Content of polyphenolic antioxidants and *trans*-resveratrol in grapes of different varieties of grapevine (*Vitis vinifera* L.)

J. LACHMAN, M. ŠULC, A. HEJTMÁNKOVÁ, V. PIVEC, M. ORSÁK

Faculty of Agronomy, Czech University of Agriculture in Prague, Prague, Czech Republic

ABSTRACT: Contents of polyphenolic antioxidants as total polyphenols and *trans*-resveratrol in grape musts, grape skins and seeds of twelve vine varieties from the harvests 2001 and 2002 were determined. Polyphenolic antioxidants of grapes are very effective in preventing cancer and cardiovascular diseases. Total polyphenolic content was determined spectrophotometrically with phenol Folin-Ciocalteau's reagent and *trans*-resveratrol content by the HPLC method. The average annual total polyphenol contents in the years 2001 and 2002 were 171 mg/l and 324 mg/l in the must, 7,470 mg/l and 15,600 mg/kg DM in grape skins and 91,450 and 107,440 mg/kg DM in the seeds. The average annual *trans*-resveratrol values in the years 2001 and 2002 reached $0.817.10^{-2}$ mg/kg DM and $4.97.10^{-2}$ mg/kg DM in grape skins and $52.7.10^{-2}$ mg/kg DM and $4.63.10^{-2}$ mg/kg DM in the seeds and there was hardly any *trans*-resveratrol presence in the must. The results were evaluated statistically by Statgraphic and Anova programmes. Statistically significant differences in total polyphenols were found between analysed vintages, varieties and contents in seeds and grape skins. Regarding the *trans*-resveratrol content, statistically significant differences between vintages were found.

Keywords: grapevine; grapes; must; skins; seeds; polyphenolic antioxidants; *trans*-resveratrol; effect of varieties, vintages, plant part

Phenolic compounds in wines possess a strong antioxidant activity, especially in red wines – 12.3 mmol/l (WANG et al. 1996). These phenolic antioxidants are more effective than vitamin C and E (MATĚJKOVÁ, GUT 2000). Phenolic compounds in wine, especially in red wine (HERTOG 1998; KONNEH, CAEN 1998), decrease the risk of arteriosclerosis. Another important compound contained in wine is resveratrol that is a free radical scavenger and inhibits the risk of cardiovascular diseases (FILIP et al. 2003). Resveratrol is mainly contained in the skins of grapes (MATĚJKOVÁ, GUT 2000; SCHMANDKE 2002) while a low content was found in fresh musts (KOPEC 1999). High amounts of *trans*-resveratrol were found in wines from Bordeaux, Burgundy, Switzerland and Oregon, and on the contrary, lower amounts are typical of Mediterranean regions – Italy, Spain, Portugal, South Africa, America and Australia (FILIP et al. 2003). During the *Botrytis cinerea* infection the plant forms a resveratrol barrier surrounding the infected site where the resveratrol concentration is low, but it is four times higher in the adjacent zone (ŠMIDRKAL et al. 2001). There is an apparent destruction effect of *B. cinerea* laccase on the resveratrol structure. It follows from this fact that the infection by *B. cinerea* to 10% shows the highest resveratrol accumulation (BAVARESCO et al. 1997a,b).

The aim of this study was to determine the effect of vintage and grapevine variety on polyphenol and *trans*-resveratrol contents in twelve varieties of the Czech grapevine region and to compare their content in must, skins, grapes and seeds regarding their health effects.

MATERIAL AND METHODS

Biological material

All twelve grapevine varieties (Table 1), whose grapes were analysed, were cultivated at Karlštejn Research Viticulture Station (Na Plešivci vineyard). The grapes were harvested in October 2001 and 2002. The infection of grapes by *Botrytis cinerea* ranged from 50 to 65% in 2001 and from 35 to 50% in 2002. The way of vineyard cultivation was the same in both years. Immediately after the harvest the samples were stored in a freezer at –32°C for 3 weeks and then analysed.

