INTRODUCTION

Wine is a complex mixture obtained by complete or partial fermentation of grape must (Cheynier, 2010). It contains more than a thousand substances, some of which have not been precisely analysed yet. Most of these substances come from berries of the grape vine, others are formed during processing. Some substances are partially or completely degraded during processing (Dominié, 2005). Wines owe their colour and structure to phenolic compounds. The concentration of phenolic substances increases during the ripening of berries, and these substances subsequently give wine its character and quality. In white wines, with gentle processing of grapes, their content changes up to 250 mg/L.1. In red wines, content of phenolic compounds is up to 450 mg L-1 (Michlovský, 2014). Phenols are compounds of great importance for viticulture and winemaking. There is a significant difference between varieties of red and white wines in the content of phenolic substances, and their composition in grapes and wine (Pavlovič, 2011). Phenolic substances are significant both to white and red wines. In white wines, higher levels of polyphenols are mostly undesirable, as they can contribute to excessive bitterness and also to the tendency of the wine to brown when it is exposed to air. In red wines, they contribute to the bitterness, astringency, and other organoleptic properties, such as colour of the wine. (Waterhouse, 2003). These substances affect the taste and appearance of the wine, in particular colour, bitterness, acerybity, absorption of oxygen and the aging process of the must or the wine (Steidl, 2010). The extraction of phenolic compounds in the process of winemaking has important effect on the colour and taste of the wine (Jiang, Zhang, 2012).

The phenolic composition of wine is affected by the composition of grapes, which is influenced by many aspects, such as cultivar, viticultural practices and environmental conditions, and various techniques, and several reactions occurring during the process of wine making (Sacchi, Biston, Adams, 2005). Viticultural practices, such as canopy management, yield regulation, irrigation, and harvest time, can influence the content and composition of different flavonoids, e.g. anthocyanins, proanthocyanidins and flavonols (Downey, Dokoziian, Kristic, 2006). Dumitriu (2015) proved that nanomaterials could decrease the total phenolic content in wines.

Vermerris and Nicholson (2006) define phenolic substances as compounds having one or more hydroxyl groups attached directly to the aromatic ring formed by benzene. They comprise of approximately 8000 compounds (Kabera et al., 2014). There is no consensus regarding how phenolic compounds should be classified. Most classifications of phenolics are based on their chemical structure. In this sense, we can classify them in four different ways: 1. Flavonoids ad non-flavonoids, 2. by the amount of aromatic rings, 3. by the carbon skeleton, and 4. by the basic chemical structure, which is most widely used (Santana-Gálvez, Jacobo-Velázquez, 2018). Phenolic compounds mainly identified in wine are hydroxycinnamic and hydroxybenzoic acids, flavonals, flavonols, flavones, flavononals, stilbenes, and anthocyanins (Monagas, 2005).

From a nutritional point of view, grapes and wine are good food sources of phenolic compounds (Cueva et al., 2017). The most significant phenolics found in the human nutrition are phenolic acids, flavonoids, and tannins (Vuolo, Lima, Junior, 2019). Lately, dietary polyphenols have drawn attention because of their ability to scavenge free radicals, chelate metal and regulate digestive enzymes, (Rasouli, Farzaei, Khodarahmi, 2017). A number of health benefits have been linked to phenolic compounds, besides antioxidant effects. Studies shown, that polyphenols also have anti-inflammatory effect, anti-lyteotropic and anti-thrombotic activity (Rechner, Kroner, 2005). They also have positive effects on the composition and function of the human microflora (Cueva et al., 2010). Phenolic compounds found in wine may prevent or defer the development of gastric diseases caused by inflammation and oxidative stress. Moreover, wine polyphenols acts as prebiotics (Blasi et al., 2014). They and their metabolites interact with epithelial cells, and by controlling the microbial composition of intestines contribute to the maintenance of gastrointestinal health. Nutritional polyphenols also act as substrates for intestinal microflora. (Hervert-Hernandez,
Goni, 2011). Phenolic compounds have been shown to have positive bactericidal and antioxidant properties, as well as beneficial effects to the health and protection of the organism (Ribéreau-Gayon et al., 2006). Due to the potential health benefits for human nutrition, studies have significantly increased in recent years, including the development of analytical methods for the determination and measurement of phenolic acids from food and beverages (Robbins, 2003). Analysis of phenolic compounds in grapes and wine may offer particular biomarkers that could help to better evaluate the chemical evolution of grapes during growth and maturation, as well to make progress in the wine authentication by developing and applying new or advanced control methods (Niculescu, 2018). Polyphenols extracted from wine and analysed by 1H NMR are a good marker for variety, geographical origin, and vintage of wines (Downey, 2016).

