalili Ghochan' (89) (3.62 mg 100^{-1} mL) and 'Gazne Uromia' (65) (3.79 mg 100^{-1} mL) cultivars had the lowest content of ascorbic acid.

There was also a significant difference between total soluble content in fruits of studied cultivars. The highest total soluble solid content in grapes (22.33%) detected in 107 Zarghan (19) and the lowest value (14%) was in 'Neishabori Gochan' (43) cultivar (Table 3).

Glucose and fructose, which compose about 99% of the soluble sugar contents in matured grape (Hulya-Orak, 2007) and are commonly used to evaluate the quality of

grapes and to predict the harvest time, were determined by refractometer in the berry juice and displayed as total soluble solids (Brix). The level of reducing sugars is also used as estimation for total sugar in grapes, juice and wines (Varandas *et al*., 2004).

The total acid contents in grape cultivars varied from 1.07% in 'Gandome Uromia' (64) to 0.40% in 'Gandome Uromia' (64) and in 'Gharechin Uromia' (70), respectively (Table 3).

The pH of berry juice in the studied cultivars also changed from 4.22 to 3.28 in 108 Zarghan (20) and in 'Keshmeshi Ghermez Ghochan' (136), respectively (Table 3). The pH of berry juice depended on genotypes, cultivars and environmental conditions.

Table 3. Quantity traits of berry juice of 35 grape cultivars used in this study.

Cultivar	pH	Brix (%)	Total acid (%)	Vitamin C (mg 100^{-1} mL)
8	3.64g-l	17.16e	0.67h-j	7.77c
19	3.53i-n	16.33e-g	0.90b-f	6.25gh
20	4.21a	22.33a	0.50kl	8.75b
36	3.31n-p	15.66f-i	0.86c-g	4.26p
46	3.78c-h	20.33b	0.67h-j	8.44b
62	3.65f-l	15.33g-j	0.66h-j	9.83a
63	3.88b-d	16.66e-g	1.00ab	6.31gh
64	3.39m-p	17.33de	1.07a	5.48j-l
65	3.50j-n	15.66f-i	0.99ab	3.79q
67	3.69d-k	15.33g-j	0.86c-g	5.57j-l
70	3.89b-d	16.66e-g	0.40 l	7.42cd
71	3.52i-n	15.33g-j	0.81e-g	5.41j-l
76	3.56h-m	14.66ij	0.90b-f	4.80no
77	3.58h-m	15.33g-j	1.02ab	6.06hi
89	3.73c-i	20.00bc	0.62i-k	3.62q
103	3.66e-k	14.33ij	0.62i-k	6.77ef
105	3.64g-l	14.33ij	0.97a-d	5.50j-l
111	3.87b-e	16.33e-g	0.77gh	5.70ij
116	3.86b-f	15.33g-j	0.76gh	4.45op
120	3.68d-k	14.66ij	0.94b-e	6.06hi
123	3.48k-p	18.66cd	0.86c-g	5.36j-l
124	3.86b-f	18.66cd	0.91b-f	3.46q
135	3.83c-g	14.83h-j	0.93b-f	5.63jk
162	3.71d-j	15.66e-i	0.91b-f	5.34j-l
200	3.68d-k	18.66cd	0.91b-f	5.36j-l
148	4.04ab	16.16 e-h	0.74g-i	7.33d
158	3.30op	16.83ef	0.65h-j	6.48f-h
149	3.55i-m	17 ef	0.86d-g	5.39j-l
72	3.43l-p	16.83ef	0.55jk	6.60fg
119	3.94bc	17.33de	0.52kl	6.81ef
95	3.55i-m	17.33de	0.62i-k	7.26d
93	3.61h-l	15.66e-i	0.67h-j	7.15de
136	3.28p	15.33g-i	0.77gh	4.88mn
75	3.58h-m	15.66e-i	0.98a-c	5.23k-m
43	3.50j-o	14.00 j	0.81fg	5.20l-n

In each column different letters indicate significant differences according to (LSD) test at $P<0.01$

Total phenolic compounds

A noticeable variation was found between the total phenolic content in the fruit of grapevine cultivars ranging from 60.77 to 975.68 mg kg^{-1} FW. The 'Gandomeb Uromia' (64) cultivar had the highest total phenolic content in its berries (975.68 mg/kg FW) and 'Divane Kashmar' (135) cultivar had the lowest (60.77 mg kg^{-1} FW) total phenolic content (Table 4).

