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# BIOCHEMICAL CHANGES IN SOME TABLE GRAPE CULTIVARS THROUGHOUT THE RIPENING PROCESS

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## ABSTRACT

This study was conducted to investigate the biochemical changes observed throughout the ripening process from veraison to harvest periods of 13 table grape cultivars of *Vitis vinifera* L. species. Present findings revealed that total acidity, total phenolics and total antioxidant capacity of the grape cultivars decreased and water soluble dry matter (WSDM) content, must pH and total anthocyanins increased throughout the ripening process. In harvest period, water soluble dry matter (WSDM) contents varied between 17.0% (Trakya İlkeren and Şilfoni cultivars) and 21.6% (Kureyş cultivar); total acidity values varied between 0.42 g $l^{-1}$ (Tekirdağ Seedless cultivar) and 1.26 g $l^{-1}$ (Kızılatım cultivar); must pH values varied between 2.58 (Köhnü cultivar) and 3.29 (Trakya İlkeren cultivar); ripening index values varied between 15.60 (Şilfoni cultivar) and 41.90 (Tekirdağ Seedless cultivar); total phenolics varied between 723.5 µg GAE $g^{-1}$ (Mazırım cultivar) and 2657 µg GAE $g^{-1}$ (Banazı Karası cultivar); total antioxidant capacities varied between 4.27 µmol TE $g^{-1}$ (Mazırım cultivar) and 8.21 µmol TE $g^{-1}$ (Köhnü cultivar); total anthocyanins varied between 32.3 malvidin-3-o-glikozit µg $g^{-1}$ (Kızılatım cultivar) and 205.2 malvidin-3-o-glikozit µg $g^{-1}$ (Banazı Karası cultivar). Berry skin colors strongly correlated with total phenolics ($R^2 = 0.9376$) and total antioxidant capacity ($R^2 = 0.8296$).

**Key words:** table grape, phenolics, anthocyanins, antioxidant capacity

## INTRODUCTION

Grape has a great production and consumption potential worldwide. Therefore, it has a great commercial potential. Grapes are either fresh-consumed or converted into various forms. They are rich in bioactive compounds and thus have various positive impacts on human health. Development, ripening and quality (color, taste, aroma) characteristics of grape berries are largely dependent on biochemical composition and various other factors [Ağaoğlu 2002]. Grape berries gain cultivar characteristics throughout the ripening stages. Ripening stage designate the quality of grape and chemical bio-composition [Ağaoğlu 2002]. Ripening stage of grapes may vary with the type of use [Sabır et al. 2010]. Optimum ripening stage could be identified through determination of physical and biochemical changes within the period from fruit-set to harvest. Berry sugar and organic acid content, ripening index, pH and phenolic compounds are important indicators of optimum ripening stage [Calo et al. 1996, Sabır et al. 2010]. Biochemical compounds ensure ripening of berried and also designate quality attributes of grape. Biochemical composition of grape berry varies with the climate, cultivar, soil conditions, cultural practices, yield and ripening level [Navarro et al. 2008, Jin et al. 2009, Yang et al. 2009, Kunter et al. 2013]. Several researches have been conducted to

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identify physical and biochemical changes during the ripening of different grape cultivars [Al-Kaisy 1981, Deryaoğlu and Canbaş 2003, Sabır et al. 2010, Cangi et al. 2011, Özdemir et al. 2016]. Identification of critical berry development periods in which quantitative and structural changes were observed in biochemical compounds of a berry allow growers to apply cultural practices, effective on ripening, more efficiently and effectively. Identification of optimum ripening stage of grape cultivars play a significant role in quality and quantity [Fidan and Eriş 1974, Jackson and Lombard 1993]. In adaptation studies, suitability of a cultivar to a region is assessed through phenological observations, pomological characteristics and biochemical compositions.

This study was conducted to investigate the emerging biochemical changes during the ripening of Amasya, Barış, Banazı Karası, Cardinal, İtalya, Kızılatım, Köhnü, Kureyş, Mazırım, Şilfoni, Tahannebi, Tekirdağ Seedless and Trakya İlkeren table grape cultivars grown under ecological conditions of Malatya (Turkey) province.

## MATERIAL AND METHOD

**Material.** Experiments were conducted with 13 different table grape cultivars of *Vitis vinifera* L. species under ecological conditions of Malatya province of Turkey in a vineyard established at 1.5 × 3 m planting spacing and cordon-trained over 50 cm stems. The cultivars of Amasya, Barış, İtalya, Kureyş, Mazırım, Şilfoni and Tahannebi have berry skin colors of green-yellow; Banazı Karası, Cardinal, Kızılatım, Köhnü, Tekirdağ Seedless and Trakya İlkeren have berry skin colors of red-black. The cultivars of Banazı Karası, Kızılatım, Kureyş, Mazırım, Trakya Seedless and Trakya İlkeren are grafted on 41B American vine rootstock and the other cultivars are grafted on 1103P American vine rootstock. During the winter pruning, grapevines were loaded as to have 20–22 buds/vine fruit loads. Vines were irrigated at different growth stages with drip irrigation. Tipping and topping were separately practiced in vines.

**Method.** Fruit samples were taken each week from investigated grape cultivars during the ripening process from veraison to harvest. Harvested fruits were subjected to analyses for water soluble dry matter (WSDM), total acidity, pH, total phenolics, total anthocyanins and antioxidant capacity. Water soluble dry matter (WSDM) content was measured with the aid of a hand refractometer; must pH values were determined with a pH meter; total acidity (g $l^{-1}$) was determined with titrimetric method and expressed in tartaric acid equivalent [Ough and Amerine 1988]. Ripening index was calculated as the ratio of water soluble dry matter content at ripening to total acidity. Analyses were terminated when the WSDM contents reached to 17.0–21.6% in cultivars with berry skin colors of white-yellow and 17.0–21.2% in cultivars with berry skin colors of red-black. Phenological observations were also made on grape cultivars. Experimental data obtained at veraison and ripening periods were subjected to statistical analyses with Statgraphics software and significant means were compared with the aid of LSD test at 5% level.

