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COMPARISON OF NORTH ITALIAN AND SOUTH MORAVIAN WINES ON THE BASE OF THEIR ANTIOXIDANT ACTIVITY, PHENOLIC COMPOSITION AND SENSORY QUALITY

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Abstract

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In the present study, antioxidant capacity, phenolic composition and sensory evaluation of selected red and white wines originating from wine-growing regions of South Moravia and North Italy (wine-growing region Trident – Alto Adige) were investigated. The sensory analysis indicated that the evaluated wine samples were very similar. As far as basic the analytical parameters were concerned, concentrations of residual sugar were significantly higher in Moravian wines. Antioxidative characteristics were estimated by means of common spectrophotometric methods (total phenols, total anthocyanins, total flavanols, DPPH and FRAP) and thereafter compared. It was found out that the compared methods were highly significantly and positively correlated as far as their results were concerned. Individual phenolic compounds were detected by means of HPLC with DAD detection. In white wines, the content of GRP products was higher and this indicated that the quality of grapes used for making Moravian wines was lower. In red Moravian wines, the content of catechins (i.e. compounds responsible for the majority of phenolic substances and considered to be health-promoting compounds) was higher. This observation was corroborated also analytically, i.e. on the base of correlation with antioxidative characteristics.

wine, antioxidant, phenolic composition, DPPH, FRAP, catechins

Phenolic compounds are naturally occurring substances in fruit, vegetables, nuts, seeds, flowers, and some herb beverages, and are integral part of human diet. Epidemiological studies have shown that consumption of phenol-rich beverages, such as tea and wine, correlates with reduced coronary heart disease mortality (Balentine *et al*., 1997; Katalinić *et al*., 2004; Cul *et al*., 2002; Serafini *et al*., 2000). The strikingly low incidence of coronary heart disease in France as compared with other western countries with comparable dietary intake has been regarded as "French paradox". Although several hypotheses have been proposed, there is strong believe that lower risk of heart disease is associated with the increased wine consumption in France (St. Leger *et al*., 1979; Xia *et al*., 1998). The protective effects of vegetable, fruit, and wine consumption against coronary artery disease and certain types of cancer are partly attributed to the flavonoid content of these foods (Bell *et al*., 2000; Frankel *et al*., 1993). It has been demonstrated both *in vitro* and *in vivo* that these phenolic compounds can offer significant antiatherogenic protection by inhibiting the oxidation of low density lipoproteins (LDLs) (Jamroz *et al*., 2001; Miller *et al*., 1995; Serafini *et al*., 2000; Nigdikar *et al*., 2000). These studies provide additional support for protective effects of polyphenolic antioxidants on cardiovascular disease. The phenolic compounds in wine range from relatively simple compounds to complex tannin-type substances.

The phenolic compounds present in wine can be divided into two major classes, based on their carbon skeletons: flavonoids and non-flavonoids. Flavonoids include anthocyanidins (malvidin, delphinidin, petunidin, peonidin, and cyanidin), flavonols (quercetin, rutin, myricetin, and kaempferol), flavanols (catechin, epicatechin, epicathecin 3-gallate, and gallocatechin), flavones (luteolin, apigenin), and flavanones (naringenin). The main non-flavonoid phenolics include cynnamic acids (caffeic, p-coumaric, and ferulic acids), benzoic acids (gallic, vanillic, and syringic acids), and stilbenes (resveratrol) (Cheynier *et al*., 2006). These compounds are primarily responsible for the health benefits associated with wine consumption. The quantities of these phenolic compounds vary considerably in different types of wines depending on the grape variety, environmental factors in the vineyard, the wine processing techniques, soil and atmospheric conditions during ripening, the ageing process, and berry maturation (Lachman *et al*., 2007). Therefore, each type of grape presents distinct biological activity, chemical composition, and sensory appeal. The composition of phenolics in wine depends on the type of fruits used (usually grapes) for vinification, their extraction, procedures employed for wine making, and the chemical reactions that occur during the aging of wine (Katalinić, 1997; Katalinić, 1999; Katalinić *et al*., 1997). The antioxidant compounds present in wine are derived almost exclusively from grapes and have been identified as phenolic acids, flavonols, monomeric catechins, and anthocyanidins. One of the most abundant of these phenolic compounds is the flavan-3-ol compound, catechin (Singleton, 1988). Presence of catechin and its derivatives in wines has been well documented.