The aim of this study was to determine and evaluate chosen properties (total polyphenol content, total flavonoid content, and antioxidant activity) and their mutual correlations in Slovak varietal wines of Muscat type, of various Slovak vineyard areas origin.

### Table 1 Characteristics of analysed wine samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Variety</th>
<th>Producer</th>
<th>Vineyard area</th>
<th>Vintage</th>
<th>Wine type</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM1</td>
<td>Moravian Muscat</td>
<td>Chateau Topoľčianky</td>
<td>SSWR</td>
<td>2015</td>
<td>sweet</td>
</tr>
<tr>
<td>MM2</td>
<td>Moravian Muscat</td>
<td>Golguz</td>
<td>LCWR</td>
<td>2016</td>
<td>semi sweet</td>
</tr>
<tr>
<td>MM3</td>
<td>Moravian Muscat</td>
<td>Vinkova</td>
<td>LCWR</td>
<td>2016</td>
<td>semi dry</td>
</tr>
<tr>
<td>MM4</td>
<td>Moravian Muscat</td>
<td>Vinkor</td>
<td>NWR</td>
<td>2017</td>
<td>dry</td>
</tr>
<tr>
<td>MM5</td>
<td>Moravian Muscat</td>
<td>Vinis Winery</td>
<td>SSWR</td>
<td>2017</td>
<td>dry</td>
</tr>
<tr>
<td>MM6</td>
<td>Moravian Muscat</td>
<td>Chateau Topoľčianky</td>
<td>NWR</td>
<td>2016</td>
<td>semi dry</td>
</tr>
<tr>
<td>MM7</td>
<td>Moravian Muscat</td>
<td>Sommelier Select</td>
<td>SSWR</td>
<td>2015</td>
<td>dry</td>
</tr>
<tr>
<td>MO1</td>
<td>Muscat Ottolene</td>
<td>Vino Chudy, s.r.o.</td>
<td>NWR</td>
<td>2016</td>
<td>dry</td>
</tr>
<tr>
<td>MO2</td>
<td>Muscat Ottolene</td>
<td>Matyšák</td>
<td>SSWR</td>
<td>2014</td>
<td>dry</td>
</tr>
<tr>
<td>MO3</td>
<td>Muscat Ottolene</td>
<td>Chateau Pevznok</td>
<td>LCWR</td>
<td>2015</td>
<td>semi sweet</td>
</tr>
<tr>
<td>MO4</td>
<td>Muscat Ottolene</td>
<td>Chateau Pevznok</td>
<td>LCWR</td>
<td>2017</td>
<td>semi sweet</td>
</tr>
<tr>
<td>MO5</td>
<td>Muscat Ottolene</td>
<td>Vino Nicta</td>
<td>NWR</td>
<td>2017</td>
<td>semi dry</td>
</tr>
<tr>
<td>MY1</td>
<td>Yellow Muscat</td>
<td>Tokaj &amp; CO, s.r.o.</td>
<td>WRoT</td>
<td>2016</td>
<td>semi sweet</td>
</tr>
<tr>
<td>MY2</td>
<td>Yellow Muscat</td>
<td>Zlatý strapec - Anna Nagyová</td>
<td>WRoT</td>
<td>2013</td>
<td>semi sweet</td>
</tr>
<tr>
<td>MY3</td>
<td>Yellow Muscat</td>
<td>J&amp;J Ostožovčič</td>
<td>WRoT</td>
<td>2015</td>
<td>semi dry</td>
</tr>
<tr>
<td>MY4</td>
<td>Yellow Muscat</td>
<td>Terra Wylak</td>
<td>SSWR</td>
<td>2017</td>
<td>semi dry</td>
</tr>
</tbody>
</table>