Preparation of samples

Juice was squeezed from grapes, and seeds and skins were separated from the solid rest. Juice was frozen immediately after pressing and seeds and grapes were lyophilised. Must was filtered through a course filter and frozen. Samples after lyophilisation and stabilisation in an exsiccator were ground in a laboratory mill and then extracted with 80% water ethanol in Soxhlet apparatus for 32 hours. The weight of samples was 6–10 g. The extracts were filled into 250 ml volumetric flasks and adjusted with 80% water ethanolic solution to the mark.

Determination of total polyphenols (TP)

For the determination of total polyphenols a modified method of LACHMAN et al. (1998) with Folin-Ciocal-

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Research Project No. 412100002.

Table 1. Analysed grapevine varieties – White varieties

White varieties	Sort
Aurelius	must variety
Bacchus	must variety
Kerner	must variety
Muscat Ottonel	must variety
Welschriesling	must variety
Green Sylvaner	must variety
Green Veltliner	must variety
Early Red Veltliner	must variety
Blue varieties	
Royal	table variety
Blue Burgundy	must variety
St. Laurent	must variety
Zweigeltrebe	must variety

teau's reagent was used. 1 ml of sample was pipetted into a 50 ml volumetric flask and diluted with distilled water. Then 2.5 ml of Folin-Ciocalteau's reagent was added and after agitation 7.5 ml of 20% sodium carbonate solution was added. After 2 hours standing at laboratory temperature the absorbance of samples was measured on the spectrophotometer Heλios γ (Spectronic Unicam, GB) at wavelength λ = 765 nm against blank. The extract of seeds was diluted at a 1:50 ratio before measuring. Results were expressed as gallic acid (in mg/kg dry matter – DM and in the case of must mg/l fresh must, gallic acid Merck, D).

Determination of *trans*-resveratrol by HPLC

HPLC with isocratic elution on the Waters™ chromatograph was used (pump Waters™, autosampler Waters™ 717 plus, detector Waters™ PDA 996 UV-VIS for the identification in UV and visible region) (BURNS et al. 2000). A mixture of acetonitrile with water (75:25, V/V) as a mobile phase was used; its pH value was adjusted to 1.5 with trifluoroacetic acid. The column ODS-Hypersil 250 × 4.6 mm, 5 µm was used, flow rate was 1 ml/min. Detection was performed at wavelength λ = 307 nm. Before chromatographic analyses samples were filtered through Spartan 0.45 µm filter. *Trans*-resveratrol of 99% purity (Sigma Aldrich®, USA) was used as a standard. Calibration range was 0.05–10 µg/ml, calibration linearity min. 0–10 µg/ml, detection limit 0.034 µg/ml and critical level of signal 0.017 µg/ml.

Statistical evaluation

Statistical evaluation of the results was made by Statgraphic and Anova programmes at the level of statistical significance α = 0.05.

RESULTS AND DISCUSSION

Grape must had a relatively high content of total polyphenols (Table 2). White varieties contained lower average amounts (213 mg/l) in comparison with blue varieties (306 mg/l). Average TP content ranged from 173 mg/l to 254 mg/l in white varieties and 166 mg/l to 447 mg/l in blue varieties in the years 2001 and 2002. Average TP content was 171 mg/l in 2001, 324 mg/l in 2002. Among blue varieties the highest amount was determined in cv. Royal (587 mg/l in 2002, average content 427 mg/l), lower contents were found for Blue Burgundy (av. 231 mg/l) and St. Laurent – Svatovavřinecké (236 mg/l). Significantly lower contents were found in white varieties – the highest content is characteristic of Muscat Ottonel (av. 267 mg/l), the lowest one in Bacchus (116 mg/l) and Early Red Veltliner (160 mg/l).

Table 2. Content of total polyphenols in grape must, skins and seeds

White varieties	Grape must (mg/l)		Grape skins (mg/kg DM)			Grape seeds (mg/kg DM)	
	2001	2002	2001	2002	Average	2001	2002
Aurelius	174.0	302	3,190	10,160	6,675	90,490	133,860
Bacchus	116.0	nd	4,140	nd	4,140	75,560	nd
Kerner	116.0	390	2,980	8,980	5,980	67,400	78,430
Muscat Ottonel	268.0	266	6,980	13,900	10,440	85,040	102,170
Welschriesling	344.0	132	6,400	11,900	9,150	76,990	78,900
Green Sylvaner	59.3	338	7,740	7,800	7,770	98,710	105,820
Green Veltliner	232.0	104	10,200	10,780	10,490	94,880	113,960
Early Red Veltliner	74.3	245	3,570	7,470	5,520	86,950	103,850
Blue varieties							
Royal	267.0	587	14,300	24,090	19,195	98,750	129,600
Blue Burgundy	114.0	348	8,570	20,420	14,495	124,110	116,790
St. Laurent	86.6	385	10,520	25,250	17,885	107,920	106,720
Zweigeltrebe	196.0	468	11,020	30,870	20,945	90,590	111,780