A well-balanced characterisation of the anti-oxidant capacity and chemical composition of wines is therefore necessary to determine their health effects. For example, Que, Mao, and Pan (2006) studied the effect of some phenolic compounds on the free radical scavenging activity measured by the DPPH (1,1-diphenyl-2-picrylhydrazyl) assay and verified that vanillic acid, p-coumaric acid, and quercetin contributed minimally to the antioxidant activity of wines. In the same way was observed that both the total phenolic compounds and total flavonoids, especially non-anthocyanin flavonoids, were the main substances responsible for *in vitro* antioxidant activity in Brazilian red wines, as measured by DPPH assay (Granato *et al*., 2010).

It is not known whether the phenolic compounds involved in the sensory quality of wines are responsible for the wines' antioxidant effects. Considering that these two aspects (sensory quality and health benefit) contribute to the consumer appeal of wines, this study aimed to comparison of 24 *V. vinifera* L. white (18) and red (6) wines from North Italia (winegrowing region Trident – Alto Adige) and South Moravia classified according to their phenolic composition, antioxidant activity and sensory quality.

MATERIALS AND METHODS

A total of 24 wines produced in North Italia (n = 12) and South Moravia (n = 12) with the most characteristic *Vitis vinifera* L. grape varieties (Müller Thurgau, Silvaner, Riesling, Chardonnay, Pinot Blanc, Pinot Gris, Sauvignon, Kerner, Gewürztraminer, Pinot Noir, Merlot and Cabernet Sauvignon, all 2009) were studied. Table I presents the samples according to country and grape variety, including their commercial value and vintage.

Determination of total phenols: total phenols content in wine was determined by modified Folin – Ciocalteu method (Waterman and Mole, 1994). To 980 µl of water in 1.5 ml eppendorf tube was add 20 µl of sample, 50 µl Folin – Ciocalteu agent and mixture was thoroughly shaken. Accurately after 3 minutes was add 150 µl of sodium carbonate decahydrate (20%), reaction mixture was shaken vigorously and let the state 120 minutes in the dark at room temperature. Then, absorbance was measured at 750 nm against a blank, which was prepared for each series of determination, when the sample was replaced by dilution buffer. Concentration of total phenols was calculated from the calibration curve using gallic acid as standard (25–1000 mg/L). The results are expressed in the form mg/L equivalents of gallic acid (gallic acid Equivalents; GAE).

Determination of total anthocyanins and the optical density at 280 nm (OD_{280}): measurements were carried out using SO_2 (Somers *et al*., 1977; Zoecklein *et al*., 1990). In 2 ml eppendorf tube was shaking 200 µl of sample with 1.8 ml of 1.1 M HCl. Blank test was prepared with each sample in the same manner in which the HCl was replaced with fresh solution of 0.22 M $K_2S_2O_5$ (SO_2). After 180 minutes was measured absorbance of the sample with HCl at 280 nm and 520 nm. The sample of SO_2 was measured only at 520 nm. These measurements were made as compared with demineralized water.

Calculations:

$$\text{Total Anthocyanins (mg/L)} = 4 \times \text{dilution} \times [A(HCl)_{520} - (5/3) \times A(SO_2)_{520}]$$

$$OD_{280} = 10 \times \text{dilution} \times A(HCl)_{280}$$
$$OD_{320} = 10 \times \text{dilution} \times A(HCl)_{320}$$
$$OD_{360} = 10 \times \text{dilution} \times A(HCl)_{360}$$
$$OD_{520} = 10 \times \text{dilution} \times A(HCl)_{520}.$$

Determination of total flavanols: total flavanols concentration was determined using a method based on reaction with p-dimethylaminocinnamaldehydu (DMACA) (Li *et al*., 1996). In this method, unlike the widely used reaction with vanillin, no interference with the anthocyanins exists. Moreover, a higher sensitivity and selectivity is reached. To 1.5 ml eppendorf tube with 980 µl reagent (0.1% DMACA and 300 mM HCl in MeOH) was added 20 µl of sample, shaken and left to react 12 minutes at room

temperature. Absorbance was measured at 640 nm against blank prepared in the same manner in which the sample was replaced by dilution buffer. Concentration of total flavanols was calculated from the calibration curve using catechin as standard (10–200 mg/L). The results are expressed in the form of mg/L catechin equivalents.