**Extraction of fruit samples.** About 100 g fruit samples taken from different vines and clusters were homogenized in blender. Resultant homogenate was extracted with the use of acetone, water and acetic acid (70 : 29.5 : 0.5) solution for an hour. Filtered extract was then used for total phenolics, total anthocyanins and antioxidant capacity analyses [Uluocak 2010].

**Total phenolics.** Fruit extracts prepared for analysis were kept in Folin-Ciocalteu chemical and distilled water mixture (1 : 1 : 20) for 8 min, then supplemented with 7% sodium carbonate. Following two hours of incubation, resultant solution got a blue color and readings were performed in a spectrophotometer at 750 nm wavelength. Results were expressed in gallic acid equivalent (µg GAE $g^{-1}$) of fresh weight [Singleton and Rossi 1965].

**Total anthocyanins.** The pH differential method was used in total anthocyanins analysis. Fruit extracts were prepared at pH 1.0 and 4.5 buffers and readings were performed at 520 and 700 nm wave lengths. Total anthocyanin content (molar extinction coefficient of 28 000 malvidin-3-glucoside) [(A520–A700) pH 1.0 – (A520–A700) pH 4.5] was expressed in µg anthocyanin per 1 g dry matter [Giusti and Wrolstad 2005].

**Total antioxidant activity.** TEAC (Trolox equivalent antioxidant capacity) method was used for total antioxidant capacity analysis. In this method, 7 mM ABTS (2,2′-Azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) was mixed with 2.45 mM potassiumbisulphate and

kept at dark for 12–16 h. Then the solution was diluted with 20 mM sodium acetate (pH 4.5) buffer as to have an absorbance value of 0.700 ±0.01 in a spectrophotometer at 734 nm wavelength. Finally, 30 µL fruit extract was supplemented with 2.97 mL buffer and absorbance readings were performed 10 min later in a spectrophotometer at 734 nm wavelength. Resultant absorbance values were calculated with the aid of Trolox (10–100 µmol/L) standard curve and expressed in µmol Trolox equivalent per 1 g of fresh weight [Özgen et al. 2006].

## RESULTS AND DISCUSSION

Ripening periods varied with the cultivars. Trakya İlkeren ripened in the second week of August was the earliest cultivar and Kızılatım and Mazırım cultivars ripened in the third week of September were the latest cultivars. Veraison dates were observed in 4-week period extending from the third and fourth weeks of July to the second week of August (Tab. 1).

The ripening process of cultivars lasted between 5–10 weeks.

Throughout the ripening process from veraison to harvest, water soluble dry matter contents and must pH values increased and total acidity decreased (Tabs 2–4). Similar findings were also reported by previous researchers [Al-Kaisy et al. 1981, Deryaoğlu and Canbaş 2003, Cangi et al. 2011, Eyduran et al. 2015, Özdemir et al. 2016]. Water soluble dry matter (WSDM) contents of the cultivars varied between 10.1–13.9% in veraison period and between 17.0–21.6% in harvest period (Tabs 2 and 5). Total acidity values of the cultivars varied between 1.22–2.86 g $l^{-1}$ in veraison period and between 0.42–1.09 g $l^{-1}$ in harvest period (Tabs 3 and 5). Must pH values of the cultivars varied between 1.82–2.81 in veraison period and between 2.58–3.29 in harvest period (Tabs 4 and 5). Özdemir et al. [2016] reported water soluble dry matter (WSDM) contents as between 12–13.83% in veraison period and between 21–25.33% in harvest period; total acidity values as between 14.58–19.02 g/l in veraison period and between 5.86–7.92 g/l in harvest period; must pH values as between 2.45–2.86 in veraison period and between 3.83–4.08 in harvest period. Şen [2008] reported water soluble dry matter (WSDM) contents of the years as between 9–11% in veraison period and between 16–18% in harvest period of table cultivars; total acidity values of the years as between 1.167–4.163% in veraison period and between 0.752–0.491% in harvest period; must pH values of the years as between 2.28–3.15 in veraison period and between 3.72–3.80 in harvest period. Must composition designate the quality of grapes and it greatly influenced by ripening period [Fanizza 1982]. It was indicated in a previous study that biochemical composition of grape berry could be influenced by the cultivars, ecological conditions, cultural practices and ripening levels [Ağaoğlu 2002]. Ripening index is also used as an important indicator of optimum harvest time. Among the investigated cultivars, the lowest ripening index (15.60) was observed in Şilfoni cultivar and the greatest ripening index (41.90) was observed in Tekirdağ Seedless cultivar (Tab. 5). Ripening index values were reported as between 31.41 (Narince cultivar) and 33.48 (Gewürtztraminer cultivar) by Cangi et al. [2011]; between 29.77 (Tannat cultivar) and 40.27 (Merlot cultivar) by Özdemir et al. [2016]; between 23.0 (Kamili cultivar) and 48.5 (Abbasi cultivar) by Al-Kaisy et al. [1981]; between 16.65 (Asılasma cultivar) and 36.97 (Antep Üzümü cultivar) by Karanis and Çelik [2002]. Previous researchers indicated that ripening index of grape cultivars may vary with the cultivars, years, ecological conditions and cultural practices [Kara and Gerçekçioğlu 1993, Deryaoğlu and Canbaş 2003, Tangolar et al. 2005].

Differences in total phenolics of the cultivars in veraison and harvest periods were found to be significant. Total phenolics of the cultivars with skin colors of red-black varied between 2281–3541.6 µg GAE $g^{-1}$ in veraison period and between 1824.6–2657.1 µg GAE $g^{-1}$ in harvest period; total phenolics of the cultivars with skin colors of green-yellow varied between 1220.7–1654.7 µg GAE $g^{-1}$ in veraison period and between 895.2–1266.8 µg GAE $g^{-1}$ in harvest period (Tabs 6 and 9). Aydın [2015] reported total phenolics in harvest period as between 355.17 ile 693.37 mg GAE $l^{-1}$ for the cultivars with skin colors of red-black and between 335.73–823.54 mg GAE $l^{-1}$ for the cultivars with skin colors of green-yellow. Cangi et al. [2011] reported total phenolics as between 2500.6 µg GAE $g^{-1}$ (Narince cultivar) and 4790.9 µg GAE $g^{-1}$ (Syrah cultivar) in veraison period and between 1081.9 µg GAE $g^{-1}$ (Narince cultivar) and 2886.9 µg GAE $g^{-1}$ (Syrah cultivar) in harvest period. Göktürk-Baydar et al. [2005]