nd – not determined in 2002 due to grape bunch atrophy

Table 3. Content of *trans*-resveratrol in grape must, skins and seeds

White varieties	Grape must (mg/l).10^{-2}		Grape skins (mg/kg DM).10^{-2}		Grape seeds (mg/kg DM).10^{-2}	
	2001	2002	2001	2002	2001	2002
Aurelius	< 0.034*	0.244	1.86	1.28	23.8	1.28
Bacchus	< 0.034*	nd	< 0.034*	nd	70.4	nd
Kerner	0.341	< 0.034*	< 0.034*	< 0.034*	6.4	< 0.034*
Muscat Ottonel	< 0.034*	< 0.034*	< 0.034*	2.74	40.7	2.74
Welschriesling	< 0.034*	< 0.034*	< 0.034*	< 0.034*	79.5	< 0.034*
Green Sylvaner	< 0.034*	< 0.034*	5.00	8.72	55.4	8.72
Green Veltliner	< 0.034*	< 0.034*	1.24	3.05	29.4	3.05
Early Red Veltliner	< 0.034*	< 0.034*	5.80	4.56	60.5	0.46
Blue varieties						
Royal	< 0.034*	6.44	1.59	6.60	59.9	6.60
Blue Burgundy	< 0.034*	< 0.034*	1.52	4.67	76.1	4.67
St. Laurent	< 0.034*	0.406	1.39	13.5	106.4	13.5
Zweigeltrebe	< 0.034*	< 0.034*	1.12	13.7	24.3	13.7

nd – not determined in 2002 due to grape bunch atrophy; * less than the detection limit 0.034 μg/ml of extract

The highest TP content was determined in seeds (99,450 mg/kg DM), it was higher in 2002 (107,440 mg per kg DM) in comparison with 2001 (91,450 mg/kg DM). Higher content was determined in blue varieties (110,780 mg/kg DM) as compared with white varieties (93,440 mg/kg DM). The highest content was found in Blue Burgundy variety (120,450 mg/kg DM), lower amounts were found in Zweigeltrebe (101,190 mg/kg DM) and St. Laurent – Svatovavřinecké (107,320 mg/kg DM). Among white varieties the highest content was found in the seeds of cv. Aurelius (112,180 mg/kg DM), the lowest one in cv. Kerner (72,920 mg/kg DM). The average annual content was higher in 2002 (15,600 mg per kg DM) in comparison with 2001 (7,470 mg/kg DM).

TP content in skins was lower in comparison with seeds, on average 11,540 mg/kg DM. Higher contents were found in blue varieties again (av. 18,130 mg/kg DM) than in white varieties (av. 7,900 mg/kg DM). Higher contents were found in 2002 (15,600 mg/kg DM) than in 2001 (7,470 mg/kg DM). The highest value was measured in cv. Zweigeltrebe (20,950 mg/kg DM)

Table 4. Variance analysis of multiple grouping of total polyphenol content in grapevine must and grape skins and seeds

Source of variability	Deg. of freedom	Sum of squares	Variance	*F*-test	*P*-value
		Main effects			
Year	1	121,730	121,730.0	7.23084	0.022738*
Variety	11	116,563	10,597.0	0.62945	0.770640
		Interaction			
Year × variety	0	–	–	–	–
Residual	10	16,835	16,835.0	–	–
Total	22	420,579			
		Main effects			
Year	1	1,377.5	1,377.5	22.233	0.000133*
Variety	11	3,422.8	311.2	5.022	0.000900*
Part of plant	1	83,909.2	83,909.2	1,354.325	0.000018*
		Interaction			
Year × variety	0	–	–	–	–
Year × part of plant	1	124.1	124.1	2.003	0.172377
Variety × part of plant	11	1,739.7	158.2	2.553	0.033091*
Year × variety	0	–	–	–	–
Residual	20	1,239.1	62.0		
Total	45	96,779.2			

