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Selected phenolics and antioxidant capacities: From Boğazkere (*Vitis vinifera* L.) grape to pomace and wine

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Abstract: In this research, the amounts of trans-resveratrol, (+)-catechin, (-)-epicatechin, and malvidin-3-glucoside which are among phenolic compounds as well as the total phenolic compound, total anthocyanin, and antioxidant capacity changes were examined in the Boğazkere (*Vitis vinifera* L.) grape, pomace before press, pomace after press and wine. In all parameters examined, a decrease was seen when proceeding from grape to wine, only (+)-catechin and (-)-epicatechin levels were detected to be higher in the prepress pomace. Total phenolic compound, total anthocyanin, and antioxidant capacity levels were found highest in grape samples, respectively, 8018 mg GAE/kg; 1606 mg/kg; 16.05 $\mu\text{mol trolox/g}$ with ABTS method; 7.75 $\mu\text{mol trolox/g}$ with DPPH method; 4.78 $\mu\text{mol trolox/g}$ with FRAP method. The highest amount of trans-resveratrol content was obtained from grape berry with 3.57 mg/kg, the highest (+)-catechin content was obtained from the pomace before press sample with 54.66 mg/kg, the highest amount of (-)-epicatechin was obtained from pomace before press sample 20.38 mg/kg and the highest amount of malvidin-3-glucoside amount was determined as 510 mg/kg in grape. According to the results of the research, it was understood that the pomace of the Boğazkere variety, which is one of the grape varieties mostly processed as wine in our country, has a high level of antioxidant capacity and phenolic content.

Key words: Grape pomace, antioxidant capacity, trans-resveratrol, phenolics

1. Introduction

Grapes and wine have been among the most studied topics in recent years due to their bioactive phenolic compounds. When the keyword “grape” is searched in PUBMED, the largest database of medical research, 21,762 articles are retrieved, 26,011 articles are retrieved when the wine keyword is searched, 2820 articles are found when searching for the words “grapes and health”, and 15,233 articles are found when the word “resveratrol” is searched which shows that a lot of research is done (PUBMED, 2022). The reason why so much research has been done on grapes and wine is that the phenolic compounds they contain have antioxidant, antiinflammatory, antimicrobial, anticarcinogen, and antimutagen effects and also have a protective effect against many diseases such as diabetes, aging, neurological damages (Dai et al., 2020; Weiskirchen and Weiskirchen, 2016). These beneficial phenolic compounds are found in the skin, seeds, and stems of grapes (Karaman Tahmaz et al., 2021), and their health effects are caused by compounds such as trans-resveratrol, (+)-catechin and (-)-epicatechin. The relationship between nutrition and health has led to the investigation of antioxidant content and bioactive aspects of foods. These

bioactive components are phenolic compounds, which are secondary metabolites produced by plants under biotic and abiotic stress factors (Jan et al., 2021). Bioactive phytochemicals found in winery byproducts are mainly represented by biogenetically occurring (poly) phenols through two main primary biosynthetic pathways, and these are the shikimate and acetate pathways. These compounds consist of one or more aromatic rings that are structurally connected to different parts. Therefore, their chemical structure includes a range from simple molecules such as phenolic acids to complex polymeric structures such as tannins (Gharras, 2009).

Wine production constitutes a large number of byproducts, especially organic and inorganic residues (Musee et al., 2007). Vinification, which begins with the harvest of grapes, continues with different techniques depending on the desired sensory characteristics of the final product. In general, 0.75 L of wine is obtained from approximately 1 kg of grapes (Amienyo et al., 2014). After the maceration stage in the process of making red wine, the skins and seeds are excluded from the process by pressing. For every 6 L of wine, 1 kg of pomace (grape seed, grape skin) is produced, and approximately 20%–

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30% of the total processed product during vinification constitutes byproducts and at least 0.3 kg of solid waste per kg (Ferri et al., 2020). Grape pomace is the main byproduct, accounting for about two-thirds of solid waste. This pomace consists of 50% grape skins, 25% seeds, and 25% stems (Yu and Ahmedna, 2013; Beres et al., 2017).

In grapes, the seeds contain 60%–70% of the extractable phenolic chemicals, whereas the skins contain 28%–35% of them. Phenolic compounds found in the skins of grapes, which stand out for their contributions to human health, can be listed as resveratrol at approximately 150 mg/g level, and catechin at 17 mg/g level (+)- catechin, 24 mg/g (-)- epicatechin. The total amount of phenolic compounds in the skin is approximately 375 mg/g as the gallic acid equivalent and the total level of phenolic compound in the seed is 2179 mg/g in Muscadine grapes (Pastrana-Bonill et al., 2003) and the total phenolic content in the seeds ranges between 27,400 and 60,250 GAE/kg DW in *Vitis vinifera* L. seeds and 21,175 and 37,875 GAE/kg DW in the skins (Karaman et al., 2021). The amount of low molecular weight phenolic compounds in the seeds varies in the range of 55–964 mg/100 g. Grape seed extracts contain 74%–78% proanthocyanin and 6% free flavanol monomers (Weber et al., 2007). The dominant stilbene in the grape seed and skin is trans-resveratrol (Nunes et al., 2017). Although the remaining pomace after the acquisition of must has the potential to be converted into a high-quality product, it is not utilized as a profitable waste. Mainly it is directed to compost or thrown into open areas that could potentially lead to environmental problems.