**Sample analysis**

### Determination of total polyphenol content

Total polyphenol content (TPC) was evaluated by modified method of Singleton and Rossi (1965). We used 20% solution of Na2CO3, Folin-Ciocalteau reagent and distilled water. We pipetted 1 mL of wine sample into 50 mL volumetric flask and diluted it with 25 mL of distilled water. Then, we added 2.5 mL Folin-Ciocalteau reagent to diluted mixture, and after 3 minutes, we added 1.5 mL of 20% solution of Na2CO3. Then we filled the sample with distilled water to volume 50 mL, and after mixing, left at the laboratory temperature for 2 hours. We prepared the blank and calibration solutions of gallic acid by the same procedure. We measured absorbance of solutions against blank solution at 765 nm. The content of total polyphenols in wines was calculated as amount of gallic acid equivalent (GAE) in mg per 1 litre of wine.

### Determination total flavonoid content

Total flavonoid content (TFC) was evaluated by aluminum chloride method (Chang et al., 2002). We used 5% solution of NaNO2, 10% solution of AlCl3, solution of NaOH and distilled water. We added 1 mL of wine sample and 4 mL of deionized water to a 10 mL volumetric flask. 5 min after adding 0.3 mL of 5% sodium nitrite, we added 0.6 mL of 10% aluminium chloride. Then we added 2 mL of sodium hydroxide with concentration 1 mol.L-1 to the reaction mixture after 6 min incubation. The final volume was immediately made up to 10 mL with deionized water. We measured absorbance of the solution at 510 nm against blank solution. The content of total flavonoids in wine samples was calculated as amount of catechin equivalent (CE) in mg per 1 litre of wine.

### Determination of antioxidant activity

Antioxidant activity (AA) was evaluated by method of Brand-Williams et al. (1995) using of DPPH (2,2-diphenyl-1-picrylhydrazyl) radical. 3.9 mL of DPPH solution was pipetted into cuvette. We measured absorbance of DPPH solution at 515.6 nm, and then added 0.1 mL of wine sample, stirred and waited for 10 minutes. After 10 minutes, we measured absorbance at 515.6 nm, and antioxidant effectiveness was expressed as % inhibition of DPPH (quantitative ability of tested compound to remove in certain period a part of DPPH radical,) and also as Trolox equivalent calculated from calibration curve.

All chemical analyses were performed as four parallels.

### Statistical analysis

MS Excel 2016 and XLSTAT were used to perform statistical analysis. To obtain statistically significant information about the differences between the tested samples, nonparametric Kruskal-Wallis test was conducted (Addinsoft, 2014).

### RESULTS AND DISCUSSION

All studied parameters –total polyphenol content, total flavonoid content and antioxidant activity of muscat type wines are described in Table 2, 3, 4.
Total polyphenol content in analysed wines variety Moravian Muscat (MM) ranged from 226.8 mg GAE to 468.6 mg GAE. Average TPC in all wines variety MM was 330.2 mg GAE. Mráz (2017) reported lower average TPC in analysed wines variety MM – 145.7 mg GAE. Kývalová (2013) reported higher average value of TPC in analysed Czech wines variety MM – 547.5 mg GAE. Snopk (2019) studied TPC in Czech white wines (including MM) and their changes during storage. He reported that average TPC of wines variety MM was 291.7 GAE. After 12 months, average TPC was 260.75 GAE. These results shows decrease in TPC during storage. Total polyphenol content in analysed wines variety Muscat Ottrelon (MO) ranged from 311.5 mg GAE to 406.1 mg GAE. Average content of TPC in all wines variety MO was 344.8 mg GAE. Mitic et al. (2010) reported that average TPC in analysed wines variety MO from Serbia is 270.2 mg GAE. Lachman et al. (2004) reported lower average TPC in analysed Czech wines variety MO – 267.0 mg GAE.