* significance level at $\alpha < 0.05$

Table 5. Variance analysis of multiple grouping of *trans*-resveratrol content in grape skins and seeds

Source of variability	Deg. of freedom	Sum of squares	Variance	*F*-test	*P*-value
		Main effects			
Year	1	449.882	449.882	18.14943	0.000383*
Variety	11	345.873	31.443	1.26849	0.309587
Part of plant	1	661.262	661.262	26.67706	0.000047*
		Interaction			
Year × variety	0	–	–	–	–
Year × part of plant	1	686.331	686.331	27.68843	0.000038*
Variety × part of plant	11	238.887	21.717	0.87612	0.575936
Year × variety × part of plant	0	–	–	–	–
Residual	20	495.753	24.788		
Total	45	3,029.618			

* significance level at $\alpha < 0.05$

Table 6. *T*-test (for $\alpha = 0.05$) for vintages and parts of plant in total polyphenols and *trans*-resveratrol content

Year	Total polyphenols		Year	*trans*-resveratrol	
	2001	2002		2001	2002
2001	–	0.00374*	2001	–	0.000420*
2002	0.000374*	–	2002	0.000420*	–
Part of plant	Seeds	Skins	Part of plant	Seeds	Skins
Seeds	–	0.000151*	seeds	–	0.000170*
Skins	0.000151*	–	skins	0.000170*	–

* significance level at $\alpha < 0.05$

and cv. Royal (19,200 mg/kg DM). Among white varieties the richest were Green Veltliner (10,490 mg/kg DM) and Muscate Ottonel (10,440 mg/kg DM). The lowest level was found in cv. Bacchus (4,140 mg/kg DM in 2001) and Early Red Veltliner (5,520 mg/kg DM).

In grape musts the *trans*-resveratrol content was very low (Table 3) with the highest concentration in blue varieties Royal in 2002 ($6.44.10^{-2}$ mg/l) and St. Laurent – Svatovavřinecké ($0.406.10^{-2}$ mg/l). Among white varieties *trans*-resveratrol was determined only in cv. Kerner ($0.341.10^{-2}$ mg/l in 2001) and Aurelius ($0.244.10^{-2}$ mg/l in 2002).

Similarly like in CP content the highest levels of *trans*-resveratrol were also found in grape seeds (av. $28.7.10^{-2}$ mg/kg DM). Blue varieties are richer in the *trans*-resveratrol content in seeds ($36.7.10^{-2}$ mg/kg DM) than white varieties ($24.6.10^{-2}$ mg/kg DM). The highest contents were estimated in blue varieties St. Laurent – Svatovavřinecké ($53.9.10^{-2}$ mg/kg DM) and Blue Burgundy ($40.4.10^{-2}$ mg/kg DM). Among white varieties the highest levels were found in cv. Welschriesling ($39.8.10^{-2}$ mg/kg DM), Green Sylvaner ($32.0.10^{-2}$ mg/kg DM) and Early Red Veltliner ($30.5.10^{-2}$ mg/kg DM). On the contrary, the lowest content was found in Kerner variety ($3.22.10^{-2}$ mg/kg DM). The seeds from the year 2001 were richer in *trans*-resveratrol ($52.7.10^{-2}$ mg/kg DM) than those from the year 2002 ($4.63.10^{-2}$ mg/kg DM).

Grape skins contained on average $2.89.10^{-2}$ mg/kg DM of *trans*-resveratrol and their content was lower in comparison with seeds. Blue varieties had the higher *trans*-resveratrol content again (on av. $5.51.10^{-2}$ mg/kg DM) as compared with white varieties ($1.42.10^{-2}$ mg/kg DM).