In recent years, numerous pieces of evidence regarding the relationship between nutrition and chronic degenerative diseases have led researchers to look for the most appropriate diet for maintaining the optimal health condition (Sofi et al., 2013; Adefegha, 2018). Researchers say that the human health benefits of a diet rich in fruits and vegetables are due to bioactive compounds with antioxidant properties (Visioli et al., 2018; Neuhaus 2019; Luvian-Morales et al., 2021). Among the natural antioxidants, red grapes (*Vitis vinifera* L.) and wine and vinification wastes are noted for their numerous bioactive polyphenols (Garrido 2019; Tang et al., 2018; Aminzare et al., 2019). Although the benefits of these compounds have been proven, the most studied are trans-resveratrol, (+)-catechin, and (-)- epicatechin (Pubmed, 2022).

During winemaking, only a fraction of grape polyphenols is selectively transferred to wine, and the final polyphenol yield depends on the grape variety and the time of the skin contact period (Bene and Kállay, 2019).

Polyphenols are transferred during the stages of vinification from grape to wine (maceration, fermentation, delestage, pumping over, etc.) (González-Lázaro et al. 2019; Peña-Neira 2019; Merkytė et al. 2020). Most polyphenols in grapes are transferred from solid parts

of grapes, such as skins and seeds, to wine (Waterhouse 2002; Miller et al., 2019; Tian et al., 2020). However, a high proportion of polyphenols still remain in these solid parts (pomace) without switching to wine. Pomace, as a product of the wine industry, can be considered a potential source of bioactive compounds as a food antioxidant (Larrauri 1996; Peixoto et al., 2018, Monari et al., 2020). Determining the chemical characterization and antioxidant capacity of pomace material, which is wine waste, constitutes the first stage of drawing attention to these byproducts.

In this research, postharvest phenolic compound and antioxidant capacity levels were examined in the Boğazkere grape variety and it was aimed to investigate the transition levels of phenolic compounds from grapes to pomace and the latest young wine. One of the most important objectives of the research is to determine the phenolic compound and antioxidant capacity amounts of the pomace of the Boğazkere variety, which is one of the most processed grapes in Turkey. As far as we know, it will be the first study to examine phenolic change and antioxidant capacity in grapes (G), pomace before press (PBP), pomace after press (PAP), and wine (W) in the Boğazkere variety.

2. Materials and methods

In the research, as material, Boğazkere (*Vitis vinifera* L.) grape variety grown in the vineyards of BAK Viticulture and Winery Inc. (40° 05 50.03 N, 33° 27 00.78 E, 688 m) in Kalecik-Ankara considered as one of the highest quality red wine grapes in Turkey and wines obtained from this variety and pomace were used. In 2005, the vineyard where the grapes are grown was planted on 41 B rootstocks with the guyot training system, at distances between 2.5 x 1.5 m rows and above. Grapes were harvested manually on 12 October 2021, at the level of technological maturity (24.2° Brix, pH 3.47, total acidity in terms of tartaric acid 5.47 mg/g). Five kg of harvested grapes samples were selected randomly for analysis. The grapes were taken to steel fermentation tanks with cooling jackets after destemming and crushing on the same day, and maceration was initiated with the addition of *Saccharomyces cerevisiae* yeast (Lalvin BRL97, Lalemand, Canada). A pomace sample was taken pre and postpress for analyses. On the second day after the press, a sample of young wine was taken. Five kg of pomace and 5 L of the young wine sample were taken with three replicates and delivered to Ankara University Faculty of Agriculture in refrigerated boxes.

2.1. Basic wine analysis

The pH, total acidity (mg/mL), residual sugar (g/L), free SO₂ (mg/L), total SO₂ (mg/L), alcohol (%), color density (absorbance unit), and color hue of Boğazkere wine (absorbance unit) analyzes were carried out (Cliff et al., 2007; OIV, 2009).

2.2. Extraction of grape, pomace, and wine

The extraction of phenolic compounds from grapes and pomace was carried out according to Colombo et al. (2019). Three mL methanol/water (1:1, v/v) was added to the samples, which weighed 2 g and powdered with liquid nitrogen, and homogenized in a homogenizer (Ultra-Turrax T25, Ika-Labortechnik, Germany) for 3 min. After homogenization, the samples were first taken to an ultrasonic bath for 15 min and then centrifuged (Sigma 3K30) for 15 min at 14,000 rpm. The same extraction procedures were applied to the solid parts of the samples whose supernatants were taken into a separate tube, which had deposited in the tube. Supernatants are combined with 0.45 µm PVDF filters and the final volume is completed to 10 mL. The extracts obtained were stored at +4 °C in the dark environment for use in a spectrophotometer and HPLC-DAD analysis. Wine samples were passed through 0.45 µm PVDF filters and used directly for analysis.

In wine, grape, and pomace extracts, total phenolic compound and antioxidant capacity analyses were performed with 4 different methods; in addition, trans-resveratrol, (+)- catechin, (-)- epicatechin, and malvidin-3-glucoside levels were determined. Spectrophotometric analyses were performed with Shimadzu UV-1208 UV-VIS spectrophotometer (Shimadzu Corp., Kyoto, Japan) and HPLC analysis was performed with Shimadzu HPLC-DAD device (Shimadzu Corp., Kyoto, Japan).

2.3. Total phenolic compound (TPC) analysis

The total phenolic compounds (TPC) were determined according to Singleton and Rossi (1965) and the results were expressed as mg/kg Gallic Acid Equivalent (GAE) for grape and pomaces, as mg/L GAE for wine.

2.4. Total anthocyanin (TA) analysis

The total anthocyanin (TA) levels of the samples were determined according to the pH differential method developed by Giusti and Wrolstad (2001). The results were expressed as mg/kg for grape and pomaces and mg/L for wine, in terms of malvidin-3-monoglycoside.