**Table 1.** Phenological observations of grape cultivars

| Cultivars | Phenological periods | | | | | |
|---|---|---|---|---|---|---|
| | bursting | shooting | full-bloom | berry-set | veraison | harvest |
| |  |  |  |  |  |  |
| T. İlkeren | 2 Apr. | 14 Apr. | 10 May | 15 May | 17 Jul. | 14 Aug. |
| Barış | 5 Apr. | 17 Apr. | 12 May | 22 May | 18 Jul. | 21 Aug. |
| Köhnü | 10 Apr. | 24 Apr. | 26 May | 1 Jun. | 28 Jul. | 1 Sept. |
| Şilfoni | 13 Apr. | 28 Apr. | 23 May | 1 Jun. | 23 Jul. | 15 Aug. |
| T. Seedless | 10 Apr. | 22 Apr. | 24 May | 28 May | 23 Jul. | 15 Aug. |
| İtalya | 13 Apr. | 25 Apr. | 26 May | 1 Jun. | 23 Jul. | 15 Aug. |
| Cardinal | 5 Apr. | 16 Apr. | 18 May | 25 May | 27 Jul. | 18 Aug. |
| B. Karası | 12 Apr. | 25 Apr. | 27 May | 2 Jun. | 1 Aug. | 4 Sept. |
| Kızılatım | 25 Apr. | 05 May | 09 Jun. | 15 Jun. | 15 Aug. | 18 Sept. |
| Kureyş | 14 Apr. | 26 Apr. | 27 May | 2 Jun. | 28 Jul. | 5 Sept. |
| Amasya | 22 Apr. | 3 May | 5 Jun. | 10 Jun. | 31 Jul. | 5 Sept. |
| Mazırım | 25 Apr. | 5 May | 7 Jun. | 10 Jun. | 10 Aug. | 18 Sept. |
| Tahannebi | 5 Apr. | 25 Apr. | 27 May | 08 Jun. | 18 Jul. | 24 Aug. |

**Table 2.** Changes in water soluble dry matetr (WSDM) contents of grape cultivars throughout the ripening process (%)

| Cultivars | Weeks from veraison to harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st week 17 Jul. | 2nd week 24 Jul. | 3rd week 31 Jul. | 4th week 7 Aug. | 5th week 14 Aug. | 6th week 21 Aug. | 7th week 28 Aug. | 8th week 4 Sept. | 9th week 11 Sept. | 10th week 18 Sept. |
| T. İlkeren | 10.1 | 12.9 | 15.4 | 16.2 | 17.0 | – | – | – | – | – |
| Barış | 11.3 | 14.6 | 16.5 | 17.4 | 18.1 | 19.2 | – | – | – | – |
| Şilfoni | – | 12.4 | 13.2 | 14.9 | 15.4 | 17.0 | – | – | – | – |
| T. Seedless | 11.1 | 12.1 | 13.8 | 14.6 | 15.6 | 17.6 | – | – | – | – |
| İtalya | 13.9 | 15.7 | 17.1 | 17.9 | 18.5 | 20.1 | – | – | – | – |
| Cardinal | – | 10.4 | 11.5 | 14.3 | 17.2 | 18.4 | – | – | – | – |
| Kureyş | – | 10.1 | 10.8 | 12.9 | 16.4 | 17.3 | 19.8 | 21.6 | – | – |
| Tahannebi | 10.9 | 12.6 | 14.1 | 15.8 | 16.4 | 17.2 | – | – | – | – |
| Köhnü | – | 12.1 | 13.9 | 15.5 | 16.0 | 18.9 | 21.2 | – | – | – |
| B. Karası | – | – | – | 13.8 | 15.6 | 16.5 | 18.6 | 20.2 | – | – |
| Amasya | – | – | – | – | 12.2 | 13.8 | 15.6 | 17.4 | – | – |
| Mazırım | – | – | – | 11.8 | 12.6 | 14.0 | 15.2 | 16.7 | 18.2 | 19.6 |
| Kızılatım | – | – | – | – | 13.9 | 14.2 e | 15.1 | 16.1 | 18.2 | 20.9 |

**Table 3.** Changes in total acidity values ofgrape cultivars throughout the ripening process(g $l^{-1}$)

| Cultivars | Weeks from veraison to harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st week 17 Jul. | 2nd week 24 Jul. | 3rd week 31 Jul. | 4th week 7 Aug. | 5th week 14 Aug. | 6th week 21 Aug. | 7th week 28 Aug. | 8th week 4 Sept. | 9th week 11 Sept. | 10th week 18 Sept. |
| T. İlkeren | 1.46 | 1.19 | 1.04 | 0.87 | 0.52 | – | – | – | – | – |
| Barış | 1.22 | 1.16 | 0.98 | 0.76 | 0.61 | 0.48 | – | – | – | – |
| Şilfoni | – | 2.04 | 1.72 | 1.48 | 1.17 | 1.09 | – | – | – | – |
| T. Seedless | 2.20 | 1.85 | 1.05 | 0.81 | 0.68 | 0.42 | – | – | – | – |
| İtalya | 1.59 | 1.14 | 1.09 | 0.93 | 0.78 | 0.54 | – | – | – | – |
| Cardinal | – | 1.49 | 1.03 | 0.95 | 0.82 | 0.73 | – | – | – | – |
| Kureyş | – | 2.38 | 2.02 | 1.68 | 1.47 | 1.26 | 1.07 | 0.92 | – | – |
| Tahannebi | 1.39 | 1.15 | 0.98 | 0.91 | 0.80 | 0.72 | – | – | – | – |
| Köhnü | – | 1.54 | 1.26 | 1.02 | 0.86 | 0.73 | 0.62 | – | – | – |
| B. Karası | – | – | – | 1.38 | 1.24 | 1.10 | 0.91 | 0.76 | – | – |
| Amasya | – | – | – | – | 1.76 | 1.52 | 1.24 | 0.81 | – | – |
| Mazırım | – | – | – | 2.12 | 1.90 | 1.61 | 1.26 | 1.03 | 0.86 | 0.65 |
| Kızılatım | – | – | – | – | 2.86 | 2.504 | 2.42 | 2.01 | 1.68 | 1.26 |