The phenolic compounds composition of fruits depended on genotypes, environmental factors and postharvest processing conditions (Benvenuti *et al*., 2004; Kadir *et al*., 2009). The phenolic compounds serve in plant as defence mechanisms, to counter oxygen species, and prevent cellular and molecular damage (Kadir *et al*., 2009).

However, the experimental data described above showed that the phenolic compound content of different cultivars depends mainly on the varietal differences, thus confirming the results of Yang *et al.* (2009), and Antonietta and Terracone (2011).

Anthocyanin content

The total anthocyanin contents of the cultivars are presented in Table 4. The total content of anthocyanin varied from 42.74 mg kg^{-1} ('Jeshnion Bavanat', 105) to 619.04 mg/kg ('Rishbaba Uromia', 75) based on fresh weight. The lowest anthocyanin content was obtained from 'Rotabi Zarghan' (116) (43.67 mg kg^{-1}), 'Divane Kashmar' (135) (46.59 mg kg^{-1}), and 'Rajabi Sefid Zarghan' (120) (55.51 mg kg^{-1}) cultivars. 'Mesghali Najafabad Abade' (95) (525.03 mg kg^{-1}) and No. 148 (520.49 mg kg^{-1}) cultivars had the highest anthocyanin contents. The anthocyanin in the grapes varies greatly with the cultivars, maturity stage, production site, seasonal conditions and yield of the vine.

Pigments are almost exclusively responsible for the red, blue and purple colours in fruits (Wei *et al*., 2011). Hulya-Orak (2007) reported the total anthocyanin content of the red grapes was ranged from 40.3 mg kg^{-1} (Md. Jean Matthias) to 990.8 mg kg^{-1} (Cabernet Sauvignon) fresh weight. Production region, seasonal conditions, fruit size and genotypes of grape cultivars may cause these differences. Wei *et al*. (2011) reported that smaller berries with higher specific surface areas, due to exposure to sufficient sunlight, had higher anthocyanin contents. The genotype seemed to influence the extent of total anthocyanin accumulation in the grape berries.

The total anthocyanin contents in dark-coloured sweet cherry cultivars were 82–298 mg 100^{-1} g of FW (Gao and Mazza, 1995), in red grape cultivars were 6.9–15.1 mg 100^{-1} g of FW (Cantos *et al*., 2002), in blackcurrant cultivars were 152–281 mg 100^{-1} g (Benvenuti *et al*., 2004), in blackberry cultivars were 126–152 mg 100^{-1} g (Pantelidis *et al*., 2007), and were 34–515 mg 100^{-1} g of FW in 30 genotypes of blueberries (Moyer *et al*., 2002). Our results were comparable with these results and it can be concluded that genotype and environmental conditions seemed to influence the extent of total anthocyanin accumulation in fruits.

Antioxidant activity

As shown in Table 4, the highest antioxidant activity was found in 'Gandome Uromia' (red, 64) extracts (66.47%), which had the highest total phenolic compounds content among the grape cultivars. The lowest antioxidant activity was found in 'Jeshnion Bavanat' (white, 105) (14.10%), which had the lowest total phenolic compound content. Similar results were also reported that the distribution and composition of phenolic compounds and their antioxidant activity are affected by the degree of maturity, cultivar, horticultural practices, geographic origin, growing season, postharvest storage conditions, processing and plant growth regulators (Kim *et al*., 2003; Jiang *et al*., 2006; Hulya-Orak, 2007).

Table 4. Antioxidant activity, total anthocyanin and total phenolic compounds in berries of 35 grape cultivars.