Determination of reducing power (Reducing Power, PR): to determine the reducing ability of wine has been modified method based on reduction of iron ions (Ferric Reducing / antioxidant power, FRAP) (Pulido *et al.*, 2000). In 1.5 ml eppendorf tube was mixed 50 µl of solution of iron ions (3 mM $FeCl_3$ in 6 mM citric acid) with 20 µl of the sample and the mixture was incubated for 30 minutes at 37 °C heating block. Then was added 930 µl of solution TPTZ (2,4,6-tripyridyl-s-triazine) in 50 mM HCl, and shaken for 12 minutes, absorbance was measured at 620 nm against a blank prepared in the same manner in which the sample was replaced by dilution buffer. Reducing power was calculated from calibration curves using gallic acid as standard (0.1–2 mM). The results are expressed in the form mM gallic equivalents.

Determination of antiradical activity (Antiradical Activity; AAR): Method is based on the deactivation of the commercially available 2.2-diphenyl-β-pikrylhydrazyl radical (DPPH), manifested by the decrease of absorbance at 515 nm (Arnous *et al.*, 2001). To 980 µl solution of DPPH in methanol (150 µM) was added 20 µl of sample, shaking for 30 minutes and measured the absorbance at 515 nm compared with demineralized water. To determination of antiradical activity was used optical density difference of the blank (dilution buffer) and sample. Antiradical activity was calculated from the calibration curve, using gallic acid as standard (10–100 mg/L). The results are expressed in the form mg/L antiradical equivalents of gallic acid.

Determination of phenolic compounds by HPLC with DAD detection: Concentrations of phenolic compounds was determined unpublished method. Wines were centrifuged (3000 x g, 6 min). White and rosé wines were diluted with 2 x 50 mM $HClO_4$, red wines were diluted with 4 x 30 mM $HClO_4$. The separation was performed in an isocratic regime with the mobile phase of 2mM sulphuric acid at the flow rate of 0.75 ml/min in the column Watrex Polymer IEX H form 10 µm; 250 × 8 mm with 10 × 8 mm. Spectrophotometric detectionwas performed by the DAD detector SPD-MAvp. Sugars and organic acids were measured at 190 nm and 210 nm, respectively. The quantification of the individual analyses was performed on the basis of external calibration.

Sensory evaluation: Seven professional wine tasters (5 men and 2 women, aged 28–40 years) were selected to evaluate the wine samples. The bottles were opened roughly 30 min before tasting, and no information about the type of wine or its country of origin was provided. Wines were evaluated by 100 points system according the International Union of Oenologists.

RESULTS AND DISCUSSION

Results of standard measurements of basic analytical values (pH, content of total titratable acids in g/L, content of free SO2 in mg/L, and residual sugar in g/L) are presented in Tab. I. Data about the content of alcohol (% vol.) presented on bottle labels were considered as reliable and true. The sensory analysis of wine samples was performed anonymously and it was found out that the character of evaluated samples was very similar (above all in case of white wine). This could be associated with a very warm year 2009, which was one of the warmest and driest vintage years above all in Moravia.

As shown in Tab. I, Pinot Gris from the wine-growing municipality of Valtice, subregion Mikulov was evaluated as the sample with the best sensory parameters among wines under study. This sample received 87.71 points and was characterised as wine with typical varietal character, flourish to fruitish tones, fresh acid, harmonic and well-balanced taste. The second best wine samples were Merlot from the municipality of Popice, subregion Mikulov (86.29 points) and Kerner from the municipality of Varna, Trentino-Alto Adige (85.43 points). Red Traminer (Savagnin Rosé) from the municipality of Caldaro, Trentino-Alto Adige received the worst evaluation (68.86 points). The taste and the smell of this wine was evaluated as "impure", with predominating oxidative tones of overipeness and "suffocation", probably due to lowest content of free SO2. Italian wine samples of Chardonnay (Trentino, Lavis) and Pinot Gris (Trentino, Lasino) received also a low evaluation (73.57 and 71.86 points, respectively). It is of interest that there was also a significant difference between contents of residual sugars in wine samples originating from both wine-growing regions ($p = 0.01598$). In Moravian wines, the content of residual sugar was in average higher than in those from Italy.