**Table 4.** Changes in must pH values of grape cultivars throughout the ripening process

| Cultivars | Weeks from veraison to harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st week 17 Jul. | 2nd week 24 Jul. | 3rd week 31 Jul. | 4th week 7 Aug. | 5th week 14 Aug. | 6th week 21 Aug. | 7th week 28 Aug. | 8th week 4 Sept. | 9th week 11 Sept. | 10th week 18 Sept. |
| T. İlkeren | 2.81 | 3.05 | 3.17 | 3.25 | 3.29 | – | – | – | – | – |
| Barış | 2.76 | 2.85 | 2.95 | 3.03 | 3.08 | 3.12 | – | – | – | – |
| Şilfoni | – | 2.64 | 2.71 | 2.76 | 2.89 | 2.93 | – | – | – | – |
| T. Seedless | 2.72 | 2.76 | 2.81 | 2.93 | 3.01 | 3.05 | – | – | – | – |
| İtalya | 2.03 | 2.18 | 2.42 | 2.51 | 2.70 | 2.96 | – | – | – | – |
| Cardinal | – | 2.28 | 2.45 | 2.56 | 2.75 | 2.97 | – | – | – | – |
| Kureyş | – | 1.88 | 1.94 | 1.98 | 2.78 | 2.90 | 3.00 | 3.08 | – | – |
| Tahannebi | 2.32 | 2.41 | 2.65 | 2.81 | 3.02 | 3.24 | – | – | – | – |
| Köhnü | – | 2.17 | 2.22 | 2.34 | 2.44 | 2.52 | 2.58 | – | – | – |
| Bonazı Karası | – | – | – | 2.45 | 2.56 | 2.75 | 2.96 | 3.27 | – | – |
| Amasya | – | – | – | – | 2.70 | 2.80 | 2.96 | 3.02 | – | – |
| Mazırım | – | – | – | 1.82 | 1.96 | 2.12 | 2.72 | 2.88 | 2.99 | 3.07 |
| Kızılatım | – | – | – | – | 2.16 | 2.30 | 2.45 | 2.56 | 2.75 | 2.96 |

**Table 5.** Water soluble dry matter (WSDM) contents, total acidity and must pH values of grape cultivars in veraison and harvest periods

| Cultivars | Parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | WSDM (%) | | total acidity (g $l^{-1}$) | | must pH values | | ripening index |
| | veraison | harvest | veraison | harvest | veraison | harvest | |
| T. İlkeren | 10.1 e | 17.0 f | 1.46 cd | 0.52 def | 2.81 a | 3.29 a | 32.69 cd |
| Barış | 11.3 d | 19.2 d | 1.22 d | 0.48 ef | 2.76 a | 3.12 ab | 40.00 a |
| Şilfoni | 12.4 b | 17.0 f | 2.04 bc | 1.09 ab | 2.64 b | 2.93 d | 15.60 i |
| T. Seedless | 11.1 d | 17.6 f | 2.20 b | 0.42 f | 2.72 ab | 3.05 bc | 41.90 a |
| İtalya | 13.9 a | 20.1 c | 1.59 cd | 0.54 def | 2.03 f | 2.96 cd | 37.22 b |
| Cardinal | 10.4 e | 18.4 e | 1.49 cd | 0.73 cde | 2.28 d | 2.97 cd | 25.21 f |
| Kureyş | 10.1 e | 21.6 a | 2.38 b | 0.92 bc | 1.88 g | 3.08 b | 23.48 g |
| Tahannebi | 10.9 cd | 17.2 f | 1.39 d | 0.72 de | 2.32 d | 3.24 a | 23.89 fg |
| Köhnü | 12.1 b | 21.2 ab | 1.54 cd | 0.62 def | 2.17 e | 2.58 e | 34.19 c |
| B. Karası | 13.8 a | 20.2 c | 1.38 d | 0.76 cd | 2.45 c | 3.27 a | 26.58 e |
| Amasya | 12.2 b | 17.4 f | 1.76 c | 0.81 cd | 2.70 ab | 3.02 bcd | 21.48 h |
| Mazırım | 11.8 c | 19.6 d | 2.12 bc | 0.65 de | 1.82 h | 3.07 b | 30.15 d |
| Kızılatım | 13.9 a | 20.9 b | 2.86 a | 1.26 a | 2.16 e | 2.96 d | 16.59 i |
| LSD (5%) | 0.80 | 1.30 | 0.92 | 0.49 | 0.16 | 0.21 | 3.65 |

* There were significant differences among the different letter (s) at $P < 0.05$ level

**Table 6.** Changes in total phenolics of the grape cultivars throughout the ripening process (μg GAE $g^{-1}$)

| Cultivars | Weeks from veraison to harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st week 17 Jul. | 2nd week 24 Jul. | 3rd week 31 Jul. | 4th week 7 Aug. | 5th week 14 Aug. | 6th week 21 Aug. | 7th week 28 Aug. | 8th week 4 Sept. | 9th week 11 Sept. | 10th week 18 Sept. |
| T. İlkeren | 2351.9 | 2204.2 | 2126.1 | 2008.5 | 1824.6 | – | – | – | – | – |
| Barış | 1308.4 | 1255.7 | 1130.3 | 1086.4 | 895.2 | – | – | – | – | – |
| Şilfoni | – | 1342.6 | 1172.6 | 1088.3 | 984.5 | – | – | – | – | – |
| T. Seedless | 2281.0 | 2293.2 | 2069.5 | 1954.7 | 1893.2 | | – | – | – | – |
| İtalya | 1654.7 | 1612.3 | 1544.8 | 1487.5 | 1266.8 | | – | – | – | – |
| Cardinal | – | 3215.4 | 2974.1 | 2655.1 | 2200.5 | | – | – | – | – |
| Kureyş | – | 1390.5 | 1428.5 | 1352.9 | 1204.6 | 1162.5 | 1042.2 | 960.0 | – | – |
| Tahannebi | 1451.0 | 1393.5 | 1356.1 | 1281.5 | 1163.3 | 980.7 | – | – | – | – |
| Köhnü | – | 3452.3 | 3266.0 | 3140.2 | 2966.5 | 2780.0 | 2351.6 | – | – | – |
| B. Karası | – | – | – | 3541.6 | 3361.6 | 3191.2 | 2833.0 | 2657.1 | – | – |
| Amasya | – | – | – | – | 1220.7 | 1139.5 | 1061.4 | 974.8 | – | – |
| Mazırım | – | – | – | 1182.3 | 1120.3 | 960.2 | 895.1 | 841.0 | 756.9 | 723.5 |
| Kızılatım | – | – | – | – | 2057.5 | 1976.8 | 2018.5 | 1880.6 | 1655.3 | 1533.7 |