2.5. Antioxidant capacity (AC) analysis

Changes in the antioxidant capacities of samples were examined by ABTS, DPPH, FRAP, and CUPRAC methods and all results were given as trolox equivalent (µmol trolox/mL). ABTS [2,2'-azinobis(3-ethyl-benzothiazoline-6-sulfonic acid)] method was applied according to Re et al. (1999) and the inhibition rate was calculated according to the following formula.

$$\text{Inhibition rate (\%)} = \frac{(\text{Initial absorbance value} - \text{Final absorbance value})}{\text{Initial absorbance value}}$$

The average percentage inhibition values obtained were transferred to a graph against sample volumes (10, 20, and 30 µL) and linear regression analysis was applied to this data to reach the curve and the equation that defines this curve.

Antioxidant activity by DPPH (2,2-diphenyl-1-picrylhydrazyl) method was performed according to Katalinic et al. (2004). DPPH free radicals were dissolved in 96% ethanol and 3 mL of this solution is mixed with a 0.2 mL sample. After 15 min, a reading was performed against blank at 517 nm.

FRAP (ferric reducing/antioxidant power) method was applied according to Benzie and Strain (1996). For this purpose, respectively 300 mM sodium acetate with pH 3.6, 10 mM TPTZ diluted in 40 mM hydrochloric acid, and 20 mM $\text{FeCl}_3 \times 6\text{H}_2\text{O}$ were mixed at a rate of 10:1:1 and heated to 37° C. In addition, the 3 mL FRAP standard is mixed with a 0.2 L sample. After 15 min, the absorbance values were measured at 593 nm.

Finally, antioxidant activity was made according to Özyürek et al. (2011) with CUPRAC (cupric reducing antioxidant capacity) method. 10 mM $\text{CuCl}_2 \times 2\text{H}_2\text{O}$ solution, 7.5 mM neocuproine solution, and 1 M ammonium acetate solution were prepared with pH 7.0. A sample of 0.2 mL of wine was mixed with 1 mL and 3.9 mL distilled water from each standard. The change of colour was measured at 450 nm after 30 min. The results were expressed as trolox equivalent (µmol trolox/g for grape and pomaces, µmol trolox/mL for wine) in terms of facilitating comparability with each other.

2.6. Individual phenolic compounds

The trans-resveratrol, (+)- catechin, (-)- epicatechin, and malvidin-3-glucoside quantities of the samples were determined by Shimadzu HPLC-DAD device (Downey and Rochfort, 2008). The diagnosis of phenolic compounds was made by using the time and spectrum of the standard substances used. Solutions were prepared at 1–50 ppm concentrations, standard curves were formed and phenolic compound amounts of samples were used. Gemini Phenomenex C18 (Calif., U.S.A.): 4.6 mm × 260 mm column and used as two different mobile phases: 10% formic acid in water (solvent A) and 10% formic acid in methanol (solvent B). The flow rate of solvents is 1.0 mL/min and gradient conditions are 0 min 18% B, 14 min 29% B, 16 min 32% B, 18 min 41% B, 18.1 min 30% B, 29 min 41% B, 32 min 50% B, 34.5 min 100% B and 35–38 min 18% B. The results were stated as mg/kg for grapes and pomaces and mg/L for wine.

2.7. Data analysis

Statistical analyses of the data were done using IBM SPSS (SPSS Inc., Chicago, Illinois) statistical program version 20 and Duncan's multiple range tests were used to compare means. All analyses were performed in triplicate and the results were given in the form of average ± standard errors. In addition, Pearson correlation analysis was performed with IBM SPSS vers. 20 to determine the correlation of antioxidant capacity determination methods with each other.

3. Results and discussion

3.1. Basic wine analysis

The basic analysis results of Boğazkere wine are given in Table 1. The results of the analysis were observed to follow the same trend as the literature (Tahmaz and Söylemezoğlu 2017; Tetik and Selli 2018).

3.2. Total phenolic compound (TPC) of grape, pomaces, and wine

The change in TPC levels of grape (G), pomace before pres (PBP), and pomace after pres (PAP) and wine (W) belonging to the Boğazkere variety is given in Figure 1. TPC content was measured as 8018 mg GAE/kg in grapes, 5395 mg GAE/kg in pomace before pres, 3018 mg GAE/kg in pomace after press, and 2817 mg GAE/L in wine ($p < 0.01$). From the results, it is understood that the content of TPC decreases in the process from grapes to wine. About 35.14% of the TPC content in grapes has been transferred to the wine. PBP and PAP pomace samples showed a very high amount of phenolic compounds, and 67.30% of the phenolic compound content in grapes remains in PBP and 37.64% in PAP. While the prepress pomace had a higher phenolic compound content, it was understood that some of these compounds were transferred to wine after the pressing process.

Özdemir (2018) determined the content of TPC in the seed, pomace, and skin of the Boğazkere grape as 115.82 μg GAE/mg, 534.81 μg GAE/mg, and 334.56 μg GAE/mg respectively. The total phenolic compound content in Boğazkere wine was measured as 2420 mg/L by Tahmaz and Söylemezoğlu (2017) and as 3300 mg/L by Cavuldak et al. (2013). In another study, TPC content was measured as 1062 mg/kg in grapes belonging to Syrah variety, 1013 mg/kg in pomace, and 1422 mg/L in wine. The same researchers found that the amount of phenolic compound increased in the transition from grapes to wine in the Syrah variety, while the Cabernet Sauvignon variety decreased (Lingua et al., 2016).

