Influence of Locality on Content of Phenolic Compounds in White Wines

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Abstract

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Phenolic compounds in grapes and wines are significantly influenced by the environment. Phenolic compounds in grapes are therefore a good reflection of terroir. The authentic wines were made from seven white grape varieties and two localities in the Czech Republic. Sádek is a location on the edge of production wine-growing in the Czech Republic and Perná is a typical wine-growing location in the Czech Republic. The profile of phenolic compounds was analysed by HPLC. Based on the statistical evaluation of these results, the following phenolic compounds were found to very well reflect the terroir conditions: protocatechuic acid, *p*-hydroxybenzoic acid, caftaric acid, *cis*-piceid, (+)-catechin and (–)-epicatechin. Since these compounds were not influenced significantly by vintage, they can be good markers of terroir.

Keywords: authenticity; grapevine; HPLC; terroir; wine analysis

The most popular food product produced from grapes is wine. Wine is also the most popular alcoholic beverage throughout the world. The significance of geographical origin to wine is greater than in any other food product – terroir. The terroir is the natural locality of each plant of grapevine in a vineyard. Each terroir is influenced by climatic, geological and soil factors, and also by human activity when treating the vineyard. Each grape produced in a specific terroir reflects the locality in its chemical composition.

Wine is also among food products that are very often subject to falsification in terms of variety or geographical origin. The terms of authenticity and traceability are therefore very important for wine producers and consumers alike.

The idea of wine authenticity evaluation on the basis of geographical origin is also recommended by Charlton *et al*. (2010), who stated that the chemical composition was able to give a perfect indication of wine origin but only if the origin was significant with a higher level of specification than the individual geographical localities. The best determination of the region of origin is possible on the basis of the analytical profile of wine.

Phenolic compounds can be used as chemical markers to confirm the authenticity of wine based on the geographical origin (Fanzome *et al*. 2010).

Phenolic synthesis is part of a coordinated suite of changes that accompanies berry ripening. Environmental factors include all external stimuli, the most influential of which for phenolic synthesis are light and temperature, as well as others such as water status, nutritional status, and pathogenesis. These factors modulate grapevine physiology and may influence vine vigour, crop load, as well as the balance between photosynthetic carbon fixation

and partitioning of assimilates to ripening berries (Castellarin *et al*. 2012).

Ali *et al*. (2010) mentioned that phenolic compounds mostly come from grape berries and some of them originate in chemical and biochemical reactions during the winemaking process. Thus the composition and the content of phenolic compounds mostly depend on the individual vineyard.

Polyphenols are a group of secondary metabolites with different chemical structures and functions that are formed in the course of normal plant growth or in response to various forms of environmental stress (Naczk *et al*. 2004) and may therefore be suitable for determining the authenticity of wines based on geographic origin, because the content of phenolic compounds in wines differs with the geographical origin, and suggests that the accumulation of phenolic compounds in grapes and wines is strongly influenced by terroir (Pereira *et al*. 2006; Rastija *et al*. 2009; Li *et al*. 2011).

Phenolic compounds are among the most important quality parameters that are divided into two main groups, non-flavonoids and flavonoids. Hydroxycinnamic acids significantly affect the colour and flavour of wine (De Luca 2011), and are therefore the major phenolic compounds in white wines. Hydroxybenzoic acids are a minority group represented by phenolic compounds in wine. Among the major flavonoids in grapes and wine are flavan-3-ols, flavonols and varieties for the production of red wine anthocyanins as well. Flavan-3-ols are the most abundant class of flavonoids and are located primarily in the skin and seeds of grapes (Waterhouse 2002).

The goal is to compare the influence of location on the content of phenolic compounds in white wines. For the evaluation, two extreme locations were selected: Sádek, a location on the edge of production wine-growing in the Czech Republic, and Perná, a typical wine-growing location in the Czech Republic

MATERIAL AND METHODS

Evaluated were wines made of white grapevine varieties of either European (E) or interspecific (I) origin, namely: Aurelius (E), Chardonnay (E), Müller Thurgau (E), Moravian Muscat (E), Hibernal (I), Malverina (I) and Merzling (I). Wines originated from two localities, i.e. from Perná (the Mikulov wine-growing subregion) and Sádek (the Znojmo wine-growing subregion). Characteristics of the Perná site: seasonal average temperature (9°C), seasonal precipitation amount (552 mm), sum of active temperatures (2900°C). The geological bedrock is limestone. The soil is sandy-loam with a higher content of lime. Characteristics of the Sádek site: seasonal average temperature (8°C), seasonal precipitation amount (480 mm), sum of active temperatures (2700°C). The geological bedrock is granite and orthogneiss. The soil is loam-sandy. Table 1 shows detailed meteorological parameters from both localities.