**Table 7.** Changes in total anthocyanins of the grape cultivars throughout the ripening process (malvidin-3-o-glikozit µg $g^{-1}$)

| Cultivars | Weeks from veraison to harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st week 17 Jul. | 2nd week 24 Jul. | 3rd week 31 Jul. | 4th week 7 Aug. | 5th week 14 Aug. | 6th week 21 Aug. | 7th week 28 Aug. | 8th week 4 Sept. | 9th week 11 Sept. | 10th week 18 Sept. |
| T. İlkeren | – | – | 21.6 | 28.7 | 42.4 | – | – | – | – | – |
| T. Seedless | – | – | 32.9 | 53.1 | 76.4 | – | – | – | – | – |
| Cardinal | – | – | 69.2 | 124.5 | 171.6 | – | – | – | – | – |
| Tahannebi | – | – | 41.2 | 59.4 | 85.6 | 138.7 | – | – | – | – |
| Köhnü | – | – | 58.5 | 94.8 | 132.7 | 160.0 | 190.6 | – | – | – |
| B. Karası | – | – | – | | 73.4 | 107.0 | 176.1 | 205.2 | – | – |
| Kızılatım | – | – | – | – | – | – | 19.5 | 24.2 | 28.1 | 32.3 |

**Table 8.** Changes in total antioxidant capacity of the grape cultivars throughout the ripening process (µmol TE $g^{-1}$)

| Cultivars | Weeks from veraison to harvest | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1st week 17 July | 2nd week 24 July | 3rd week 31 July | 4th week 7 Aug | 5th week 14 Aug | 6th week 21 Aug | 7th week 28 Aug | 8th week 4 Sep | 9th week 11 Sep | 10th week 18 Sep |
| T. İlkeren | 19.85 | 18.22 | 14.35 | 10.63 | 6.45 | – | – | – | – | – |
| Barış | 13.40 | 13.37 | 9.872 | 7.15 | 5.34 | – | – | – | – | – |
| Şilfoni | – | 14.60 | 10.34 | 11.22 | 5.88 | – | – | – | – | – |
| T. Seedless | 22.25 | 18.90 | 16.11 | 11.22 | 7.45 | – | – | – | – | – |
| İtalya | 18.33 | 15.53 | 12.36 | 10.50 | 6.20 | – | – | – | – | – |
| Cardinal | – | 30.3 | 21.80 | 11.62 | 8.04 | | – | – | – | – |
| Kureyş | – | 19.70 | 17.35 | 12.31 | 10.88 | 9.55 | 8.73 | 6.18 | – | – |
| Tahannebi | 14.83 | 14.03 | 12.55 | 10.92 | 8.03 | 5.10 | – | – | – | – |
| Köhnü | – | 26.50 | 24.7 | 19.55 | 14.45 | 11.23 | 8.21 | – | – | – |
| B. Karası | – | – | – | 28.10 | 19.60 | 13.08 | 10.32 | 7.80 | – | – |
| Amasya | – | – | – | – | 15.37 | 12.06 | 8.43 | 4.75 | – | – |
| Mazırım | – | – | – | 13.90 | 12.14 | 10.95 | 9.31 | 8.22 | 6.26 | 4.27 |
| Kızılatım | – | – | – | – | 18.31 | 15.03 | 10.80 | 9.07 | 7.35 | 6.12 |

**Table 9.** Total phenolics, total anthocyanins and total antioxidant capacity of the grape cultivars in veraison and harvest periods

| Cultivars | Parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | total phenolics (µg GAE $g^{-1}$) | | total antioxidant capacity (µmol TE $g^{-1}$ ) | | total anthocyanins (µg $g^{-1}$) | | berry skin color |
| | veraison | harvest | veraison | harvest | veraison | harvest | color (value) |
| T. İlkeren | 2351.9 d | 1824.6 d | 19.85 de | 6.45 abc | 21.6 f | 42.4 f | red-purple (4) |
| Barış | 1308.4 hi | 895.2 h | 13.40 f | 5.34 cd | – | – | green-yellow (1) |
| Şilfoni | 1342.6 h | 984.5 g | 14.60 f | 5.88 c | – | – | green-yellow (1) |
| T. Seedless | 2281.0 d | 1893.2 d | 22.25 d | 7.45 ab | 32.9 e | 76.4 e | red-purple (4) |
| İtalya | 1654.7 f | 1266.8 f | 18.33 e | 6.20 bc | – | – | yellow (2) |
| Cardinal | 3215.4 c | 2200.5 c | 30.30 a | 8.04 a | 69.2 b | 171.6 c | red-purple (4) |
| Kureyş | 1390.5 gh | 960.0 gh | 19.70 e | 6.18 c | – | – | yellow (2) |
| Tahannebi | 1451.0 g | 980.7 g | 14.83 f | 5.10 cd | 41.2 d | 138.7 d | green-yellow (1) |
| Köhnü | 3452.3 b | 2351.1 b | 26.50 c | 8.21 a | 58.5 c | 190.6 b | dark red-purple (5) |
| B. Karası | 3541.6 a | 2657.1 a | 28.10 b | 7.80 a | 73.4 a | 205.2 a | dark red-purple (5) |
| Amasya | 1220.7 ij | 974.8 g | 15.37 f | 4.75 cd | – | – | green-yellow (1) |
| Mazırım | 1182.3 i | 723.5 i | 13.90 f | 4.27 d | – | – | green-yellow (1) |
| Kızılatım | 2057.5 e | 1533.7 e | 18.31 e | 6.12 c | 19.5 f | 32.3 g | red (3) |
| LSD % 5 | 102.17 | 81.03 | 4.51 | 2.81 | 3.36 | 11.45 | |