3.3. Total anthocyanin (TA) of grape, pomaces, and wine

The TA results of the samples were measured at 1606 mg/kg, 1016 mg/kg, 779 mg/kg, and 596 mg/L levels in G, PBP, PAP with the order from highest to lowest, and the difference between the results was statistically significant at $p < 0.01$ (Figure 2). 37.11% of the total anthocyanin in the Boğazkere grape at the level of 1606 mg/L has been transferred to the wine. Tahmaz and Söylemezoğlu (2017) determined the content of anthocyanin of Boğazkere wine at levels of 109.1 mg/L, Peri et al. (2015) 5.394 mg C3G/100 mL. Pomace samples also contain undeniable levels of anthocyanin (779–1016 mg/kg). The content of anthocyanin in red wine varies depending on many factors such as climate, height, cultural processes, especially grape variety (Schultz and Jones, 2010; Kharadze et al., 2018;

Table 1. Basic wine analysis.

pH	3.60
Total acidity (g/L)*	6.01
Alcohol (% v/v)	13.50
Residual sugar (g/L)	0.9
Volatile acidity** (g/L)	0.25
Free SO ₂ (mg/L)	12
Total SO ₂ (mg/L)	20
Total extract (g/L)	30.0
Color intensity ($A_{420}+A_{520}+A_{620}$)	1.48
Color hue (A_{420}/A_{520})	0.94
Malic acid (mg/mL)	0.02

*In terms of tartaric acid, ** in terms of sulphuric acid.

Martinez de Toda and Ramos, 2019). For example, the total content of anthocyanin in 1-year-old red wine varies from 40 to 1269 mg/L, and in bottled wine, at the year of 4 years, it decreases by about 60% (Mattivi and Nicolini, 1997). Antioxidants, anti-inflammatory properties, and protective properties against heart disease, cancer, diabetes, and cognitive dysfunctions are attributed to anthocyanins (Snopek et al., 2018).

3.4. Antioxidant capacities (AC) of grape, pomaces, and wine

Figure 3 provides the variation of G, PBP, PAP, and W samples measured with the ABTS, DPPH, and FRAP methods and antioxidant capacity levels (AC) and samples. In all three methods, the highest antioxidant capacity was measured in grapes and the lowest antioxidant capacity was measured in wine ($p < 0.01$). Antioxidant capacity values in G, PBP, PAP, and W were found to be 16.05 μmol trolox/g, 13.82 μmol trolox/g, 11.08 μmol trolox/g, 8.74 μmol trolox/mL, respectively, according to ABTS method; 7.75 μmol trolox/g, 6.68 μmol trolox/g, 5.38 μmol trolox/g, 4.50 μmol trolox/mL according to DPPH method; 4.78 μmol trolox/g, 3.70 μmol trolox/g, 3.26 μmol trolox/g, 2.91 μmol trolox/mL according to FRAP method. Ruberto et al. (2007) measured the antioxidant capacity in winery wastes belonging to Sicilian red grape varieties in the ranges of 1.58–2.24 $\mu\text{g}/\text{mL}$ with the TEAC method and 15.90–38.93 $\mu\text{g}/\text{mL}$ with the DPPH method. Our antioxidant activity results in grapes, pomace, and wine are in line with the literature (Yang et al., 2009; Tseng, and Zhao 2013; Lingua et al., 2016).

The reason why antioxidant capacity was determined by 3 different methods in the research is that antioxidant capacity determination methods are based on precise

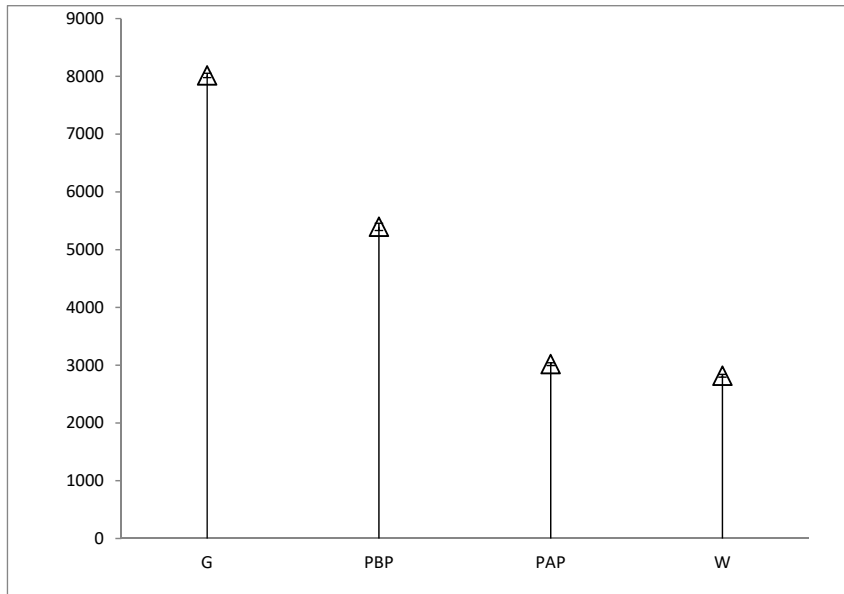


Figure 1. TPC of grape, pomaces, and wine ($p < 0.01$). G: Grape, PBP: Pomace before press, PAP: Pomace after press, W: Wine. Results are given in mg GAE/ kg for grape and pomace, and mg GAE /L for wine.

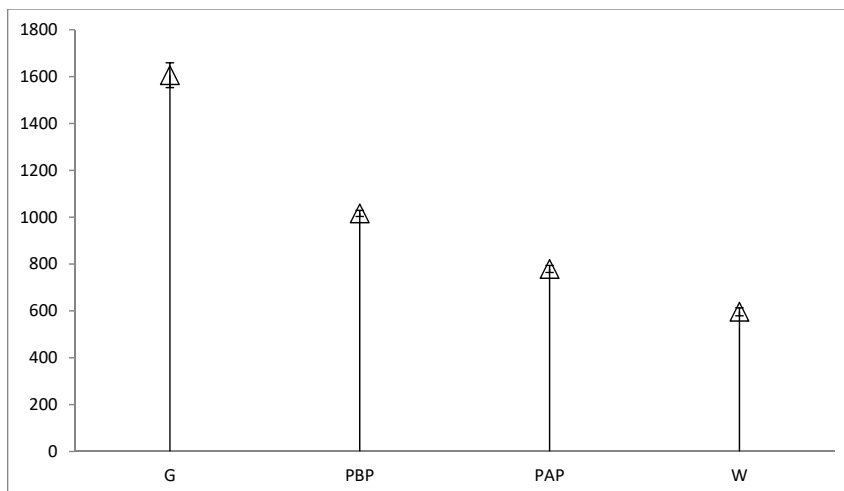


Figure 2. TA of grape, pomaces and wine ($p < 0.01$). G: Grape, PBP: Pomace before press, PAP: Pomace after press, W: Wine. Results are given in mg/kg for grape and pomace, and mg/L for wine.