Total polyphenol content in analysed wines variety Yellow Muscat (YM) ranged from 308.7 mg GAE to 568.3 mg GAE. Average TPC in all wines variety YM was 471.4 mg GAE. Bájčan et al. (2018) reported lower average TPC in analysed wines variety YM – 420.5 mg GAE. Rugovská (2018) reported higher average TPC in wines variety YM – 525.6 mg GAE. Lugasi and Hovari (2003) reported that average TPC in wines variety YM from Hungary is 250 mg GAE. This is almost half of the value we determined. Our study showed that average TPC in wines varies between wines of same variety. Bájčan et al. (2017) analysed Slovak white wines variety Welschriesling and Chardonnay, and reported that their average TPC is 303.2 mg GAE and 356.6 mg GAE respectively. Spálovská et al. (2012) analysed Slovak white wines, and reported that their average TPC range from 299 mg GAE to 407 mg GAE. Stasko et al. (2008) reported that average TPC in Slovak white wines (including MM and MO) is 270 mg GAE. More studies of TPC in Slovak white wines (Nedelják, 2013; Vasková, 2013; Štefánková 2014) reported average TPC in range from 305.6 mg GAE to 365.7 mg GAE. According to the average value of TPC an order for wines by variety could be as following: Young Muscat (471.38 mg GAE) > Muscat Ottrelon (344.8 mg GAE) > Moravian Muscat (330.2 mg GAE). According to the average value of TPC an order for wines by vineyard could be as following: wines from WroT (525.6 mg GAE) > wines from SSWR (355.46 mg GAE) > wines from NWR (340.5 mg GAE) > wines from LCWR (301.18 mg GAE). We found statistically significant difference between TPC of Muscat Ottrelon and TPC of Yellow Muscat (p < 0.0001, α = 0.05), and between TPC of Moravian and TPC of Yellow Muscat (p < 0.0001, α = 0.05). We found statistically significant difference between TPC of wines from NWR and LCWR, and between TPC of wines from WroT and LCWR, WroT and SSWR, and WroT and NWR (p < 0.0001, α = 0.05). Total flavonoid content (TFC) in analysed wines variety Moravian Muscat ranged from 24.8 to 64.0 mg CE. Average TFC in all wines variety MM was 42.8 mg CE. Mráz (2017) reported that average TFC in analysed wines variety MM is 52.0 mg CE, which is higher value compared to average value of TFC in our samples. There are not many studies analysing TFC of Moravian Muscat, mainly because it is relatively new variety, mostly grown in Czech Republic and Slovakia. Total flavonoid content in analysed wines variety Muscat Ottrelon ranged from 42.2 mg CE to 67.2 mg CE. Average TFC in all wines variety MO was 50.4 mg CE. Bleiziffer et al. (2017) reported that average TFC in Serbian wines variety MO is 37.5 mg CE, which is slightly lower value than ours. Total flavonoid content in analysed wines variety Yellow Muscat ranged from 43.8 mg CE to 169.1 mg CE. Average TFC in all wines variety YM was 100.5 mg CE. Rugovská (2018) reported that average TFC in wines variety YM is 99.1 mg CE. Bájčan et al. (2018) reported lower average TPC in analysed wines variety YM – 83.0 mg CE. Our study showed that average TFC in wines varies between wines of same variety. Bájčan et al. (2017) analysed Slovak white wines variety Welschriesling and Chardonnay, and found out their average TPC is 51.9 mg CE and 60.1 mg CE respectively. More studies of TFC in Slovak white wines (Nedelják, 2013; Vasková, 2013; Štefánková 2014) reported average TFC in range from 38.8 mg CE to 67.4 mg CE.

According to the average value of TFC an order for wines by variety could be as following: Yellow Muscat (100.5 mg CE) > Muscat Ottrelon (50.4 mg CE) > Moravian Muscat (42.8 mg CE). According to the average value of TFC an order for wines by vineyard could be as following: wines from WroT (119.4 mg CE) > wines from SSWR (50.6 mg CE) > wines from VR (45.6 mg CE) > wines from LCWR (39.9 mg CE). We found statistically significant difference between TFC of Muscat Ottrelon and TFC of Yellow Muscat (p < 0.0001, α = 0.05), and between TFC of Moravian and TFC of Yellow Muscat (p < 0.0001, α = 0.05). We found statistically significant difference between TFC of wines from LCWR and SSWR, and between TPC of wines from WroT and LCWR, WroT and SSWR, and WroT and NWR (p < 0.0001, α = 0.05).
Antioxidant activity (AA) in analysed wines variety Moravian Muscat ranged from 27.9 % inhib. of DPPH (0.317 mmol Trolox.L⁻¹) to 67.0 % inhib. of DPPH (0.787 mmol Trolox.L⁻¹). Average value of AA in all wines variety MM was 38.7 % inhib. of DPPH (0.443 mmol Trolox.L⁻¹). Krivárová, 2016 reported lower average AA in wines variety MM – 29.95 % inhib. of DPPH.