* There were significant differences among the different letter (s) at $P < 0.05$ level

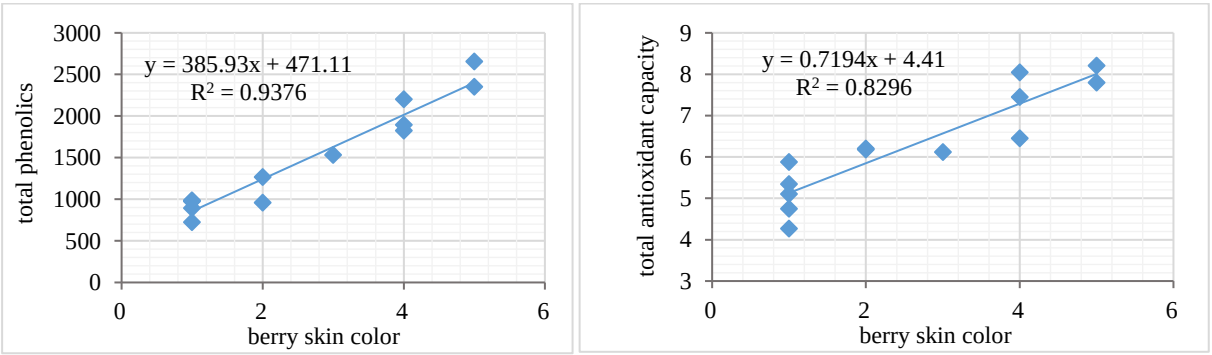


**Fig. 1.** Regression analyses for berry skin colors and total phenolics and total antioxidant capacity of the grape cultivars

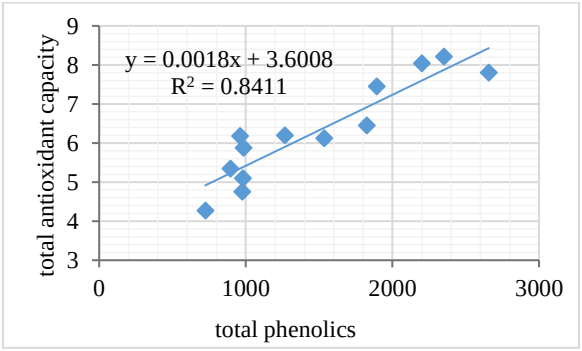


**Fig. 2.** Regression analysis for total phenolics and total antioxidant activity of grape cultivars

reported total phenolics 2.758 mg/g for İtalia cultivar, 2.093 mg $g^{-1}$ for Hafızali cultivar, 2.317 mg $g^{-1}$ for Çavuş cultivar, 1.957 mg $g^{-1}$ for Kozak Beyazı cultivar, 3.466 mg $g^{-1}$ for Alphonse Lavallée cultivar, 2.610 mg $g^{-1}$ for Trakya İlkeren cultivar and 2.255 mg $g^{-1}$ for Siyah Gemre cultivar. Decreasing were observed in total phenolics of the cultivars throughout the ripening process from veraison to harvest. Previous researchers also reported that total phenolics varied with the cultivars and years and decreased throughout the ripening process [Bakker et al. 1986, Navarro et al. 2008, Jin et al. 2009, Cangi et al. 2011, Aydın 2015]. Decrease in total phenolics throughout the ripening process were mostly attributed to high tannen content of berries at early ripening period and decreased surface-volume ratio toward to harvest [Cangi et al. 2011]. Thusly, Çelik et al. [2008] and Özgen et al. [2009] reported similar findings for cranberry and Greek Strawberry (Arbutus Andrachne) fruits. Throughout the ripening process, greater total phenolics were observed in cultivars with red-black skin colors than the cultivars with green-yellow skin colors. These findings comply with the results of earlier studies [Cangi et al. 2011, Aydın 2015]. There was a strong relationship between berry skin color and total phenolics ($R^2$ = 0.9376) – Figure 1). Total phenolics increased from green-yellow skin colors (1) to dark red-purple (5) skin colors. It was reported in previous studies that increasing anthocyanins concentrations throughout the ripening process also increased total phenolics of color-skin cultivars [Mazza 1995, Alonso Borbalan et al. 2003, Scheerens et al. 2005, Bozan et al. 2008, Söylemezoğlu et al. 2015].

While anthocyanins were not identified in cultivars with berry skin colors of green-yellow, anthocyanins of the cultivars with red-black berry skin colors were expressed in malvidin-3-o-glikozit equivalent. Differences in total anthocyanins of the cultivars in veraison and harvest periods were found to be significant. Total anthocyanins of the cultivars varied between 19.5–73.4 µg $g^{-1}$ in veraison period and between 42.4–205.2 µg $g^{-1}$ in harvest period (Tabs 7 and 9). Çetin et al. [2012] reported total anthocyanins in harvest period as 139.41 color value per 1 g for Cardinal cultivar and 319.15 color value per 1 g for Trakya İlkeren cultivar; Göktürk-Baydar et al. [2005] reported the value as 0.37 malvidin-3-o-glikozit mg $g^{-1}$ for Trakya İlkeren cultivar; Orak [2007] reported the value as 173.83 malvidin-3-o-glikozit mg $kg^{-1}$ for Tekirdağ Seedless cultivar; Karasu et al. [2016] reported the same value as 32.59 siyanidin-3-glikozit mg $kg^{-1}$ for Cardinal cultivar. Total anthocyanins of the cultivars decreased throughout the ripening process from veraison to harvest. Previous researchers also reported that total anthocyanins varied with the cultivars and years and increased toward to harvest [Gomez et al. 1995, Ağaoğlu 2002, Navarro et al. 2008, Cangi et al. 2011].