Contents of total polyphenols, flavanols and anthocyanins are presented in Tab. II. These data indicate that among white wines the highest and the lowest contents of total polyphenols were detected in Italian Kerner and Moravian Chardonnay ((366 mg/L) and 253 mg/L, respectively). As far as red wines were concerned, the highest and lowest contents were measured in Moravian Cabernet Sauvignon and Italian Pinot Noir (3.494 mg/L and 1.455 mg/L, respectively). The average content of total polyphenols in Moravian and Italian white wines was 325.6 mg/L and 331.1 mg/L, respectively. In red wines, the corresponding values were 3.274 mg/L and 1.942 mg/L, respectively.

In white wine, the highest and the lowest contents of total flavanols were found out in Moravia, viz. in Pinot Blanc and Kerner (28.1 mg/L and 6.8 mg/L, respectively). Average contents of flavanols in Moravian and Italian wines were 14.26 mg/L

I: *Basic analytical parameters and sensory evaluation of wines under study*

Wine - subregion	Country	Alcohol [% vol.]	Free SO_2 [mg/L]	pH	Titr. acids [g/L]	Res. sugar [g/L]	Sensory Eval.
Müller Thurgau - Velké Pavlovice	CZE	11.5	31.81	3.65	5.36	3.50	80.14
Silvaner - Mikulov	CZE	13.0	53.44	3.53	5.85	12.60	76.86
Riesling - Mikulov	CZE	13.0	43.26	3.22	6.73	3.30	82.29
Pinot Blanc - Velké Pavlovice	CZE	12.5	29.27	3.51	6.41	4.30	77.86
Pinot Gris - Mikulov	CZE	13.0	57.26	3.41	6.87	3.90	87.71
Chardonnay - Mikulov	CZE	13.0	31.81	3.68	5.96	3.60	79.57
Sauvignon - Mikulov	CZE	13.0	39.45	3.59	6.46	12.90	80.43
Kerner - Mikulov	CZE	11.5	33.08	3.45	5.39	11.40	80.86
Gewürztraminer - Velké Pavlovice	CZE	14.0	35.63	3.87	4.84	8.80	74.71
Müller Thurgau - Trentino	IT	12.5	15.27	3.33	6.12	3.60	81.14
Silvaner DOC Alto Adige	IT	13.0	52.17	3.56	5.78	2.90	79.86
Riesling DOC Trentino	IT	12.5	44.54	3.11	7.35	3.40	82.86
Pinot Blanc DOC Dolomiti	IT	13.5	39.45	3.91	5.5	1.70	76.00
Pinot Gris DOC Delle Venezie	IT	12.0	17.81	3.79	6.18	1.90	71.86
Chardonnay DOC Trentino	IT	14.5	36.90	4.8	4.99	1.40	73.57
Sauvignon IGT Vigneti delle Dolomiti	IT	13.0	25.45	3.5	5.77	3.60	82.71
Kerner DOC Alto Adige Valle Isarca	IT	14.0	55.99	3.34	6.9	6.10	85.43
Gewürztraminer DOC	IT	15.0	12.72	3.87	4.96	6.80	68.86
Pinot Noir - Mikulov	CZE	14.5	39.45	4.19	5.36	3.80	84.86
Merlot - Mikulov	CZE	14.5	53.44	4.2	4.69	4.80	86.29
Cabernet Sauvignon - Mikulov	CZE	13.0	71.26	3.54	4.89	8.10	84.29
Pinot Noir DOC Trentino	IT	13.0	35.63	3.76	4.87	2.70	78.43
Merlot DOC Trentino	IT	12.5	52.17	3.62	4.75	4.40	84.71
Cabernet Sauvignon DOC Trentino	IT	12.5	54.72	3.80	5.10	4.90	81.29

