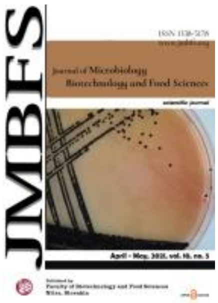

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PHENOLIC CONTENT AND ANTIOXIDANT ACTIVITY OF SLOVAK VARIETAL WINES OF MUSCAT TYPE

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ABSTRACT

Grapes and wine are important sources of antioxidants in human diet. Phenolic substances contained in grapevine berries belong to an important group of natural substances that get into wine in the process of wine making. Polyphenols and flavonoids are primarily accountable for the colour and taste of the wine, they affect the perception of bitterness and acerbity. They also have antioxidant properties, thus have a positive effect on human health. Health benefits of polyphenolic substances from wine may be associated with a wide range of biological processes. Thanks to the development of modern analytical methods, wine is constantly being researched in terms of the content of antioxidants, and its importance to human health. Sixteen Slovak white wines of Muscat type produced in different geographical regions were analysed in this study. The object of this work was to determine total polyphenol content and total flavonoid content, and to evaluate antioxidant effects of quality wines of Muscat varieties produced in Slovakia. Antioxidant activity, total polyphenol content, and total flavonoid content of particular wines is described in the study. Studied characteristics were analysed by UV-VIS spectrometry method. Muscat wines showed weak to high antioxidant activity, ranging from 25.2% inhibition of DPPH to 67.7% inhibition of DPPH. Average antioxidant activity was 38.7% inhibition of DPPH. Total polyphenol content in the Muscat type varietal wines varied from 262.1 GAE.L^{-1} to 568.3 GAE.L^{-1}. Average total polyphenol content was 382.13 GAE.L^{-1}. The content of total flavonoids in Muscat type varietal wines ranged from 24.8 mg CE.L^{-1} to 169.1 mg CE.L^{-1}. Average total flavonoid content was 100.5 mg CE.L^{-1}.

Keywords: wine, muscat, polyphenols, flavonoids, antioxidants

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 **(Dominé, 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 **(Pavloušek, 2011)**. Phenolic substances are significant to both 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, acerbity, 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 procces of wine making **(Sacchi, Bisson, 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, Dokoozlian, Krstic, 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, flavanols, flavonols, flavones, flavanonols, 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-hypertensive 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 **(Biasi *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.

MATERIAL AND METHODS

Chemicals and instruments

The chemicals used for analysis were: Folin-Ciocalteau reagent, monohydrate of gallic acid p.a., anhydrous natrium carbonate p.a., aluminium chloride p.a., sodium nitrite p.a., sodium hydroxide p.a., 35%, catechin hydrate 98%, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical p.a., methanol p.a. All analysed parameters – total polyphenol content, total flavonoid content and antioxidant activity in wines were analysed using UV/VIS spectrophotometry (spectrophotometer Shimadzu UV/VIS-1240, Shimadzu, Japan).

Samples

Analysed bottled, Slovak varietal wines of Muscat type, namely Moravian Muscat, Muscat Ottonel and Yellow Muscat and their characteristics are described in Table 1. Wine samples of origin in various Slovak vineyard areas were purchased in retail network, to provide that analysed samples of wine would have the same characteristics as wines that are consumed by customers.

Table 1 Characteristics of analysed wine samples

Sample	Variety	Producer	Vineyard area	Vintage	Wine type
MM1	Moravian Muscat	Chateau Topoľčianky	SSWR	2015	sweet
MM2	Moravian Muscat	Golguz	LCWR	2016	semi sweet
MM3	Moravian Muscat	Vinkova	LCWR	2016	semi dry
MM4	Moravian Muscat	Vinkor	NWR	2017	dry
MM5	Moravian Muscat	Vinis Winery	SSWR	2017	dry
MM6	Moravian Muscat	Chateau Topoľčianky	NWR	2016	semi dry
MM7	Moravian Muscat	Sommelier Select	SSWR	2015	dry
MO1	Muscat Ottonel	Víno Chudý, s.r.o.	NWR	2016	dry
MO2	Muscat Ottonel	Matyšák	SSWR	2014	dry
MO3	Muscat Ottonel	Chateau Pezinok	LCWR	2015	semi sweet
MO4	Muscat Ottonel	Chateau Pezinok	LCWR	2017	semi sweet
MO5	Muscat Ottonel	Víno Nichta	NWR	2017	semi dry
MY1	Yellow Muscat	Tokaj&CO, s.r.o.	WRoT	2016	semi sweet
MY2	Yellow Muscat	Zlatý strapec - Anna Nagyová	WRoT	2013	semi sweet
MY3	Yellow Muscat	J&J Ostožovič	WRoT	2015	semi dry
MY4	Yellow Muscat	Terra Wylak	SSWR	2017	semi dry