analytical procedures and thus accuracy is increased with 3 different methods. In addition, the antioxidant capacity results were tested with Pearson correlation and the results are given in Table 1. When correlation coefficients (R) are examined, it is seen that there is a correlation between DPPH and ABTS at 0.984 ($p < 0.01$), DPPH at 0.960 ($p < 0.01$), ABTS at 0.945 ($p < 0.01$). The results of correlation analysis showed that these methods are almost comparable and interchangeable in characterizing antioxidant

capacities. Other research using antioxidant capacity measurement methods has also shown a high correlation (Alañón et al., 2011; Jiang et al., 2018).

3.5. trans-resveratrol, (+)- catechin, (-)- epicatechin, and malvidin-3-glucoside contents of grape, pomaces, and wine

Trans-resveratrol, (+)- catechin, (-)- epicatechin, and malvidin-3-glucoside levels were measured in Boğazkere grapes, prepress, and postpress pomace and wine, and the

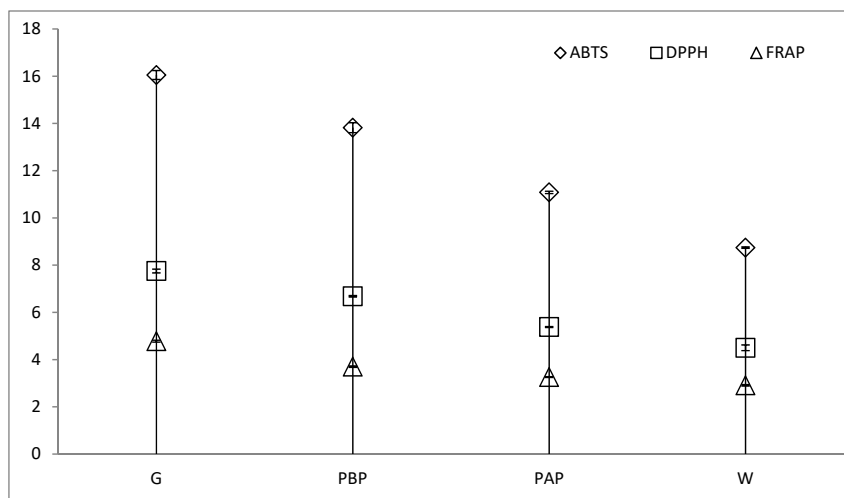


Figure 3. Antioxidant capacities (ABTS, DPPH, FRAP) of grape, pomaces and wine ($p < 0.01$). G: Grape, PBP: Pomace before press, PAP: Pomace after press, W: Wine. Results are given in $\mu\text{mol trolox/g}$ for grape and pomace, and $\mu\text{mol trolox/mL}$ for wine.

results are given in Table 2. The highest trans-resveratrol was determined in grapes at 3.57 mg/kg and the highest malvidin-3-glucoside at 510 mg/kg ($p < 0.01$). (+)- catechin and (-)- epicatechin amounts were measured in prepress pomace at 54.66 mg/kg and 20.38 mg/kg respectively ($p < 0.01$). Trans-resveratrol was measured in the range of 0.76–3.57 mg/kg, in grapes, wine, prepress pomace, postpress pomace, respectively, from highest to lowest. (+)- catechin was detected in the range of 25.80–54.66 mg/kg, (-)- epicatechin was detected in the range of 11.99–20.38 in the range from highest to lowest, respectively, in pomace before press, pomace after press, wine, and grape. Malvidin-3-glucoside was measured in grapes, prepress pomace, postpress pomace, and wine, respectively, from highest to lowest.

The seeds contain the vast majority of flavan-3-ols and are found in the external hydrophobic cuticle and the inner lignified layers. The transition of catechins and (-)- epicatechins in the seeds to wine takes place within 2–3 weeks of maceration (Gonzalez-Manzano et al. 2004; Koyama et al., 2007). Twenty-three anthocyanidins have been detected in vascular plants, but grapes (*Vitis vinifera* L.) have only 6 of these compounds: Cyanidin, peonidin, delphinidin, petunidin, and malvidin. Malvidin-3-glucose is anthocyanidin, which is commonly found in *Vitis vinifera* L. varieties and accounts for 40% to 72% of the total anthocyanin profile (Manfra et al. 2011). The transition of anthocyanins from grape skin to must (+)- peaks in the 3rd to 5th days of maceration, such as catechins and (-)-epicatechins (Casassa et al. 2013). The transition of the trans-resveratrol compound, known for its health benefits, from grapes to wine is influenced by viticultural and enological factors (Atanacković et al., 2012; Kostadinović et

Table 2. Pearson's correlation coefficients of antioxidant capacity (ABTS, DPPH, FRAP).