Table 7. *T*-test (for $\alpha = 0.05$) for parts of plant and vintages in *trans*-resveratrol content

		2001 skins	2001 seeds	2002 skins	2002 seeds
2001	skins	–	0.000176*	0.882208	0.936077
2001	seeds	0.000176*	–	0.000179*	0.000178*
2002	skins	0.882208	0.000179*	–	0.998864
2002	seeds	0.936007	0.000178*	0.998864	–

*significance level at $\alpha < 0.05$

Table 8. *T*-test (for $\alpha = 0.05$) for varieties in total polyphenol content

Variety	Aurelius	Bacchus	Blue Burgundy	Kerner	Muscat Ottonel	Royal	Welsch-riesling	St. Laurent	Green Sylvaner	Early Red Veltliner	Green Veltliner	Zweigel-trebe
Aurelius	–	0.223177	0.939049	0.059593	0.964526	0.968896	0.230564	0.999977	0.999472	0.886194	1.000000	1.000000
Bacchus	0.223177	–	0.023086*	1.000000	0.807730	0.029379*	0.999986	0.097075	0.551503	0.905524	0.349346	0.147449
Blue Burgundy	0.939049	0.023086*	–	0.002865*	0.260512	1.000000	0.013573*	0.998703	0.543985	0.162766	0.800346	0.987315
Kerner	0.059593	1.000000	0.002865*	–	0.531049	0.003858*	0.999727	0.018400*	0.251814	0.701286	0.117864	0.032821*
Muscat Ottonel	0.964526	0.807730	0.260730	0.531049	–	0.323791	0.917146	0.745939	0.999987	1.000000	0.996644	0.880733
Royal	0.968896	0.029379*	1.000000	0.003858*	0.323791	–	0.018563*	0.999741	0.630770	0.207827	0.866668	0.995519
Welschriesling	0.230564	0.999986	0.013753*	0.999727	0.917146	0.018563*	–	0.082452	0.652498	0.977956	0.393430	0.138650
St. Laurent	0.999977	0.097075	0.998703	0.018400*	0.745939	0.999741	0.082452	–	0.958214	0.578276	0.997861	1.000000
Green Sylvaner	0.999472	0.551503	0.543985	0.251814	0.999987	0.630770	0.652498	0.958214	–	0.999283	0.999998	0.991978
Early Red Veltliner	0.886194	0.905524	0.162766	0.701286	0.100000	0.207827	0.977956	0.578276	0.999283	–	0.976114	0.744346
Green Veltliner	1.000000	0.349346	0.800346	0.117864	0.996644	0.866668	0.393430	0.997861	0.999998	0.976114	–	0.999920
Zweigeltrebe	1.000000	0.147449	0.987315	0.032821*	0.880733	0.995519	0.138650	1.000000	0.991978	0.744346	0.999920	–

* significance level at $P < 0.05$

Table 9. *T*-test (for $\alpha = 0.05$) for varieties in *trans*-resveratrol content

Variety	Aurelius	Bacchus	Blue Burgundy	Kerner	Muscat Ottonel	Royal	Welsch-riesling	St. Laurent	Green Sylvaner	Early Red Veltliner	Green Veltliner	Zweigel-trebe
Aurelius	–	0.904073	0.988367	0.999999	1.000000	0.928661	0.991436	0.339589	0.982623	0.999858	1.000000	1.000000
Bacchus	0.904073	–	0.999938	0.739819	0.965602	1.000000	0.999894	0.999980	0.999973	0.995901	0.968929	0.971401
Blue Burgundy	0.988367	0.999938	–	0.901403	0.999012	1.000000	1.000000	0.934520	1.000000	0.999998	0.999237	0.999383
Kerner	0.999999	0.739819	0.901403	–	0.999779	0.738898	0.916294	0.169841	0.877759	0.989922	0.999700	0.999620
Muscat Ottonel	1.000000	0.965602	0.999012	0.999779	–	0.983501	0.999391	0.499639	0.998147	0.999999	1.000000	1.000000
Royal	0.928661	1.000000	1.000000	0.738898	0.983501	–	1.000000	0.989906	1.000000	0.999444	0.985817	0.987473
Welschriesling	0.991436	0.999894	1.000000	0.916294	0.999391	1.000000	–	0.921693	1.000000	0.999999	0.999539	0.999633
St. Laurent	0.339589	0.999980	0.934520	0.169841	0.499639	0.989906	0.921693	–	0.950200	0.738774	0.514025	0.525514
Green Sylvaner	0.982623	0.999973	1.000000	0.877759	0.998147	1.000000	1.000000	0.950200	–	0.999992	0.998535	0.998790
Early Red Veltliner	0.999858	0.995901	0.999998	0.989922	0.999999	0.999444	0.999999	0.738774	0.999992	–	1.000000	1.000000
Green Veltliner	1.000000	0.968929	0.999237	0.999700	1.000000	0.985817	0.999539	0.514025	0.998535	1.000000	–	1.000000
Zweigeltrebe	1.000000	0.971404	0.999383	0.999620	1.000000	0.987473	0.999633	0.525514	0.998790	1.000000	1.000000	–