Legend: SSWR – South Slovakia Wine Region, LCWR – Little Carpathians Wine Region, NWR – Nitra Wine Region, WRoT – Wine Region of Tokaj

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 Na_2CO_3, 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 Na_2CO_3. 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 samples 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 aluminium chloride method (**Chang *et al*., 2002**). We used 5% solution of $NaNO_2$, 10% solution of $AlCl_3$, 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.

Table 2 Total polyphenol content, total flavonoid content and antioxidant activity in analysed wines variety Moravian Muscat

Sample	TPC (mg GAE.L^{-1})	TFC (mg CE.L^{-1})	AA (% inhib. DPPH)	AA (mmol Trolox.L^{-1})
MM1	468.6 ± 8.0	64.0 ± 0.8	67.0 ± 1.1	0.787 ± 0.014
MM2	262.1 ± 5.3	29.9 ± 0.8	29.8 ± 0.8	0.339 ± 0.010
MM3	286.9 ± 5.3	40.6 ± 1.1	29.7 ± 0.9	0.337 ± 0.011
MM4	300.5 ± 5.3	29.0 ± 0.5	32.5 ± 0.8	0.369 ± 0.010
MM5	226.8 ± 2.6	24.8 ± 0.5	27.9 ± 0.6	0.317 ± 0.007
MM6	394.8 ± 10.7	57.9 ± 0.5	46.6 ± 0.8	0.529 ± 0.010
MM7	371.6 ± 5.3	53.2 ± 0.8	37.4 ± 1.1	0.424 ± 0.014
Average	**330.2 ± 84.8**	**42.8 ± 15.7**	**38.7 ± 14.0**	**0.443 ± 0.168**

Legend: MM – Moravian Muscat, MO – Muscat Ottonel, YM – Yellow Muscat, TPC – total polyphenol content, TFC – total flavonoid content, AA – antioxidant activity. Values of TPC, TFC and AA are expressed as arithmetic average ± standard deviation,

Table 3 Total polyphenol content, total flavonoid content and antioxidant activity in analysed wines variety Muscat Ottonel

Sample	TPC (mg GAE.L^{-1})	TFC (mg CE.L^{-1})	AA (% inhib. DPPH)	AA (mmol Trolox.L^{-1})
MO1	355.2 ± 5.3	52.4 ± 0.5	40.7 ± 1.2	0.461 ± 0.015
MO2	401.6 ± 2.6	67.2 ± 1.3	39.5 ± 0.7	0.448 ± 0.009
MO3	316.9 ± 5.3	47.2 ± 0.5	33.6 ± 0.6	0.381 ± 0.007
MO4	338.8 ± 2.6	42.2 ± 0.8	40.1 ± 0.8	0.454 ± 0.010
MO5	311.5 ± 6.0	43.1 ± 1.3	39.0 ± 1.0	0. 442 ± 0.012
Average	**344.8 ± 36.3**	**50.4 ± 10.2**	**38.6 ± 2.9**	**0.437 ± 0.032**

Legend: MM – Moravian Muscat, MO – Muscat Ottonel, YM – Yellow Muscat, TPC – total polyphenol content, TFC – total flavonoid content, AA – antioxidant activity. Values of TPC, TFC and AA are expressed as arithmetic average ± standard deviation,

Table 4 Total polyphenol content, total flavonoid content and antioxidant activity in analysed wines variety Yellow Muscat

Sample	TPC (mg GAE.L^{-1})	TFC (mg CE.L^{-1})	AA (% inhib. DPPH)	AA (mmol Trolox.L^{-1})
MY1	513.7 ± 9.3	99.5 ± 1.3	57.6 ± 0.8	0.662 ± 0.010
MY2	494.8 ± 10.6	89.6 ± 1.5	51.4 ± 0.6	0.586 ± 0.007
MY3	568.3 ± 13.3	169.1 ± 1.3	67.4 ± 0.6	0.793 ± 0.007
MY4	308.7 ± 8.0	43.8 ± 0.6	43.9 ± 1.3	0.498 ± 0.017
Average	**471.4 ± 112.8**	**100.5 ± 51.8**	**55.1 ± 9.9**	**0.635 ± 0.125**