	ABTS	DPPH	FRAP
ABTS	1		
DPPH	0.984**	1	
FRAP	0.945**	0.960**	1

**Correlation is significant at the 0.01 level (2-tailed).

al., 2012). In this study, some of the (+)- catechin and (+)-epicatechin, which were found undissolved in the tissues of the grape, dissolved more with the resulting alcohol and was transferred to wine, and the result was determined in large quantities in wine compared to grapes. In addition, these compounds dissolved from the skin and seeds of the grape, but they were measured in higher amounts in pre and postpress pomace and wine than in grapes. In light of these results, winery pomace material containing a high amount of antioxidant, antiinflammatory, antimicrobial, antidiabetic, and antitumor effects (Prakash et al., 2019) and (+)- catechin and (-)- epicatechin can be considered a highly valuable bioactive food. According to our research results, there is a higher amount (+)- catechin and (-)-epicatechin in pomace than in grapes and wine. Peixoto et al. (2018) revealed that bio-residues belonging to the wine industry are important bioactive molecules with high antioxidant and antibacterial activity, that is, good sources of phenolic compounds. They also emphasized that the use of winery byproducts containing these bioactive molecules in the food, pharmaceutical, and cosmetic industries

Table 3. trans-resveratrol, (+)- catechin, (-)- epicatechin and malvidin-3-glucoside contents of grape, pomaces and wine.

	T-Res	(+)- Catechin	(-)- Epicatechin	Malvidin -3-glucoside
G	3.57 ± 0.03 ^a	25.80 ± 0.87 ^d	11.99 ± 0.07 ^d	510 ± 0.5 ^a
PBP	0.99 ± 0.00 ^c	54.66 ± 0.59 ^a	20.38 ± 0.10 ^a	496 ± 1.6 ^b
PAP	0.76 ± 0.02 ^d	40.63 ± 0.18 ^b	17.80 ± 0.10 ^b	482 ± 0.9 ^c
W	1.13 ± 0.01 ^b	31.34 ± 0.18 ^c	15.09 ± 0.03 ^c	446 ± 1.9 ^d

Different letters in the same column indicate statistical differences at the $p < 0.01$ level. Results are given in mg/kg for grape and pomace, and mg/L for wine.

would be a good way to add value to winery pomace waste (Peixoto et al., 2018) (Table 3).

4. Conclusions

According to the results of the research, the highest total amounts of phenolic compound, total anthocyanin, antioxidant capacity, trans-resveratrol, and malvidin-3-glucosides were measured in Boğazkere grapes. At the same time, these parameters were detected in grapes, prepress pomace, postpress pomace, and wine, respectively, from highest to lowest. Only (+)- catechin and (+)- epicatechin of the measured phenolic compounds were measured in higher amounts in the prepress pomace, going beyond this order. As with all agricultural productions, the wine production process produces several potential organic

byproducts as waste that can be recovered. In light of these results, pomaces, which are winery wastes belonging to the Boğazkere variety, can be attributed as important bioactive raw materials and the reuse of properly managed winery byproducts for alternative purposes such as value-added products should be encouraged.

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Conflict of interest

On behalf of the authors, the corresponding author states that there is no conflict of interest.

References

- Adefegha SA (2018). Functional foods and nutraceuticals as dietary intervention in chronic diseases; novel perspectives for health promotion and disease prevention. *Journal of Dietary Supplements* 15 (6): 977-1009.
- Alañón ME, Castro-Vázquez L, Díaz-Maroto MC, Gordon MH, Pérez-Coello MS (2011). A study of the antioxidant capacity of oak wood used in wine ageing and the correlation with polyphenol composition. *Food Chemistry* 128 (4): 997-1002.
- Amienyo D, Camilleri C, Azapagic A (2014). Environmental impacts of consumption of Australian red wine in the UK. *Journal of Cleaner Production* (72): 110-119.
- Aminzare M, Hashemi M, Ansarian E, Bimkar M, Azar HH et al. (2019). Using natural antioxidants in meat and meat products as preservatives: A review. *Advances in Animal and Veterinary Sciences* 7 (5): 417-426.
- Atanacković M, Petrović A, Jović S, Gojković-Bukarica L, Bursać M et al. (2012). Influence of winemaking techniques on the resveratrol content, total phenolic content and antioxidant potential of red wines. *Food Chemistry* 131 (2): 513-518.
- Bene Z, Kállay M (2019). Polyphenol contents of skin-contact fermented white wines. *Acta Alimentaria* 48 (4): 515-524.
- Benzie IFF, Strain JJ (1996). The ferric reducing ability of plasma (FRAP) as measurement of "antioxidant power": The Frap assay. *Analytical Biochemistry* 239: 70-76.
- Beres C, Costa GN, Cabezudo I, da Silva-James NK., Teles AS, Cruz AP, Mellinger-Silva C, Tonon RV, Cabral LMC, Freitas SP (2017). Towards integral utilization of grape pomace from winemaking process: A review. *Waste management* 68: 581-594.
- Casassa LF, Beaver CW, Mireles MS, Harbertson JF (2013). Effect of extended maceration and ethanol concentration on the extraction and evolution of phenolics, color components and sensory attributes of Merlot wines. *Australian Journal of Grape and Wine Research* 19: 25-39.
- Cavuldak ÖA, Anlı RE, Vural N (2013). Phenolic Composition and Antioxidant Capacity of Some Red Wines from Turkey. *International Journal of Food Science and Nutrition Engineering* 3 (3): 40-47.
- Cliff MA, King MC, Schlosser J (2007). Anthocyanin, phenolic composition, colour measurement and sensory analysis of BC commercial red wines. *Food Research International* 40 (1): 92-100.