The average *trans*-resveratrol content in 2002 was higher ($4.97.10^{-2}$ mg/kg DM) than in 2001 ($0.817.10^{-2}$ mg per kg DM). The highest *trans*-resveratrol contents were found in blue varieties Zweigeltrebe ($7.41.10^{-2}$ mg/kg DM) and St. Laurent – Svatovavřinecké ($7.42.10^{-2}$ mg per kg DM). On the contrary, no *trans*-resveratrol levels above the detection limit were found in white varieties Bacchus, Kerner, Welschriesling.

Based on the statistical analysis of variance, statistically significant differences in total polyphenols were found between vintages (Table 4). Significant differences were also proved between total polyphenol contents in grape skins and seeds and between the variety and the part of the plant (Table 6). Some varieties differed significantly from each other (Table 8). As for the *trans*-resveratrol content, vintages, skins and seeds and vintage and the part of the plant were significantly different (Tables 5–7). No statistically significant differences between the varieties were found in the *trans*-resveratrol content in skins and seeds (Table 9).

All analysed varieties were cultivated at the Research Viticulture Station Karlštejn in the same conditions of microclimate, soil and cultivation practices. The blue varieties contained higher amounts of polyphenolic compounds in comparison with white varieties due to enhanced biosynthesis of colorants and tannins, which is in good correlation with the results of CANTOS et al. (2002), CHICON et al. (2002), DE BEER et al. (2003), UHLIG and CLINGELEFFER (1998). As determined by MAKRIS et al. (2003), the total polyphenol concentration is principally correlated with the antioxidant potency and the antiradical activity. BORBALAN et al. (2003) also confirmed a good correlation between the total polyphenol content and their antioxidant power.

Our results also proved the effect of vintage. In 2001 the TP levels were lower in comparison with 2002. It could be correlated with the extraordinary warm year 2002 (Δt = +1.7°C) in comparison with the year 2001 (Δt = +0.9°C). Both years could be evaluated as humid. ZOECKLEIN et al. (1998) illustrated the effect of microclimate manipulation on phenol-free grape glycosides. The higher TP levels in 2002 are in accordance with the results of UHLIG (1998) that total polyphenol concentrations in berry skin were higher in sun-exposed grapes. An increased grapevine water deficit also causes small increases in anthocyanins and decreases in flavonols (KENNEDY et al. 2002).

The effect of the *Botrytis cinerea* infection as a biotic stress factor (MONTERO et al. 2003) apparently influenced the higher content in 2001. The lower content in skins in comparison with seeds could be caused by its metabolisation (ADRIAN et al. 1998) and the fact that only free *trans*-resveratrol was determined. Higher levels of *trans*-resveratrol were found in blue varieties as compared with white ones (BIANCHINI, VAINIO 2003) because resveratrol is more sensitive to oxidation in white musts (CASTELLARI et al. 1998). Some statistically significant differences were found between some varieties, esp. Blue Burgundy × Bacchus, Royal, Kerner, Welschriesling or Kerner × Royal, St. Laurent, Zweigeltrebe and Royal × Welschriesling. Very low levels of *trans*-resveratrol in musts could be correlated with the activity of the isoenzyme B_5, whose activity is the highest at pH 3.0–4.0 (MORALES et al. 1997) and with the average pH values in our samples 3.18 (2001) and 3.33 (2002).