Legend: MM – Moravian Muscat, MO – Muscat Ottonel, YM – Yellow Muscat, TPC – total polyphenol content, TFC – total flavonoid content, AA – antioxidant activity. Values of TPC, TFC and AA are expressed as arithmetic average ± standard deviation

Total polyphenol content in analysed wines variety Moravian Muscat (MM) ranged from 226.8 mg GAE.L^{-1} to 468.6 mg GAE.L^{-1}. Average TPC in all wines variety MM was 330.2 mg GAE.L^{-1}. **Mráz (2017)** reported lower average TPC in analysed wines variety MM – 145.7 mg GAE.L^{-1}. **Kývalová (2013)** reported higher average value of TPC in analysed Czech wines variety MM – 547.5 mg.GAE.L^{-1}. **Snopek (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.L^{-1}. After 12 months, average TPC was 260.75 GAE.L^{-1}. These results shows decrease in TPC during storage.

Total polyphenol content in analysed wines variety Muscat Ottonel (MO) ranged from 311.5 mg GAE.L^{-1} to 401.6 mg GAE.L^{-1}. Average content of TPC in all wines variety MO was 344.8 mg GAE.L^{-1}. **Mitić *et al*. (2010)** reported that average TPC in analysed wines variety MO from Serbia is 252.0 mg GAE.L^{-1}. **Lachman *et al*. (2004)** reported lower average TPC in analysed Czech wines variety MO – 267.0 mg GAE.L^{-1}.

Total polyphenol content in analysed wines variety Yellow Muscat (YM) ranged from 308.7 mg GAE.L^{-1} to 568.3 mg GAE.L^{-1}. Average TPC in all wines variety YM was 471.4 mg GAE.L^{-1}. **Bajčan, *et al.* (2018)** reported lower average TPC in analysed wines variety YM – 420.5 mg GAE.L^{-1}. **Rugovská (2018)** reported higher average TPC in wines variety YM – 525.6 mg GAE.L^{-1}. **Lugasi and Hovari (2003)** reported that average TPC in wines variety YM from Hungary is 250 mg GAE.L^{-1}. This is almost half of the value we determined.

Our study shown that average TPC in wines varies between wines of same variety. **Bajčan *et al*. (2017)** analysed Slovak white wines variety Welschriesling and Chardonnay, and reported that their average TPC is 303.2 mg GAE.L^{-1} and 355.6 mg GAE.L^{-1} respectively. **Špakovská *et al*. (2012)** analysed Slovak white wines, and reported that their average TPC range from 299 mg GAE.L^{-1} to 407 mg GAE.L^{-1}. **Staško *et al*. (2008)** reported that average TPC in Slovak white wines (including MM and MO) is 270 mg GAE.L^{-1}. More studies of TPC in Slovak white wines **(Nedeljak, 2013; Vasková, 2013; Štefanková 2014)** reported average TPC in range from 305.6 mg GAE.L^{-1} to 365.7 mg GAE.L^{-1}.

According to the average value of TPC an order for wines by variety could be as following: Yellow Muscat (471.38 mg GAE.L^{-1}) > Muscat Ottonel (344.8 mg GAE.L^{-1}) > Moravian Muscat (330.2 mg GAE.L^{-1}). According to the average value of TPC an order for wines by vineyard area could be as following: wines from WRoT (525.6 mg GAE.L^{-1}) > wines from SSWR (355.46 mg GAE.L^{-1}) > wines from NWR (340.5 mg GAE.L^{-1}) > wines from LCWR (301.18 mg GAE.L^{-1}). We found statistically significant difference between TPC of Muscat Ottonel and TPC of Yellow Muscat ($p < 0.0001$, $\alpha = 0.05$), and between TPC of Muscat Moravian and TPC of Yellow Muscat ($p < 0.0001$, $\alpha = 0.05$). 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 ($p < 0.0001$, $\alpha = 0.05$).

Total flavonoid content (TFC) in analysed wines variety Moravian Muscat ranged from 24.8 to 64.0 mg CE.L^{-1}. Average TFC in all wines variety MM was 42.8 mg CE.L^{-1}. **Mráz (2017)** reported that average TFC in analysed wines variety MM is 52.0 mg CE.L^{-1}, 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 Ottonel ranged from 42.2 mg CE.L^{-1} to 67.2 mg CE.L^{-1}. Average TFC in all wines variety MO was 50.4 CE.L^{-1}. **Bleiziffer *et al*. (2017)** reported that average TFC in Serbian wines variety MO is 37.5 mg CE.L^{-1}, which is slightly lower value than ours.