- Colombo F, Di Lorenzo C, Regazzoni L, Fumagalli M, Sangiovanni E et al. (2019). Phenolic profiles and anti-inflammatory activities of sixteen table grape (*Vitis vinifera* L.) varieties. *Food & function* 10 (4): 1797-1807.
- Dai Y, Lim JX, Yeo SCM, Xiang X, Tan KS et al. (2020). Biotransformation of piceatannol, a dietary resveratrol derivative: Promises to human health. *Molecular nutrition & food research* 64 (2): 1900905.
- Downey MO, Rochfort S (2008). Simultaneous separation by reversed-phase high-performance liquid chromatography and mass spectral identification of anthocyanins and flavonols in Shiraz grape skin. *Journal of Chromatography A* 1201: 43-47.
- FAO 2022. <http://www.fao.org/faostat/en/#home>
- Ferri M, Vannini M, Ehrnell M, Eliasson L, Xanthakis E, Monari S (2020). From winery waste to bioactive compounds and new polymeric biocomposites: a contribution to the circular economy concept. *Journal of Advanced Research* 24: 1-11.
- Garrido T, Gizdavic-Nikolaidis M, Leceta I, Urdanpilleta M, Guerrero P et al. (2019). Optimizing the extraction process of natural antioxidants from chardonnay grape marc using microwave-assisted extraction. *Waste Management* 88: 110-117.
- Gharras HE (2009). Polyphenols: Food sources, properties and applications-A review. *International Journal of Food Science & Technology* 44: 2512-2518.
- Giusti MM, Wrolstad RE (2001) Characterization and measurement of anthocyanins by UV-visible spectroscopy. In: Wrolstad RE, Acree TE, An H, Decker EA, Penner MH, Reid DS, Schwartz SJ, Shoemaker CF, Sporns P, editors. *Current protocols in food analytical chemistry*. New York: John Wiley & Sons. p F1.2.1-F1.2.13.
- González-Lázaro M, Martínez-Lapuente L, Palacios A, Guadalupe Z, Ayestarán B et al. (2019). Effects of different oenological techniques on the elaboration of adequate base wines for red sparkling wine production: phenolic composition, sensory properties and foam parameters. *Journal of the Science of Food and Agriculture* 99 (10): 4580-4592.
- Gonzalez-Manzano S, Rivas-Gonzalo JC, Santos-Buelga C (2004). Extraction of flavan-3-ols from grape seed and skin into wine using simulated maceration. *Analytica Chimica Acta* 513: 283-89.
- Jan R, Asaf S, Numan M, Kim KM (2021). Plant secondary metabolite biosynthesis and transcriptional regulation in response to biotic and abiotic stress conditions. *Agronomy* 11 (5): 968.
- Jiang B, Zhang ZW (2018). A Preliminary study of aroma composition and impact odorants of Cabernet Franc wines under different terrain conditions of the Loess Plateau Region (China). *Molecules* 23 (5): 1096.
- Karaman, HT, Küskü DY, Söylemezoğlu G (2021). Phenolic Compounds and Antioxidant Capacities in Grape Berry Skin, Seed and Stems of Six Wine Grape Varieties Grown in Turkey. *Acta Scientiarum Polonorum-Hortorum Cultus* 20 (1): 15-25.
- Katalinić V, Milos M, Modun D, Musić I, Boban M (2004). Antioxidant effectiveness of selected wines in comparison with (+)-catechin. *Food chemistry* 86 (4): 593-600.
- Kharadze M, Japaridze I, Kalandia A, Vanidze M (2018). Anthocyanins and antioxidant activity of red wines made from endemic grape varieties. *Annals of Agrarian Science* 16 (2): 181-184.
- Kostadinović S, Wilkens A, Stefova M, Ivanova V, Vojnoski B et al. (2012). Stilbene levels and antioxidant activity of Vranec and Merlot wines from Macedonia: Effect of variety and enological practices. *Food Chemistry* (135) 4: 3003-3009.
- Koyama K, Goto-Yamamoto N, Hashizume K (2007). Influence of maceration temperature in red wine vinification on extraction of phenolics from berry skins and seeds of grape (*Vitis vinifera*). *Bioscience Biotechnology Biochemistry* 71: 958-65
- Larrauri JA, Ruperez P, Calixto FS (1996). Antioxidant activity of wine pomace. *American Journal of Enology and Viticulture* 47 (4): 369-372.
- Lingua MS, Fabani MP, Wunderlin DA, Baroni MV (2016). In vivo antioxidant activity of grape, pomace and wine from three red varieties grown in Argentina: Its relationship to phenolic profile. *Journal of Functional Foods* 20: 332-345.
- Luvian-Morales J, Varela-Castillo FO, Flores-Cisneros L, Cetina-Pérez L, Castro-Eguiluz D (2021). Functional foods modulating inflammation and metabolism in chronic diseases: a systematic review. *Critical Reviews in Food Science and Nutrition* (2021): 1-22.
- Manfra M, De Nisco M, Bolognese A, Nuzzo V, Sofo A et al. (2011). Anthocyanin composition and extractability in berry skin and wine of *Vitis vinifera* L. cv. Aglianico. *Journal of the Science of Food and Agriculture* 91: 2749-55.
- Martínez de Toda F, Ramos Martín M C (2019). Variability in grape composition and phenology of 'Tempranillo' in zones located at different elevations and with differences in the climatic conditions. *Vitis: Journal of Grapevine Research* 58 (4): 131-139.
- Mattivi F, Nicolini G (1997). Analysis of polyphenols and resveratrol in Italian wines. *BioFactors* 6 (4): 445-448.
- Merkytė V, Longo E, Windisch G, Boselli E (2020). Phenolic Compounds as Markers of Wine Quality and Authenticity. *Foods* 9 (12): 1785.
- Miller, KV, Noguera R, Beaver J, Medina-Plaza C, Oberholster A, Block DE (2019). A mechanistic model for the extraction of phenolics from grapes during red wine fermentation. *Molecules* 24 (7): 1275.
- Monari S, Ferri M, Vannini M, Sisti L, Marchese P et al. (2020). Cascade strategies for the full valorisation of Garganega white grape pomace towards bioactive extracts and bio-based materials. *Plos one* 15 (9): e0239629.
- Musee N, Lorenzen L, Aldrich C (2007). Cellar waste minimization in the wine industry: A systems approach. *Journal of Cleaner Production* 15: 417-431.