CONCLUSION

The total polyphenol content in grape must was statistically significantly affected by vintage, and in the skin and seeds by vintage, variety and the part of the plant. In 2001 and 2002 average TP values reached 171 mg/l and 324 mg/l in grape must, 7,470 mg/kg DM and 15,600 mg per kg DM in grape skins and 91,450 and 107,440 mg per kg DM in seeds. Blue varieties showed on average higher TP content in comparison with white varieties. Stilben *trans*-resveratrol was contained in skins only in trace amounts and its content in grape skins was very low in comparison with seeds. In 2001 the grape skins contained $0.817.10^{-2}$ mg/kg DM and $4.97.10^{-2}$ mg/kg DM and the seed content was $52.7.10^{-2}$ mg/kg DM and $4.63.10^{-2}$. The *trans*-resveratrol content was statistically significantly affected by vintage and the part of plant. The *trans*-resveratrol content was also higher in 2002.

References

ADRIAN M., RAJAEI H., JEANDET P., VENEAU J., BESSIS R., 1998. Resveratrol oxidation in *Botrytis cinerea* conidia. Phytopathology, *88*: 472–476.

BAVARESCO L., CANTU E., FREGONI M., TREVISAN M., 1997a. Constitutive stilbene contents of grapevine cluster stems as potential source of resveratrol in wine. Vitis, *36*: 115–118.

BAVARESCO L., PETEGOLLI D., CANTU E., FREGONI M., CHIUSA G., TREVISAN M., 1997b. Elicitation and accumulation of stilbene phytoalexins in grapevine berries infected by *Botrytis cinerea*. Vitis, *36*: 77–83.

BIANCHINI F., VAINIO H., 2003. Wine and resveratrol mechanisms of cancer prevention? Eur. J. Cancer Prevention, *12*: 417–425.

BORBALAN A.M.A., ZORRO L., GUILLEN D.A., BARROSO C.G., 2003. Study of the polyphenol content of red and white grape varieties by liquid chromatography – mass spectrometry and its relationship to antioxidant power. J. Chromatogr. A, *1012*: 31–38.

BURNS J., GARDNER P.T., O'NEIL J., CRAWFORD S., MORECROFT I., MC PHAIL D.B., LISTER C., MATTHEWS D., MAC LEAN M.R., DUTHIE G.G., CROZIER A., 2000. Relationship among antioxidant activity, vasodilation capacity, and phenolic content of red wines. J. Agr. Food Chem., *48*: 220–230.

CANTOS E., ESPIN J.C., TOMAS-BARBERAN F.A., 2002. Varietal differences among the polyphenol profiles of seven table grape cultivars studied by LC/DAD/MS/MS. J. Agric. Food Chem., *50*: 5691–5696.

CASTELLARI M., SPINABELLI U., RIPONI C., AMATI A., 1998. Influence of some technological practices on the quantity of resveratrol in wine. Z. Lebensm. Unters. Forsch. A, *206*: 151–155.

CHICON R.M., SANCHEZ-PALOMO E., CABEZUDO M.D., 2002. The colour and polyphenol composition of red wine varieties in Castilla – La Mancha (Spain). Afinidad, *59*: 435–443.

DE BEER D., JOUBERT E., GELDERBLOM W.C.A., MANLEY M., 2003. Antioxidant activity of South African red and white cultivar wines: Free radical scavenging. J. Agric. Food Chem., *51*: 902–909.

FILIP V., PLOCKOVÁ M., ŠMIDRKAL J., ŠPIČKOVÁ Z., MELZOCH K., SCHMIDT S., 2003. Resveratrol and its antioxidant and antimicrobial effectiveness. Food Chem., *83*: 585–593.

HERTOG M.G.L.,1998. Flavonols in wine and tea and prevention of coronary heart disease. In: VERCAUTEREN J., CHÈZE C., TRIAUD J. (eds.), Polyphenols 96, July 15–18, 1996, Bordeaux. Paris, INRA: 117–131.

KENNEDY J.A., MATTHEWS M.A., WATERHOUSE A.L., 2002. Effect of maturity and vine water status on grape skin and wine flavonoids. Amer. J. Enol. Vitic., *53*: 268–274.

KONNEH M., CAEN J., 1998. Red wine derived compounds and their putative antiaherogenic properties. In: VERCAUTEREN J., CHÈZE C., TRIAUD J. (eds.), Polyphenols 96, July 15–18, 1996, Bordeaux. Paris, INRA: 105–115.