Total flavonoid content in analysed wines variety Yellow Muscat ranged from 43.8 mg CE.L^{-1} to 169.1 mg CE.L^{-1}. Average TFC in all wines variety YM was 100.5 mg CE.L^{-1}. **Rugovská (2018)** reported that average TFC in wines variety YM is 99.1 mg CE.L^{-1}. **Bajčan *et al*. (2018)** reported lower average TFC in analysed wines variety YM – 83.0 mg CE.L^{-1}.

Our study shown that average TFC in wines varies between wines of same variety. **Bajčan *et al*. (2017)** analysed Slovak white wines variety Welschriesling and Chardonnay, and found out their average TPC is 51.9 mg CE.L^{-1} and 60.1 mg CE.L^{-1} respectively.

More studies of TFC in Slovak white wines **(Nedeljak, 2013; Vasková, 2013; Štefanková 2014)** reported average TFC in range from 38.8 mg CE.L^{-1} to 67.4 mg CE.L^{-1}.

According to the average value of TFC an order for wines by variety could be as following: Yellow Muscat (100.5 mg CE.L^{-1}) > Muscat Ottonel (50.4 mg CE.L^{-1}) > Moravian Muscat (42.8 mg CE.L^{-1}) According to the average value of TFC an order for wines by vineyard region could be as following: wines from WRoT (119.4 mg CE.L^{-1}) > wines from SSWR (50.6 mg CE.L^{-1}) > wines from VR (45.6 mg CE.L^{-1}) > wines from LCWR (39.9 mg CE.L^{-1}). We found statistically significant difference between TFC of Muscat Ottonel and TFC of Yellow Muscat ($p < 0.0001$, $\alpha = 0.05$), and between TFC of Muscat Moravian and TFC of Yellow Muscat ($p < 0.0001$, $\alpha = 0.05$). We found statistically significant difference between TFC of wines from LCWR and SSWR, and between TFC of wines from WRoT and LCWR, WRoT and SSWR, and WRoT and NWR ($p < 0.0001$, $\alpha = 0.05$)

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}). **Křivová, 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 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 is 47.2 % inhib. of DPPH (0.542 mmol Trolox.L^{-1}). **Rugovská (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; Štefanková 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) > Muscat Ottonel (38.6 % inhib. of DPPH). According to the average value of AA an order for wines could be as following: wines from WRoT (58.8 % inhib. of DPPH) > wines from SSWR (43.14 % inhib. of DPPH) > wines from NWR (38.94 % inhib. of DPPH) > wines from LCWR (33.3 % inhib. of DPPH). We found statistically significant difference between average AA of Moravian Muscat wines and Yellow Muscat wines ($p < 0.0001$, $\alpha = 0.05$), and statistically significant difference between average AA of Muscat Ottonel wines and Yellow Muscat wines ($p < 0.0001$, $\alpha = 0.05$). We found statistically significant difference between average AA of wines from LCWR and NWR, and between average AA of wines from WRoT and LCWR, WRoT and SSWR, WRoT and NWR ($p < 0.0001$, $\alpha = 0.05$).

In order to examine the mutual relations between analysed parameters, the linear regressions were attained. The statistical evaluation of the obtained results confirmed strong linear correlation between TPC and TFC (r=0.784), very strong linear correlation between TPC and AA (r=0.912), and strong linear correlation between TFC and AA (r=0.804). Based on the results, it can be stated that there are high to very high positive correlations between the individual monitored properties of wines. This is in agreement with other authors (**Nedeljak, 2013; Mitić *et al*., 2010).**

Ratio of total flavonoid content and total phenolic content was evaluated. In white wines, flavonoids form less than 20 % of total polyphenol content, in red wines, it is often more than 85 % **(Jackson, 2008)**. Average ratio of TFC and TPC in wines variety Moravian Muscat was 12.95 %. Average Ratio of TFC and TPC in wines variety Muscat Ottonel was 14.62 %. Average Ratio of TFC and TPC in wines variety Yellow Muscat was 21.32 %. **Nedeljak (2013)** evaluated average ratio of TFC and TPC in wines variety Grüner Veltliner as 18.3 %, and average ratio of TFC and TPC in wines variety Chardonnay as 19.46 %.

CONCLUSION

Total phenolic content, total flavonoid content, and antioxidant activity of white wines variety Moravian Muscat, Muscat Ottonel, Yellow Muscat made in Slovak vineyard areas were assessed in the presented study. The highest total phenolic content, total flavonoid content, and highest 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 (TPC, TFC 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.

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