- Neuhouser ML (2019). The importance of healthy dietary patterns in chronic disease prevention. *Nutrition Research* 70: 3-6.
- Nunes MA, Rodrigues F, Oliveira MBP (2017). Grape processing by-products as active ingredients for cosmetic proposes. In *Handbook of grape processing by-products* (pp. 267-292). Academic Press.
- OIV (2009). Compendium of international methods of wine and must analysis. International Organisation of Vine and Wine: Paris, France, 154-196.
- Özdemir G (2018). Determination of the effect of some organic and organo-mineral fertilizers on total phenolic, flavonoid and anthocyanin content of Bogazkere (*Vitis vinifera* L.) grapes. *Fresenius Environmental Bulletin* 27: 3199-3205.
- Özyürek M, Güçlü K, Tütem E, Bakan KS, Erçağ E et al. (2011). A comprehensive review of CUPRAC methodology. *Analytical Methods* 3: 2439-2453.
- Pastrana-Bonilla E, Akoh CC, Sellappan S, Krewer G (2003). Phenolic content and antioxidant capacity of Muscadine grapes. *Journal of Agricultural and Food Chemistry* 51: 5497-5503.
- Peixoto CM, Dias MI, Alves MJ, Calhelha RC, Barros L et al. (2018). Grape pomace as a source of phenolic compounds and diverse bioactive properties. *Food Chemistry* 253: 132-138.
- Peri P, Kamiloglu S, Capanoglu E, Ozcelik B (2015). Investigating the Effect of Aging on the Phenolic Content, Antioxidant Activity and Anthocyanins in Turkish Wines. *Journal of Food Processing and Preservation* 39 (6): 1845-1853.
- Peña-Neira A (2019). Management of astringency in red wines. In *Red Wine Technology* (pp. 257-272). Academic Press.
- Prakash M, Basavaraj BV, Murthy KC (2019). Biological functions of epicatechin: Plant cell to human cell health. *Journal of Functional Foods* 52: 14-24.
- PUBMED 2022. Pubmed. (<https://pubmed.ncbi.nlm.nih.gov/>), (Date of access: 20.05.2021).
- Re R, Pellegrini N, Proteggente A, Pannala A, Yang M, Rice-Evans C (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine* 26 (9-10): 1231-1237.
- Ruberto G, Renda A, Daquino C, Amico V, Spatafora C et al. (2007). Polyphenol constituents and antioxidant activity of grape pomace extracts from five Sicilian red grape cultivars. *Food Chemistry* 100 (1): 203-210.
- Schultz HR, Jones GV (2010). Climate induced historic and future changes in viticulture. *Journal of Wine Research* 21 (2-3): 137-145.
- Singleton VL, Rossi JJA (1965). Colorimetric of total phenolics with phosphomolybdic- phosphotungstic acid reagents. *American Journal of Enology and Viticulture* 16 (3): 144-58.
- Sofi, F, Macchi C, Abbate R, Gensini GF, Casini A (2013). Mediterranean diet and health. *Biofactors* 39 (4): 335-342.
- Snopek L, Mlcek J, Sochorova L, Baron M, Hlavacova I et al. (2018). Contribution of red wine consumption to human health protection. *Molecules* 23 (7): 1684.
- Tahmaz H, Söylemezoğlu G (2017). Effects of Vinification Techniques Combined with UV-C Irradiation on Phenolic Contents of Red Wines. *Journal of Food Science* 82 (6): 1351-1356.
- Tang GY, Zhao CN, Liu Q, Feng XL, Xu XY et al. (2018). Potential of grape wastes as a natural source of bioactive compounds. *Molecules* 23 (10): 2598.
- Tetik MA, Selli S (2018). Öküzgözü Şaraplarında Sıkma İşleminin Genel Bileşim ve Duyusal Özellikler Üzerine Etkisi. *Ç.Ü. Fen ve Mühendislik Bilimleri Dergisi* 35 (6): 91-100.
- Tian B, Harrison R, Morton J, Jaspers M (2020). Influence of skin contact and different extractants on extraction of proteins and phenolic substances in Sauvignon Blanc grape skin. *Australian Journal of Grape and Wine Research* 26 (2): 180-186.
- Tseng A, Zhao Y (2013). Wine grape pomace as antioxidant dietary fibre for enhancing nutritional value and improving storability of yogurt and salad dressing. *Food chemistry* 138 (1): 356-365.
- Visioli F, Franco M, Toledo E, Luchsinger J, Willett WC et al. (2018). Olive oil and prevention of chronic diseases: Summary of an International conference. *Nutrition, Metabolism and Cardiovascular Diseases* 28 (7): 649-656.
- Waterhouse AL (2002). Wine phenolics. *Annals of the New York Academy of Sciences* 957 (1): 21-36.
- Weber HA, Hodges AE, Guthrie JR, O'Brien BM, Robaugh D et al. (2007). Comparison of proanthocyanidins in commercial antioxidants: Grape seed and pine bark extracts. *Journal of Agricultural and Food Chemistry* 55: 148-156.
- Weiskirchen S, Weiskirchen R (2016). Resveratrol: how much wine do you have to drink to stay healthy? *Advances in Nutrition* 7 (4): 706-718.
- Yang J, Martinson TE, Liu RH (2009). Phytochemical profiles and antioxidant activities of wine grapes. *Food Chemistry* 116 (1): 332-339.
- Yu J, Ahmedna M (2013). Functional components of grape pomace: their composition, biological properties and potential applications. *International Journal of Food Science & Technology* 48 (2): 221-237.