Vintage years ranged from 2005 to 2006. Laboratory analysis were performed in the laboratory of the Department of Viticulture and Oenology (Mendel University in Brno, Czech Republic) in Lednice.

Vinification technology. All kinds of white wine were made using an identical technology of vinification. Fermentation and ageing of wine took place in glass balloons of 50 l in volume. Harvested

Table 1. Average monthly temperature and monthly rainfall for the locality Sádek and Perná

Locality	Year	April	May	June	July	August	September	October
Average monthly temperature (°C)								
Sádek	2005	9.6	12.9	16.4	18.4	16.5	14.6	9.3
	2006	8.9	12.9	17.2	21.5	15.7	15.9	10.5
Perná	2005	10.9	14.9	18.0	19.9	18.2	16.1	10.1
	2006	10.9	14.9	18.4	22.4	16.9	17.2	11.5
Monthly rainfall (mm)								
Sádek	2005	60.2	65.8	60.6	71.7	109.8	33.1	5.1
	2006	56.1	60.3	92.7	29.1	127.6	7.2	16.4
Perná	2005	53.5	70.6	37.7	92.5	77.8	31.5	4.8
	2006	64.9	79.7	71.7	92.7	151.4	15.2	14.1

grapes were destemmed, macerated for a short period (2 h at the temperature of 15°C) and pressed to the must yield of 60%. The obtained must was clarified with Seporit bentonite (Erbsloeh, Geisenheim, Germany) used in the dose of 100 g/hl. The yeast nutrient Enovit (AEB Group, Brescia, Italy) and pure yeast culture were added into the clear must in doses of 10 g/hl, respectively. After the end of fermentation, the young wine was racked and treated with sulphur dioxide to the content of 30 mg/l free SO_2. Thereafter, the young wine was bottled (without any further clarification and/or filtration) for analysis.

Determination of phenolic compounds. In all wine samples the following phenolic compounds were analysed: hydroxybenzoic acids (gallic acid, protocatechuic acid, *p*-hydroxybenzoic acid, syringic acid), hydroxycinnamic acid (caffeic acid, caftaric acid, *p*-coumaric acid, *p*-coutaric acid, ferulic acid, fertaric acid), stilbenes (*trans*-resveratrol, *cis*-resveratrol, *trans*-piceid, *cis*-piceid), and flavan-3-ols [(+)-catechin, (–)-epicatechin].

HPLC analysis. Concentrations of the individual phenolic compounds were determined by an unpublished method with direct injection of a sample as described below. The samples of wine were centrifuged at 3000 *g* for 6 min and diluted with 100mM $HClO_4$ at a 1:1 ratio.

The Shimadzu LC-10A chromatographic system consisted of two LC-10ADvp pumps, a column thermostat with manual injection valve, a DAD detector SPD-M10Avp and a personal computer running the chromatographic software LC solution (all from Shimadzu, Kyoto, Japan). The chromatographic separations were performed on an Alltech Alltima C18 column (3 µm × 3 × 150 mm; Grace, Derrfield, USA) equipped with a guard column (3× 7.5 mm *i.d.*) filled with the same sorbent. The temperature of separations was 60°C. The mobile phases were the following: A = 15mM $HClO_4$ and B = 15mM $HClO_4$, 10% MeOH, 50% ACN. The gradient programme is described in Table 2, with a flow rate of 0.6 ml/minutes.

The total duration of the analysis was 43 min and the regeneration time was 4 minutes. Data were recorded in the wavelength range of 200–520 nm.

The detection wavelength was 200 nm for (+)-catechin and (–)-epicatechin, 260 nm for protocatechuic and *p*-hydroxybenzoic acid, 275 nm for gallic and syringic acid, 285 nm for *cis*-piceid and *cis*-resveratrol, 310 nm for *p*-coumaric acid and its derivatives, *trans*-piceid and *trans*-resveratrol, 325 nm for caffeic acid.