The differences in total antioxidant capacity of the cultivars in veraison and harvest periods were also found to be significant. Total antioxidant capacity of the cultivars with red-black berry skin colors varied between 19.85–30.30 µmol TE $g^{-1}$ in veraison period and between 6.45–8.21 µmol TE $g^{-1}$ in harvest period; total antioxidant capacity of the cultivars with green-yellow berry skin colors varied between 13.40–19.70 µmol TE $g^{-1}$ in veraison period and between 4.27–6.20 µmol TE $g^{-1}$ in harvest period (Tabs 8 and 9). Aydın [2015] reported the lowest total antioxidant capacity in harvest periods as 2.06 µmol TE $ml^{-1}$ for Sarı Kokulu cultivar and the greatest as 9.33 µmol TE $ml^{-1}$ for Civek cultivar. Cangi et al. [2011] reported total antioxidant capacity in harvest period as 5.67 µmol TE $g^{-1}$ for Narince cultivar, 6.57 µmol TE $g^{-1}$ for Gewürtztraminer cultivar, 10.93 µmol TE $g^{-1}$ for Pinot Noir cultivar and 11.7 µmol TE $g^{-1}$ for Syrah cultivar. Total antioxidant capacity decreased 2–4 times throughout the ripening process and the cultivars with red-black berry skin colors had greater antioxidant capacity then the cultivars with green-yellow berry skin colors. Cangi et al. [2011] reported that total antioxidant capacity of Gewürtztraminer, Narince, Pinot Noir and Syrah cultivars decreased from the veraison period and such decreases were attributed to high tannin content of the berries in early ripening period and decreasing surface-volume ratios towards to harvest. There was a strong relationship between berry skin color and total antioxidant capacity ($R^2$ = 0.8296) – Figure 1. Total antioxidant capacity increased from green-yellow skin colors (1) to dark red-purple (5) skin colors. There was also a strong relationship between total phenolics and total antioxidant capacity ($R^2$ = 0.8411) – Figure 2. Generally the greatest total phenolics and antioxidant capacity of Banazı Karası and Köhnü cultivars with berry skin colors of dark red-purple and same

statistical group of these cultivars proved that relationships between these parameters (Tab. 9).

## CONCLUSION

Desired harvest ripening levels were achieved through a ripening process of 5–10 weeks. Biochemical analyses were performed on samples taken each week from the veraison to harvest period. Analyses revealed that total acidity, total phenolics and total antioxidant capacity decreased, water soluble dry matter content, must pH and total anthocyanins increased throughout the ripening process. All these parameters varied with the cultivars. Throughout the ripening process, the cultivars with red-black berry skin colors had greater total phenolics and total antioxidant capacity than the cultivars with green-yellow berry skin colors. Berry skin colors strongly correlated with total phenolics ($R^2$ = 0.9376) and total antioxidant capacity ($R^2$ = 0.8296); these parameters increased from green-yellow skin colors to dark red-purple skin colors. Similarly, there was a strong correlation between total phenolics and antioxidant capacity ($R^2$ = 0.8411). Since the cultivars with red-black berry skin colors were richer in phytochemicals with great benefits on human health than the cultivars with green-yellow berry skin colors, they are mostly preferred as table grapes for fresh consumptions.

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## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## REFERENCES

Ağaoğlu, Y.S. (2002). Scientific and applied viticulture. Vol. 2: Grape physiology. Kavaklıdere Boks: 5, Ankara, Turkey, pp. 444.

Alonso Borbalan, A.M., Zorro, L., Guillen, D.A., Barroso, C.G. (2003). Study of the polyphenol content of red and white grape varieties by liquid chromatographıy-mass spectrometry and its relationship to antioxidant power. J. Chromat. A, 1012(1), 31–38.

Al-Kaisy, A.M., Sachde, A.G., Ghalib, H.A., Hamel, S.M. (1981). Physical and chemical changes during ripening of some grape varieties grown in Basrah. Am. J. Enol. Vitic., 32(4), 268–271.

Aydın, M. (2015). The determination of some chemical contents in different maturation period grape varieties grown in Amasya. M.Sc. Thesis, Gaziosmanpaşa University, Graduate School of Natural and Applied Sciences, Horticulture Department, pp. 52.

Bakker, J., Preston, N.W., Timberlake, C.F. (1986). The determination of antochiyanins in agening red wines: comparison of HPLC and spectral methods. Amer. J. Enol. Vitic., 37, 121–126.

Bozan B., Tosun G., Özcan D. (2008). Study of polyphenol content in the seeds of red grape (*Vitis vinifera* L.) varieties cultivated in Turkey and their antiradical activity. Food Chem., 109, 426–430.

Calo A., Tomasi D., Crespan M., Costacurta A., (1996). Relationship between environmental factors and the dynamics of growth and composition of the grapevine. Proc. Workshop Sperimentale Per La Viticoltura Canegliano, 265–299.

Cangi R., Saraçoğlu O., Uluocak E., Kılıç D., Şen A. (2011). The chemical changes of some wine grape varieties during ripening period in Kazova (Tokat) ecology. Igdir Univ. J. Inst. Sci. Tech., 1(3), 9–14.

Çelik H., Özgen M., Serçe S., Kaya C. (2008). Phytochemical acumulation and antioxidant capacity at four maturity stages of Cranberry Fruit. Sci. Hortic., 117(4), 345–348.

Çetin, E.S., Babalık, Z., Göktürk Baydar, N. (2012). Determination of total carbohydrate, phenolic compound, anthocyanin, β-carotene and vitamin C content on berries in some table grape varieties. IV. National Berry Fruits Symposium Proceedings, 151–156.

Deryaoğlu, A., Canbaş, A. (2003). Physical and chemical changes occured during maturation of Öküzgözü grape variety grown in Elazığ region. J. Food, 28(2), 131–140.

Eyduran, S.P., Akin, M., Ercişli, S., Eyduran, E., Maghradze, D. (2015). Sugars, organic acids, and phenolic compounds of ancient grape cultivars (*Vitis Vinifera* L.) from Igdir province of eastern Turkey. Biol. Res., 48, 1–8.

Fanizza G. (1982). Factor analyses for the choice of a criterion of wine grape (v.v.) maturity in warm regions. Vitis, 21(4), 334–336.