II: *Antioxidative characteristics of wines under study*

Wine - subregion	Country	Total phenols [mg/L]	Total flavanols [mg/L]	T. anthocyanins [mg/L]	DPPH [mM GA]	FRAP [mM GA]	OD 280	OD 360	OD 520
Müller Thurgau - Velké Pavlovice	CZE	363	22.7	1.2	51.1	56.6	7.98	1.3	0.06
Silvaner - Mikulov	CZE	355	10.7	1.2	38.1	56.4	8.2	1.7	0.06
Riesling - Mikulov	CZE	333	3.2	1	39.3	48.1	9.05	1.92	0.05
Pinot Blanc - Velké Pavlovice	CZE	387	28.1	2.4	53.4	60.5	9.26	2.06	0.12
Pinot Gris - Mikulov	CZE	385	24.5	2.5	46.1	64.5	8.06	1.65	0.13
Chardonnay - Mikulov	CZE	253	10.8	0.8	34.2	41.3	7.21	1.42	0.04
Sauvignon - Mikulov	CZE	326	10.8	0.8	36.2	49.3	9.03	1.68	0.04
Kerner - Mikulov	CZE	264	6.8	0.6	33	41.9	7.09	1.45	0.03
Gewürztraminer - Velké Pavlovice	CZE	264	10.7	1.2	31.1	37.5	7.12	1.47	0.06
Müller Thurgau - Trentino	IT	320	18.8	1.3	46.9	46.6	8.38	1.2	0.07
Silvaner DOC Alto Adige	IT	353	11.7	1.5	46.6	59.2	7.26	1.5	0.08
Riesling DOC Trentino	IT	298	11	1.5	40.4	46.3	7.46	2	0.08
Pinot Blanc DOC Dolomiti	IT	357	17.6	2.5	47.8	53.4	8.57	1.74	0.13
Pinot Gris DOC Delle Venezie	IT	267	14.2	2.4	31.9	35	6.6	1.27	0.12
Chardonnay DOC Trentino	IT	369	22.2	1.1	60.8	64.1	9.29	2.44	0.06
Sauvignon IGT Vigneti delle Dolomiti	IT	322	13.2	1	44.3	49.6	9.26	1.55	0.05
Kerner DOC Alto Adige Valle Isarca	IT	366	10	0.6	62.3	71.4	8.48	1.67	0.03
Gewürztraminer DOC	IT	328	10.1	1.6	34.4	43.3	9.15	1.55	0.08
Pinot Noir - Mikulov	CZE	2963	993	157.8	653.6	269.9	55.11	7.05	9.69
Merlot - Mikulov	CZE	3365	668.1	384.8	796.6	301	71.46	10.5	21.84
Cabernet Sauvignon - Mikulov	CZE	3494	820.6	233.4	795.1	287.1	67.98	8.4	14.07
Pinot Noir DOC Trentino	IT	1455	389.9	139.8	314.1	162.8	30.72	5.82	7.89
Merlot DOC Trentino	IT	2177	459.1	256.6	518.3	202.6	45.87	7.5	14.73
Cabernet Sauvignon DOC Trentino	IT	2194	474	240.6	516.7	207.5	44.31	6.93	13.83