Table 2. HPLC gradient programme for analysis of phenolic compounds

Time (min)	A (%)	B (%)
0.00	96	4
20.00	72	28
30.00	58	42
35.00	40	60
38.00	0	100
40.00	0	100
40.01	100	0
41.00	96	4
43.00	96	4

A = 15mM $HClO_4$; B = 1mM $HClO_4$, 10% MeOH, 50% acetonitrile

Chemicals. Acetonitrile (ACN) and methanol (MeOH) were of HPLC super gradient grade purity. Vanillic acid, protocatechuic acid, *p*-hydroxybenzoic acid, gallic acid, syringic acid, *p*-coumaric acid, *trans*-resveratrol, *trans*-piceid, caffeic acid, ferulic acid, (+)-catechin, (–)-epicatechin, and perchloric acid were obtained from Sigma-Aldrich (St. Louis, USA). Other used chemicals were at least of analytical grade and were obtained from local suppliers (Lachema-Penta, Brno, Czech Republic).

A stock standard solution was prepared by accurately weighing about 10 mg of each phenol in a 25 ml volumetric flask. The standard was dissolved in 10 ml of acetonitrile and refilled to the volume with distilled water.

cis-Resveratrol was obtained by exposing the *trans*-resveratrol standard solution to direct UV light for 10 minutes. The source of UV light was a Philips Ultraviolet TUV 30W/G30 T fluorescent tube (Philips, Rosemont, USA). The sample was placed directly below the tube in a sealed quartz cell. The concentration of *cis*-resveratrol was expressed as a decrease in the concentration of *trans*-resveratrol (71% conversion).

Statistical data processing. The obtained data were processed according to the wine-growing regions and expressed as mean values and standard deviations. The use of two-way analysis of variance (ANOVA) with the aim to find the influence of a locality and vintage was a further step. All statistical analyses were performed by the UNISTAT statistical programme (Unistat, Brno, Czech Republic).

Table 3. Mean values, standard deviations and analysis of variance of hydroxybenzoic acids in white wines from localities Sádek and Perná

Locality	Variety	Hydroxybenzoic acid (mg/l)			
		gallic	protocatechuic	*p*-hydroxybenzoic	syringic
Sádek	Aurelius	0.80 ± 0.34	1.80 ± 0.57	1.02 ± 0.06	0.83 ± 0.77
	Chardonnay	0.87 ± 0.47	1.71 ± 0.30	0.63 ± 0.11	0.85 ± 0.72
	Hibernal	0.81 ± 0.08	1.31 ± 0.47	0.74 ± 0.40	0.47 ± 0.06
	Malverina	0.95 ± 0.70	1.51 ± 0.03	0.75 ± 0.06	1.13 ± 0.24
	Merzling	0.76 ± 0.28	1.62 ± 0.55	1.28 ± 0.86	0.49 ± 0.28
	Moravian Muscat	1.42 ± 0.11	2.14 ± 1.34	0.92 ± 0.41	0.43 ± 0.12
	Müller Thurgau	1.21 ± 0.77	1.04 ± 0.03	0.40 ± 0.03	0.70 ± 0.59
	Mean	0.97 ± 0.42	1.59 ± 0.57	0.82 ± 0.40	0.70 ± 0.43
Perná	Aurelius	0.94 ± 0.02	1.53 ± 0.91	0.81 ± 0.25	0.72 ± 0.39
	Chardonnay	0.95 ± 0.29	0.74 ± 0.06	0.42 ± 0.16	0.64 ± 0.14
	Hibernal	0.94 ± 0.06	0.88 ± 0.16	0.52 ± 0.35	0.56 ± 0.04
	Malverina	0.68 ± 0.53	1.62 ± 0.21	0.42 ± 0.13	0.79 ± 0.33
	Merzling	0.71 ± 0.04	0.95 ± 0.43	0.51 ± 0.06	0.47 ± 0.06
	Moravian Muscat	0.92 ± 0.45	0.73 ± 0.28	0.54 ± 0.12	0.48 ± 0.19
	Müller Thurgau	0.93 ± 0.49	1.67 ± 1.46	0.86 ± 0.73	0.66 ± 0.14
	Mean	0.86 ± 0.27	1.16 ± 0.65	0.58 ± 0.30	0.62 ± 0.20
Locality (L)		ns	*	*	ns
Year (Y)		**	ns	ns	*
L × Y		ns	ns	*	ns

*$P < 0.05$; **$P < 0.01$; ns – not significant

RESULTS AND DISCUSSION

Gallic acid and protocatechuic acid are hydroxybenzoic acids which are found in grapes and demonstrate the close relationship to their environment – the terroir.