Antioxidant activity in analysed wines variety Muscat Ottonel ranged from 33.6 % inhib. of DPPH (0.318 mmol Trolox.L⁻¹) to 40.7 % inhib. of DPPH (0.461 mmol Trolox.L⁻¹). Average value of AA in all wines variety MO was 38.6 % inhib. of DPPH (0.437 mmol Trolox.L⁻¹). Bleiziffer et al. (2017) reported higher average AA in analysed wines variety MO – 43.9 % inhib. of DPPH.

Antioxidant activity in analysed wines variety Yellow Muscat ranged from 43.9 % inhib. of DPPH (0.498 mmol Trolox.L⁻¹) to 67.4 % inhib. of DPPH (0.793 mmol Trolox.L⁻¹). Average value of AA in all wines variety YM was 55.1 % inhib. of DPPH (0.635 mmol Trolox.L⁻¹). Bajčan et al. (2018) reported that average AA in analysed wines variety YM was 47.2 % inhib. of DPPH (0.542 mmol Trolox.L⁻¹). Rugsévá et al. (2018) reported that average AA in wines variety YM is 47.2 % inhib. of DPPH. Eftimová (2016) reported higher average AA in wines variety YM – 63.8 % inhib. of DPPH. Bajčan et al. (2017) analysed Slovak white wines variety Welschriesling and Chardonnay, and found out their average AA is 35.0 % inhib. of DPPH and 43.3 % inhib. of DPPH respectively. More studies of AA in Slovak white wines (Nedeljak, 2013; Vasková, 2013; Štefánková 2014) reported average AA in samples in range from 35.75 % inhib. of DPPH to 50.3 % inhib. of DPPH. According to the average value of AA an order for wines could be as following: Yellow Muscat (55.1 % inhib. of DPPH) > Moravian Muscat (38.7 % inhib. of DPPH) > Yellow Muscat (55.1 % inhib. of DPPH) > Muscat Ottonel (36.9 % inhib. of DPPH) > White Muscat (36.6 % inhib. of DPPH).

The highest total phenolic content, total flavonoid content, and antioxidant activity were determined in wines variety Yellow Muscat. Results showed statistically significant differences between total polyphenolic content, total flavonoid content and antioxidant activity between Moravian Muscat and Yellow Muscat, and between Muscat Ottonel and Yellow Muscat. Results also showed statistically significant difference between wines from Vineyard region of Tokaj and wines from other vineyard areas. Based on statistical evaluation of our results, we can state that statistically significant correlations were recognised among all 3 analysed parameters (TFC, TPC and AA). Results showed that in comparison with other white Slovak varietal wines of Muscat type, wines variety Yellow Muscat from the wine region of Tokaj have higher content of polyphenolic substances and flavonoids.

The study of phenolic substances in wine is subject to constant development. There are many studies regarding antioxidant activity in red wines. Until recently, the prevailing opinion was that the consumption of white wine does not have beneficial effects on the human health, in terms of antioxidant content. White wines have also been shown to have antioxidant activity and health benefits.

Acknowledgments: Work was supported by the Slovak Science Foundation VEGA (Grant no. 1/0114/18).

This publication was supported by the Operational Program Integrated Infrastructure within the project: Demand- driven research for the sustainable and innovative food, Drive4SIFood 313011V336, cofinanced by the European Regional Development Fund.

REFERENCES

ADINSSOFT. (2014). XLSTAT. Analyse de données et statistique avec Excel. Addinsoft, NY, USA.


compounds of Muscat of Bornova wines from 3 different sub-regions of Aegean, Turkey. Bio web of Conferences, 5, 02017. http://dx.doi.org/10.1051/biocen/20150502017