III: *Contents of individual phenolic substances in white wines*

		Chemical composition [mg/L]													
		Cinnamic acids			Tartaric esters of cinnamic acids			Grape reduction products		Flavan-3-ols		Benzoic acids		Stilbene	
Wine - subregion	Country	p-coumaric acid	Caffeic acid	Ferulic acid	Coutaric acid	Caftaric acid	Fertaric acid	GRP1	GRP2	Catechin	Epicatechin	Gallic acid	Vanillic acid	Trans-resveratrol	Trans-piceid
Müller Thurgau - Velké Pavlovice	CZE	1.533	3.055	0.457	0.547	5.712	1.000	2.129	2.981	6.059	1.488	1.636	0.457	0.254	0.019
Silvaner - Mikulov	CZE	0.133	2.019	0.358	0.427	6.280	1.734	0.496	4.566	3.485	0.400	5.722	0.284	0.122	0.043
Riesling - Mikulov	CZE	0.254	9.925	0.575	0.049	8.834	2.922	2.373	4.461	1.003	0.264	5.424	0.222	0.089	0.029
Pinot Blanc - Velké Pavlovice	CZE	0.200	2.826	0.282	1.747	15.851	1.251	1.597	4.605	9.508	2.911	4.547	0.408	0.287	0.158
Pinot Gris - Mikulov	CZE	0.219	3.666	0.238	0.814	9.159	1.082	3.477	3.718	7.077	1.779	3.225	0.282	0.145	0.030
Chardonnay - Mikulov	CZE	0.351	1.203	0.307	0.581	4.071	0.989	2.059	7.817	3.182	0.640	3.870	0.609	0.056	0.050
Sauvignon - Mikulov	CZE	0.155	2.649	0.360	1.017	16.842	0.783	0.893	4.148	2.424	0.387	4.323	0.328	0.150	0.162
Kerner - Mikulov	CZE	0.173	3.860	0.686	0.825	9.783	1.903	2.017	3.514	1.470	0.481	3.969	0.792	0.065	0.047
Gewürztraminer - Velké Pavlovice	CZE	0.207	2.647	1.435	0.313	2.267	0.850	3.247	3.639	2.501	0.523	2.881	0.502	0.041	0.043
Müller Thurgau - Trentino	IT	0.063	4.739	0.138	0.545	12.434	0.667	0.686	1.562	6.929	1.755	13.162	0.270	0.231	0.058
Silvaner DOC Alto Adige	IT	0.151	5.012	0.381	0.448	9.361	1.165	2.442	3.661	2.717	0.657	5.181	0.395	0.070	0.003
Riesling DOC Trentino	IT	0.202	2.698	0.263	2.211	28.112	3.322	0.920	3.673	3.833	0.971	6.062	0.294	0.050	0.092
Pinot Blanc DOC Dolomiti	IT	0.161	1.705	0.253	1.675	16.149	1.019	4.268	2.281	5.937	1.422	2.318	0.236	0.055	0.042
Pinot Gris DOC Delle Venezie	IT	0.147	1.178	0.281	1.131	6.646	0.875	0.826	2.843	3.596	0.917	2.179	0.304	0.080	0.006
Chardonnay DOC Trentino	IT	0.120	1.890	0.166	4.006	46.416	1.004	0.712	3.840	6.134	1.449	2.456	0.195	0.122	0.012
Sauvignon IGT Vigneti delle Dolomiti	IT	0.118	5.605	0.134	0.712	15.152	0.624	1.227	1.917	3.647	0.540	6.028	0.299	0.337	0.142
Kerner DOC Alto Adige Valle Isarca	IT	0.177	10.375	0.017	0.489	13.689	1.716	1.158	3.566	2.497	0.610	7.218	0.312	0.054	0.009
Gewürztraminer DOC	IT	0.053	2.274	1.490	0.720	8.981	1.057	3.203	0.435	1.774	0.398	5.523	0.507	0.038	0.062

IV: *Contents of individual phenolic substances in red wines*

		Chemical composition [mg/L]															
		Cinnamic acids			Flavan-3-ols		Benzoic acids		Flavonols						Stilbene	
Wine - subregion	Country	p-coumaric acid	Caffeic acid	Ferulic acid	Catechin	Epicatechin	Gallic acid	Vanillic acid	Kaempferol	Myricetin	Quercetin	Rutin	Isorhamnetin	Morin	Trans-resveratrol	Trans-piceid
Pinot Noir - Mikulov	CZE	0.206	6.255	1.097	94.632	91.178	39.070	9.958	0.007	0.214	0.025	0.895	0.084	0.785	0.356	0.187
Merlot - Mikulov	CZE	0.381	46.851	1.547	89.412	33.958	78.312	5.844	0.038	6.656	1.939	13.972	0.456	1.002	5.390	0.684
Cabernet Sauvignon - Mikulov	CZE	0.510	2.933	0.322	112.387	45.857	100.986	4.197	0.235	2.689	4.737	7.800	0.634	1.051	8.894	4.249
Pinot Noir DOC Trentino	IT	0.214	3.220	0.411	60.392	43.189	19.849	4.161	0.030	2.270	1.688	4.320	0.362	0.767	13.193	0.456
Merlot DOC Trentino	IT	0.582	9.340	0.368	51.214	2.270	43.525	2.825	0.014	10.120	0.697	6.184	0.327	1.921	4.291	0.511
Cabernet Sauvignon DOC Trentino	IT	0.404	4.091	0.388	58.507	24.233	33.379	3.520	0.014	5.444	0.383	4.188	0.077	1.308	4.923	0.658

and 14.31 mg/L, respectively. As far as red wines were concerned, the maximum and the minimum contents of total flavanols were detected in Moravian Pinot Noir and Italian Merlot (993.0 mg/L and 459.1 mg/L, respectively). In Moravia and Italy, average values were 827.2 mg/L and 441.0 mg/L, respectively.