The dominant hydroxybenzoic acids in selected wines were protocatechuic acid and gallic acid (Table 3). The average content of gallic acid was higher in wines from the Sádek site (mean 0.97 mg/l), which ranged from 0.76 mg/l to 1.42 mg/l. Similar levels of gallic acid in white wines were found in Brazil (Ballus *et al*. 2012) and in the Canary Islands (Darias-Martín *et al*. 2008). A higher content of gallic acid was demonstrated in white wine from South Africa (De Villiers *et al*. 2005) and Croatia (Rastija *et al*. 2009). The content of gallic acid in white wines from the Czech Republic was also evaluated by Soyollkham *et al*. (2011), who found significantly higher values in the range of 5.04 mg/l to 14.70 mg/l.

Protocatechuic acid content in the wine showed a dependence on the location but not on the year (Table 3). Protocatechuic acid content in selected white wines was significantly lower than the levels that were found in Croatia (Komes *et al*. 2007). The influence of location was also demonstrated in the content of *p*-hydroxybenzoic acid.

Hydroxycinnamic acids are among the simplest phenolic compounds in grapes and wine (Medić-Šarić *et al*. 2013). The main hydroxycinnamic acids are *p*-coumaric, caffeic acid and ferulic acid (Cheynier *et al*. 2010).

The dominant hydroxycinnamic acid in selected wines is caftaric acid whose content is also significantly affected by the location. White wines for the Sádek area show on average a doubled content when compared with wines from the Perná site (Table 4). The average caftaric acid content ranges from 18.67 mg/l to 36.76 mg/l, which is comparable with the value of white wines from the Canary Islands (Darias-Martín *et al*. 2008).

Table 4. Mean values, standard deviations and analysis of variance of hydroxycinnamic acids in white wines from localities Sádek and Perná

Locality	Variety	Hydroxycinnamic acid (mg/l)					
		caffeic	caftaric	*p*-coumaric	*p*-coutaric	ferulic	fertaric
Sádek	Aurelius	1.59 ± 0.28	24.78 ± 0.44	1.01 ± 0.94	8.96 ± 4.65	0.48 ± 0.13	3.50 ± 0.44
	Chardonnay	1.57 ± 0.63	37.11 ± 7.02	1.16 ± 0.73	11.00 ± 2.56	0.50 ± 0.03	3.20 ± 0.15
	Hibernal	1.43 ± 0.09	38.29 ± 29.06	0.84 ± 0.63	10.55 ± 4.34	0.49 ± 0.08	6.12 ± 2.04
	Malverina	2.09 ± 0.39	54.88 ± 9.49	0.62 ± 0.21	11.37 ± 2.99	0.85 ± 0.57	6.02 ± 2.31
	Merzling	0.93 ± 0.17	22.74 ± 20.54	0.59 ± 0.42	6.48 ± 3.97	0.50 ± 0.06	3.06 ± 0.78
	Moravian Muscat	1.51 ± 0.01	37.00 ± 5.54	1.00 ± 0.88	13.87 ± 3.20	0.45 ± 0.25	2.41 ± 1.03
	Müller Thurgau	1.78 ± 0.01	42.52 ± 12.86	0.34 ± 0.31	8.67 ± 3.33	0.45 ± 0.18	4.02 ± 0.82
	Mean	1.55 ± 0.41	36.76 ± 15.41	0.79 ± 0.55	10.13 ± 3.50	0.53 ± 0.23	4.04 ± 1.71
Perná	Aurelius	2.48 ± 1.73	16.14 ± 0.40	1.17 ± 1.07	4.13 ± 0.36	0.53 ± 0.33	2.80 ± 0.74
	Chardonnay	1.82 ± 0.26	24.00 ± 3.44	0.80 ± 0.54	4.75 ± 0.64	0.55 ± 0.28	2.83 ± 0.10
	Hibernal	1.33 ± 0.23	26.69 ± 23.72	1.35 ± 0.27	6.78 ± 4.16	0.76 ± 0.23	5.72 ± 2.31
	Malverina	3.26 ± 2.07	24.58 ± 10.16	0.98 ± 0.30	2.94 ± 0.11	1.76 ± 0.90	6.08 ± 0.53
	Merzling	1.28 ± 0.52	12.99 ± 9.27	0.81 ± 0.47	3.22 ± 2.76	0.69 ± 0.18	2.69 ± 0.40
	Moravian Muscat	2.26 ± 0.57	8.33 ± 1.73	1.52 ± 1.32	2.78 ± 0.93	0.55 ± 0.23	1.62 ± 0.41
	Müller Thurgau	2.14 ± 1.44	17.97 ± 8.46	1.08 ± 0.97	4.65 ± 3.99	0.48 ± 0.22	2.39 ± 0.49
	Mean	2.08 ± 1.10	18.67 ± 11.50	1.10 ± 0.67	4.17 ± 2.39	0.76 ± 0.53	3.44 ± 1.81
Locality (L)		ns	**	*	**	ns	ns
Year (Y)		ns	ns	**	*	ns	ns
L × Y		ns	ns	ns	ns	ns	ns