Cultivar	Antioxidant activity (%)	Anthocyanin (mg per kg FW)	Total phenolic compounds (mg kg^{-1} FW)
8	31.74 h	60.67 st	173.06 s
19	17.48 mn	212.35 mL	144.68 u
20	24.73 ij	166.67 o	157.17 t
36	55.31 c	361.11 fg	566.09 e
46	47.06 d	275.35 k	552.25 f
62	36.44 ef	152.18 p	452.73 i
63	34.00 f-h	123.55 q	425.31 j
64	66.47 a	467.55 d	975.68 a
65	22.88 jk	148.14 p	317.18 p
67	33.84 f-h	354.72 g	412.77 kl
70	34.22 f-h	312.69 i	463.91 h
71	16.55 m-o	54.31 t	275.69 r
76	35.75 e-g	194.03 n	415.50 k
77	53.50 c	418.44 e	595.23 d
89	14.81 no	109.44 r	325.48 o
103	19.07 lm	205.36 m	288.45 q
105	14.10 o	42.74 u	85.41 z
111	38.37 e	325.48 h	405.82 h
116	15.11 no	43.67 u	94.65 y
120	20.97 kl	55.51 st	112.88 x
123	21.25 kl	62.80 s	131.28 v
124	22.48 jk	309.82 i	158.54 t
135	16.13 m-o	44.59 u	60.77 á
162	14.55 no	21.80 l	157.54 t
200	26.82 i	331.47 h	288.45 q
148	32.83 gh	520.49 b	342.72 m
158	52.79 c	420.47 e	560.31 ef
149	18.45 lm	125.51 q	125.55 vw
72	36.88 ef	365.50 f	280.51qr
119	36.26 ef	288.20 j	338.21 mn
95	48.38 d	525.03 b	526.93 g
93	63.04 b	360.62 fg	655.43 c
136	31.99 h	478.26 c	331.09 no
75	64.47 ab	619.04 a	855.81 b
43	19.06 lm	115.12 r	177.78 wx

In each column different letters indicate significant differences according to (LSD) test at $P<0.01$.

The correlation between antioxidant activities with other characteristics

A correlation coefficient analysis was performed between the total phenolic compounds, anthocyanins and antioxidant activity. According to the results of the analyses, the antioxidant activity was correlated to a higher degree with total phenolic compound content ($r^2 = 0.91^{**}$), anthocyanin ($r^2 = 0.74^{**}$) and vitamin C ($r^2 = 0.23^{**}$), (Table 5).

Table 5. Correlations coefficients analysis between different traits of berries 35 grape cultivars used in this study.

	Vitamin C	Total acid	Brix	Phenol	Anthocyanin	Antioxidant	pH
Vitamin C	1						
Total acid	-0.15**	1					
Brix	0.19*	- 0.031	1				
Phenol	0.13	0.054	0.03	1			
Anthocyanin	0.07	-0.05	0.051	0.72**	1		
Antioxidant	0.23**	-0.001	0.043	0.91**	0.74**	1	
pH	0.27**	-0.19*	0.29**	-0.24**	-0.16*	-0.25**	1

*Indicates significant differences (P <0.05) between the means of the different characteristics.
**Indicates significant differences (P <0.01) between the means of the different characteristics.
ns- Not significant.

A similar correlation (antioxidant activity with total phenolic compounds) was found by other researchers (Frankel *et al*., 1995; Burns *et al*., 2000; Arnous *et al*., 2002) in red wines. Javanmardi *et al. (*2003) reported the existence of a linear positive relationship between the antioxidant activity and total phenolic acid content of the tested Iranian basil accessions. Positive correlations between total phenolic and antioxidant capacity have also been reported (Hulya-Orak, 2007). One of the important aims of this research was to determine the correlation between antioxidant activity, total phenolic compound and anthocyanin in grapes. Previously some researchers reported a strong correlation between antioxidant activity and total anthocyanins, whereas several authors reported that anthocyanins had less correlation with the antioxidant properties. However, we found that some grape cultivars had a wide range of anthocyanin content, total phenolic compounds and a significant positive correlation with antioxidant activity. According to these results, there was a strong correlation between total phenolic content and antioxidant activity than anthocyanin content and antioxidant activity.

Conclusions

Grape cultivars investigated in this study are a significant source of phenolic compounds and anthocyanins. Antioxidant activity varied greatly among these grape cultivars and was highly correlated with their content of phenolic compounds.

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