In white wine, the maximum contents of anthocyanins (2.5 mg/L) were detected in Moravian Pinot Gris and Italian Pinot Blanc. In both wine-growing regions, the minimum contents of 0.6 mg/L were found out in wine made of the variety Kerner. In white wine, the average contents of anthocyanins were 1.3 mg/L (Moravia) and 1.5 mg/L (Italy). The highest and the lowest contents of anthocyanins were detected in Moravian Merlot and Italian Pinot Noir (384.8 mg/L and 139.8 mg/L, respectively). In Moravian red wines the average content of anthocyanins was 258.7 mg/L; in Italy, the corresponding value was 212.3 mg/L.

When comparing data presented in Tab. II, no significant differences between white wines originating from both regions were found out. In red wines, however, there were significant differences in total polyphenols ($p = 0.01025$), total flavanols ($p = 0.01658$), DPPH ($p = 0.02255$) and FRAP ($p = 0.004782$). In Moravia, all these parameters were better than in Italy.

Contents of individual phenolic substances in Moravian and Italian white and red wines are presented in Tabs. III and IV. These values corresponded with total contents presented in Tab. II and significant differences were found out only between white wines in the parameter GRP 2 ($p = 0.01145$). It is known that glutathione, a thiol-containing peptide present in grape must, helps to prevent the occurrence of enzymatic browning reaction. When an o-quinone is formed from caftaric (or coutaric) acid by means of grape polyphenol oxidase (PPO), glutathione can react with it, thus regenerating the o-diphenol group. The product of this reaction is 2-S-glutathionylcaftaric acid (also known as grape reaction product, GRP), which is nonoxidizable by grape PPO, and its formation avoids the browning of must that develops via the o-quinones (Singleton *et al.*, 1985; Cheynier *et al.*, 1986). However, it can undergo an additional oxidation under the laccase action (Salgues *et al.*, 1986,) from *Botrytis cinerea*, on botrytized grapes. The laccase oxidation of GRP yields the corresponding o-quinones which, in turn, can proceed to brown polymers and also gives rise to 2.5-di-S-glutathionylcaftaric acid in the presence

V: *Correlations existing between antioxidative characteristics and levels of individual substances contained in white wines*

	Total phenols	Total flavanols	T. anthocyanins	DPPH	FRAP
p-coumaric acid	0.14	0.28	-0.09	0.17	0.11
Caffeic acid	0.24	-0.36	-0.39	0.36	0.37
Ferulic acid	-0.35	-0.34	-0.07	-0.57	-0.51
Coutaric acid	0.23	0.46	0.22	0.43	0.25
Caftaric acid	0.31	0.29	-0.03	0.54	0.37
Fertaric acid	-0.05	-0.45	-0.17	-0.06	0.02
GRP1	0.07	0.03	0.39	-0.15	-0.06
GRP2	-0.17	-0.09	-0.24	-0.08	0.06
Catechin	0.55	0.96	0.60	0.55	0.42
Epicatechin	0.50	0.92	0.62	0.54	0.38
Gallic acid	0.02	-0.16	-0.26	0.12	0.03
Vanillic acid	-0.54	-0.25	-0.32	-0.46	-0.42
Trans-resveratrol	0.38	0.57	0.07	0.35	0.24
Trans-piceid	0.01	0.12	-0.01	-0.12	-0.12

VI: *Correlations existing between antioxidative characteristics and levels of individual substances contained in red wines*

	Total phenols	Total flavanols	T. anthocyanins	DPPH	FRAP
p-coumaric acid	0.25	-0.20	0.51	0.32	0.13
Caffeic acid	0.45	0.06	0.86	0.51	0.54
Ferulic acid	0.52	0.46	0.52	0.52	0.64
Catechin	0.87	0.86	0.13	0.82	0.86
Epicatechin	0.32	0.79	-0.47	0.22	0.38
Gallic acid	0.88	0.49	0.57	0.89	0.82
Vanillic acid	0.41	0.81	-0.20	0.34	0.50
Kaempferol	0.55	0.34	0.06	0.52	0.44
Myricetin	-0.12	-0.57	0.64	-0.02	-0.15
Quercetin	0.48	0.18	0.18	0.46	0.40
Rutin	0.48	-0.11	0.90	0.54	0.49
Isorhamnetin	0.40	0.02	0.35	0.41	0.34
Morin	-0.17	-0.43	0.32	-0.09	-0.24
Trans-resveratrol	-0.40	-0.54	-0.20	-0.41	-0.43
Trans-piceid	0.54	0.32	0.07	0.52	0.43