*$P < 0.05$; **$P < 0.01$; ns – not significant

Significant impacts of sites were also found on the content of *p*-coumaric and *p*-coutaric acid. Both acids were also significantly affected by the year (Table 4). The average content of *p*-coumaric acid was lower in wines from the Sádek site than from Perná. Wines found to contain *p*-coumaric acid were comparable to white wines of Canada (Soleas *et al*. 1997), but lower than the wines from the Canary Islands (Darias-Martín *et al*. 2008). Locations in the Czech Republic are therefore more comparable with sites in Canada.

Stilbenoids are a very interesting group of compounds with significant biological activity, particularly in relation to the prevention of chronic diseases associated with aging (Pawlus *et al*. 2012). Stilbenes belong to non-flavonoid compounds. Resveratrol exists in two isomer forms (*cis* and *trans*). 3-*O*-β-D-glucosides of *cis*- and *trans*-resveratrol are called piceids (Rentzsch *et al*. 2009).

Resveratrol in grapes is dominant in its *trans*-form (Cheynier *et al*. 2010). Observed in white wines, the contents of trans-resveratrol are between 0.62 mg/l to 0.71 mg/l (Table 5). White wines from the Czech Republic were also investigated by the analysis of 76 samples of wine. The concentration of *trans*-resveratrol in samples from the Bohemian wine-growing region ranged from 0.033 mg/l to 0.421 mg/l with a mean value of 0.117 mg/l. The concentration of *trans*-resveratrol in samples from the Moravian wine-growing region ranged from 0.033 mg/l to 0.875 mg/l with a mean value of 0.123 mg/l (Faitová *et al*. 2004).

The content of *trans*-resveratrol from Sádek and Perná was not affected by the location. Contrarily, the influence of the site is most obvious in the content of *trans*-piceid (Table 5).

The main flavan-3-ol monomers, which are contained in grapes and wine, are (+)-catechin and (–)-epicatechin. The content of (+)-catechin and (–)-epicatechin was affected by the location. The average content of (+)-epicatechin was higher for white wines from the Sádek site than from Perná.

Table 5. Mean values, standard deviations and analysis of variance of stilbenes in white wines from localities Sádek and Perná

Locality	Variety	Stilbenes (mg/l)			
		trans-resveratrol	*cis*-resveratrol	*trans*-piceid	*cis*-piceid
Sádek	Aurelius	0.64 ± 0.23	0.78 ± 0.46	0.48 ± 0.45	1.25 ± 0.49
	Chardonnay	0.80 ± 0.58	0.80 ± 0.17	0.11 ± 0.06	0.34 ± 0.01
	Hibernal	0.48 ± 0.05	0.60 ± 0.18	0.28 ± 0.26	0.86 ± 0.62
	Malverina	0.86 ± 0.18	1.31 ± 0.61	0.87 ± 0.01	3.39 ± 1.07
	Merzling	0.30 ± 0.13	0.36 ± 0.13	0.23 ± 0.17	0.88 ± 0.31
	Moravian Muscat	0.71 ± 0.10	0.60 ± 0.20	0.35 ± 0.14	1.09 ± 0.34
	Müller Thurgau	0.55 ± 0.23	0.56 ± 0.13	0.55 ± 0.52	1.08 ± 0.30
	Mean	0.62 ± 0.27	0.71 ± 0.37	0.41 ± 0.32	1.27 ± 1.02
Perná	Aurelius	0.85 ± 0.74	1.02 ± 0.17	0.16 ± 0.09	0.67 ± 0.21
	Chardonnay	0.51 ± 0.20	0.44 ± 0.21	0.44 ± 0.02	1.03 ± 0.02
	Hibernal	0.45 ± 0.05	0.55 ± 0.38	0.31 ± 0.28	0.85 ± 0.14
	Malverina	1.61 ± 1.05	2.27 ± 0.56	0.14 ± 0.11	0.52 ± 0.01
	Merzling	0.26 ± 0.13	0.36 ± 0.16	0.07 ± 0.06	0.34 ± 0.15
	Moravian Muscat	0.53 ± 0.50	0.48 ± 0.21	0.08 ± 0.01	0.55 ± 0.45
	Müller Thurgau	0.78 ± 0.66	0.79 ± 0.45	0.05 ± 0.04	0.32 ± 0.10
	Mean	0.71 ± 0.64	0.84 ± 0.69	0.18 ± 0.17	0.61 ± 0.29
Locality (L)		ns	ns	**	*
Year (Y)		**	ns	**	ns
L × Y		ns	ns	ns	ns