Fidan, Y., Eriş, A. (1974). A research on determination of ripening time of Hafızali and Karagevrek grape cultivars grafted on different rootstocks. Agric. Fac. Yearbook Ankara Univ., 24(3–4), 324– 339.

Giusti, M.M., Wrolstad, R.E. (2005). Characterization and measurement of anthocyanins by UV-visible spectroscopy. In: Handbook of food analytical chemistry, Wrolstad, R.E., Schwartz, S.J. (eds.). Wiley, New York,19–31.

Gomez, E., Martinez, A., Laencina, J. (1995). Chances in volatile compounds during maturation of same grape varieties. J. Sci. Food Agric, 67, 229–233.

Göktürk-Baydar, N., Çetin, A.S., Hallaç, F., Babalık, Z. (2005). Determination of phenolic compounds in grapes by spectrophotometric method. Turkey 6th Viticulture Symposium Proceedings, 1, 329–334.

Jackson, D.I., Lombard, P.B. (1993). Environmental and management practices affecting grape composition and wine quality-a rewiev. Amr. J. Enol. Vitic., 44(4), 409–430.

Jin, Z.M., He, J.J., Bi, H.Q., Cui, X.Y., Duan, C.Q. (2009). Phenolic compound profiles in berry skins from nine red wine grape cultivars in northwest China. Molecules, 14(12), 4922–4935.

Kara, Z., Gerçekcioğlu, R. (1993). A research on some maturity characteristics of narince grape variety grafted to 12 different american vine rootstocks. J. Agric. Fac., 3(5), 5–17.

Karanis, C., Çelik, H. (2002). Investigation of changes in berry contents of some grape varieties grown in Amasya and determination of optimum harvest times. Turkey 5th Viticulture and Oenology Symposium Proceedings, 441–448.

Karasu, S., Baslar, M., Karaman, S., Kilicli, M., Us, A.A., Yaman, H., Sagdic, O. (2016). Characterization of some bioactive compounds and physicochemical properties of grape varieties grown in Turkey: thermal degradation kinetics of anthocyanin. Turkish J. Agric. For., 40, 177–185.

Kunter, B., Cantürk, S., Keskin, N. (2013). Histochemical structure of grape berry. Iğdır Univ. J. Inst. Sci. Tech., 3(2), 17–24.

Mazza, G. (1995). Anthocyanins in grapes and grape products. Crit. Rev. Food Sci. Nutr., 35(4), 341–371.

Navarro, S., León, M., Roca-Pérez, L., Boluda, R., García-Ferriz, L., Pérez-Bermúdez, P., Gavidia, I. (2008). Characterisation of Bobal and Crujidera grape cultivars, in comparison with Tempranillo and Cabemet Sauvignon: Evolution of leaf macronutrients and berry composition during grape ripening. Food Chem., 108(1), 182–190. https://doi.org/10.1016/j.foodchem.2007.10.060

Orak, H.H. (2007). Total antioxidant activities, phenolics, anthocyanins, polyphenoloxidase activities of selected red grape cultivars and their correlations. Sci. Hort, 111, 235–241.

Ough, C.S., Amerine, M.A. (1988). Methods for analysis of musts and wines. John Wiley and Sons. New York, pp. 377.

Özdemir, G., Söğüt, A.B., Pirinççioğlu, M., Kızıl, G., Kızıl, M. (2016). Changes in the phytochemical components in wine grape varieties during the ripening period. Sci. Papers, B, Hortic., 15, 85–93.

Özgen, M., Reese, R.N., Tulio, A.Z., Miller, A.R., Scheerens, J.C. (2006). Modified 2,2-azino-bis-3-ethylbenzothiazoline-6-sul- fonic acid (ABTS) method to measure antioxidant capacity of selected small fruits and comparison to ferric reducing antioxidant power (FRAP) and 2,2'-diphenyl-l-picıylhydrazyl PPPH) methods. J. Agric. Food Chem., 54, 1151–1157.

Özgen, M., Torun, A.A., Ercişli, S., Serçe, S. (2009). Changes in chemical composition, antioxidant activities and total phenolic content of arbutus andrachne fruits at different maturation stages. Italian J. Food Sci., 21(l), 65–72.

Sabır, A., Kafkas, E., Tangolar, S. (2010). Distribution of major sugars, acids and total phenols in juice of five grapevine (*Vitis* spp.) cultivars at different stages of berry development. Spanish J. Agric. Res., 8(2), 425–433.

Scheerens, J.C., Steiner. T.E., Tulio, Z. Jr, Ozgen, M., Miller, D.D., Reese, R.N., Miller, A.R, Ferree, D.C. (2005). The commercial potential and antioxidant characteristics of unique varietal grape juices. Hort. Sci., 40(4), 386.

Singleton, V.L., Rossi, J.L. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Amr. J. Enol. Viticult., 16, 144–158.

Söylemezoğlu, G., Tahmaz, H., Yüksel, D., Göktürk-Baydar, N. (2015). Determination of phenolic compounds on some table and wine grape varieties. Agric. Food Sci. J. Selçuk Univ., 27(S), 375–383.

Şen, A. (2008). Determination of the effect heat summation and optimum harvest time of some grape cultivars grown in Kazova (Tokat) ecology. M.Sc. Thesis, Gaziosmanpaşa University, Graduate School of Natural and Applied Sciences, Horticulture Department, pp. 79.

Tangolar, S., Özdemir, G., Bilir, H., Sabır, A. (2005). Determination of cluster and berry properties of some grape cultivars in Pozantı/ Adana conditions. Turkey 6th Viticulture Symposium Proceeding, Vol, 1, 58–64.

Uluocak, E. (2010). The physical and chemical changes during ripening period of some wine grape varieties grown in Kazova Ttokat) ecology. M.Sc. Thesis, Gaziosmanpaşa University, Graduate School of Natural and Applied Sciences, Hotriculture Department, pp. 78.

Yang, J., Martinson, T.E., Liu, R.H. (2009). Phytochemical profiles and antioxidant activities of wine grapes. Food Chem., 116(1), 332–339. https://doi.org/10.1016/j.foodchem.2009.02.021