VII: *Correlation matrix of methods used for the estimation of antioxidative characteristics*

	Total flavanols	T. anthocyanins	DPPH	FRAP
Total phenols	0.97	0.94	1.00	0.99
Total flavanols		0.86	0.96	0.97
T. anthocyanins			0.95	0.94
DPPH				0.99

of an excess of glutathione, also known as GRP 2. Higher concentrations of GRP 2 in Moravian white wines indicated a higher occurrence of infested grapes than in Italy.

In red wines (Tab. IV), there was only one significant difference between both regions, viz. in the concentration of catechins, which was higher in Moravia ($p = 0.004936$). This parameter is really interesting because for example Baroni (2012) showed that antioxidant capacity was highly correlated to their polyphenolic profile, with significant contribution of kaempferol and catechin. None of the phenolic compounds evaluated in this study could be associated with the sensory differences existing among groups.

Correlations existing among contents of individual measured substances and antioxidative characteristics of white ($n = 18$) and red ($n = 6$) wines are presented in Tabs. V and VI. A significant correlation ($p = 0.05$) was found between the antioxidant capacity and contents of some phenolic acids, including gallic acid, catechins, epicatechins, caffeic acid and rutin. This indicated that these compounds could make a major contribution to the overall antioxidant power of wine. The high antioxidant activity of gallic acid in red wines was demonstrated also by others authors (Bakkalbase *et al.*, 2009; Canas *et al.*, 2008). Antioxidative properties of red wine are determined by the presence of three free phenolic hydroxyl groups per molecule. However, no strong correlation between the rest of the phenolic acids and antioxidant capacity was found out.

The correlation matrix of antioxidative characteristics of analysed wine samples ($n = 24$) is presented in Tab. VII ($p = 0.01$). The correlations between the assays under study were highly positive ($0.86 < r < 1.00$; $p < 0.01$). This indicated that the assays provided comparable values when used for the estimation of antioxidant characteristics. A high correlation between these techniques was also reported by other authors (Awika *et al.*, 2003; Thaipong *et al.*, 2006).

CONCLUSIONS

In the present study, antioxidant capacity, phenolic composition and sensory evaluation of selected red and white wines originating from wine-growing regions of South Moravia and North Italy were investigated. The sensory analysis indicated that the evaluated wine samples were very similar. Antioxidative characteristics were estimated by means of common spectrophotometric methods (total phenols, total anthocyanins, total flavanols, DPPH and FRAP) and thereafter compared. It was found out that the compared methods were highly significantly and positively correlated as far as their results were concerned. Individual phenolic compounds were detected by means of HPLC with DAD detection. In white wines, the content of GRP products was higher and this indicated that the quality of grapes used for making Moravian wines was lower. In red Moravian wines, the content of catechins (i.e. compounds responsible for the majority of phenolic substances and considered to be health-promoting compounds) was higher. This observation was corroborated also analytically, i.e. on the base of correlation with antioxidative characteristics.

SUMMARY

Results of this experiment indicate the existence of a significant sensory and analytical similarity of 2009 vintage wines originating from South Moravia and Northern Italy. Italian wines (from the wine-growing region Trident – Alto Adige) showed a lower content of residual sugar. As far as the sensory properties were concerned, the best one was the sample of Pinot Gris originating from Valtice (subregion Mikulov). This sample was characterised as a wine with varietal character, flourish and fruitish tones, fresh acid, harmonic and well-balanced.

A significant correlation was found out between the antioxidant capacities on the one hand and contents of some phenolic acids (including gallic acid, catechins, epicatechins, caffeic acid, and rutin). This indicated that these compounds could contribute at most to the overall antioxidative power of wine.

Basing on these results, it is concluded that the four tested methods (i.e. DPPH, FRAP, determination of total phenols, and determination of total flavanols) gave comparable results as far as the antioxidant characteristics of white and red wines were concerned. With the use of statistical techniques, it was possible to conclude that red wines originating from South Moravia presented the best antioxidant activity. Especially the content of catechins was significantly higher in Moravian wines. None of the phenolic compounds evaluated in this study could be associated with the sensory differences among groups.

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