*$P < 0.05$; **$P < 0.01$; ns – not significant

The average content of (+)-catechin in the Sádek location was 11.35 mg/l (Table 6). The content was significantly higher than in white wines from Croatia (Rastija *et al*. 2009) and Canada (Soleas *et al*. 1997). The high content of (+)-catechin is an indicator for white wines from South Africa Fracassetti *et al*. (2011). Similar results were observed for (–)-epicatechin, which showed a higher mean level (6.82 mg/l) at the Sádek location.

Based on the results of the statistical analysis it can be concluded that the phenolic compounds, which are significantly affected by the location and are not affected by variety and vintage, can include protocatechuic acid, *p*-hydroxybenzoic acid, caftaric acid, *cis*-piceid, and *cis*-(+)-catechin and (–)-epicatechin.

Hydroxybenzoic acids serve as important location markers. Similar results were found out when comparing the Italian and Spanish wines where the geographical origin as a marker revealed mainly hydroxybenzoic acid (Andreu-Navarro *et al*. 2011). Caftaric acid also proved as a location marker, similar to wines from the Canary Islands (Darias-Martín *et al*. 2008).

In contrast, trans-resveratrol did not show to be a significant location marker, even though it was a marker for the geographic origin detected in Croatian wines. When evaluating Croatian wines, samples of wines from Central and Southern Dalmatia were found to have the highest content of *trans*-resveratrol, while wines from Istria are low in this compound (Rastija *et al*. 2009).

This study demonstrated a significant effect of the environment on the profile of phenolic compounds in white wines. These results can be used for the terroir classification in the Czech Republic.

CONCLUSION

Using the HPLC method, phenolic compounds in white wines from two localities were identified. Differences between Sádek and Perná localities

Table 6. Mean values, standard deviations and analysis of variance of flavan-3-ols in white wines from localities Sádek and Perná

Locality	Variety	Flavan-3-ols (mg/l)	
		(+)-catechin	(–)-epicatechin
Sádek	Aurelius	9.74 ± 0.86	5.73 ± 0.08
	Chardonnay	13.54 ± 3.91	7.58 ± 1.54
	Hibernal	7.89 ± 3.66	5.21 ± 3.45
	Malverina	10.22 ± 2.11	5.84 ± 0.24
	Merzling	8.49 ± 1.82	4.94 ± 2.39
	Moravian Muscat	17.69 ± 1.07	12.62 ± 5.28
	Müller Thurgau	11.87 ± 5.85	5.86 ± 2.77
	Mean	11.35 ± 4.03	6.82 ± 3.31
Perná	Aurelius	8.47 ± 1.63	4.89 ± 0.42
	Chardonnay	7.76 ± 3.70	4.11 ± 1.99
	Hibernal	9.36 ± 1.48	5.58 ± 2.26
	Malverina	4.68 ± 0.59	3.16 ± 0.37
	Merzling	7.85 ± 0.72	4.60 ± 0.92
	Moravian Muscat	9.00 ± 1.61	4.96 ± 0.74
	Müller Thurgau	7.53 ± 3.95	4.77 ± 2.45
	Mean	7.80 ± 2.25	4.58 ± 1.53
Locality (L)		**	*
Year (Y)		ns	ns
L × Y		ns	ns

*$P < 0.05$; **$P < 0.01$; ns – not significant

were found out in six phenolic compounds. Phenolic compounds that show the most significant difference between the study locations, and thus they are closest to the conditions of terroir locations include: protocatechuic acid, *p*-hydroxybenzoic acid, caftaric acid, *cis*-piceid, and (+)-catechin and (-)-epicatechin.

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