KOPEC K., 1999. Resveratrol – chemoprotektivní složka vinných hroznů. Zahradnictví – Hort.. Sci. (Prague), *26*: 135–138.

LACHMAN J., HOSNEDL V., PIVEC V., ORSÁK M., 1998. Polyphenols in cereals and their positive and negative role in human and animal nutrition. Proc. of Cereals for Human Health and Preventive Nutrition, July 7–11, Brno: 118–125.

MAKRIS D.P., PSARRA E., KALLITHRAKA S., KEFALAS P., 2003. The effect of polyphenolic composition as related to antioxidant capacity in white wines. Food Res. Int., *36*: 805–814.

MATĚJKOVÁ Š., GUT I., 2000. Polyphenols in nutrition as protective compounds. Remedia, *10*: 272–281.

MONTERO C., CRISTESCU S.M., JIMENEZ J.B., OREA J.M., HEKKERT S.T.L., HARREN F.J.M., URENA A.G., 2003. *Trans*-resveratrol and grape disease resistance. A dynamical study by high-resolution laser-based techniques. Plant Physiol., *131*: 129–138.

MORALES M., ALCÁNTARA J., BARCELÓ A.R., 1997. Oxidation of *trans*-resveratrol by a hypodermal peroxidase isoenzyme from Gamay rouge grape (*Vitis vinifera*) berries. Am. J. Enol. Vitic., *48*: 33–39.

SCHMANDKE H., 2002. Resveratrol and piceid in grapes and soybeans and products made from them. Ernährungs-Umschau, *49*: 349–352.

ŠMIDRKAL J., FILIP V., MELZOCH K., HANZLÍKOVÁ I., BUCKIOVÁ D., KRIŠA B., 2001. Resveratrol. Chem. Listy, *95*: 602–609.

UHLIG B.A., CLINGELEFFER P.R., 1998. Ripening characteristics of the fruit from *Vitis vinifera* L. drying cultivars sultana and Merbein seedless under furrow irrigation. Amer. J. Enol. Vitic., *49*: 375–382.

UHLIG B.A., 1998. Effects of solar radiation on grape (*Vitis vinifera* L.) composition and dried fruit colour. J. Hort. Sci. & Biotechnol., *73*: 111–123.

WANG H., CAO G., PRIOR R.L., 1996. Total antioxidant capacity of fruits. J. Agric. Food Chem., *44*: 701–705.

ZOECKLEIN B.W., WOLF T.K., DUNCAN S.E., MARCY J.E., JASINKI Y., 1998. Effect of fruit zone removal on total glycoconjugates and conjugate fraction concentration of Riesling and Chardonnay (*Vitis vinifera* L.) grapes. Amer. J. Enol. Vitic., *49*: 259–265.

Received for publication January 27, 2004
Accepted after corrections March 12, 2004

Obsah polyfenolických antioxidantů a *trans*-resveratrolu v hroznech různých odrůd révy vinné (*Vitis vinifera* L.)

ABSTRAKT: Byl stanoven obsah polyfenolických antioxidantů jako celkových polyfenolů a *trans*-resveratrolu ve dvanácti odrůdách révy vinné ze sklizně 2001 a 2002. Polyfenolické antioxidanty hroznů jsou velmi účinné jako ochranné látky proti vzniku rakoviny a kardiovaskulárních onemocnění. Obsah celkových polyfenolů byl stanoven spektrofotometricky s fenolovým Folin-Ciocalteuovým činidlem a obsah *trans*-resveratrolu metodou HPLC. Byl stanoven obsah v moštu, slupkách a semenech hroznů. Průměrné obsahy v ročnících 2001 a 2002 byly 171 mg/l a 324 mg/l v moštu, 7 470 mg/kg sušiny a 15 600 mg/kg sušiny ve slupkách hroznů a 91 450 mg/kg sušiny a 107 440 mg/kg sušiny v semenech. Průměrné roční obsahy *trans*-resveratrolu v letech 2001 a 2002 dosahovaly hodnot $0,817.10^{-2}$ mg/kg sušiny a $4,97.10^{-2}$ mg/kg sušiny ve slupkách hroznů a $52,7.10^{-2}$ mg/kg sušiny a $4,63.10^{-2}$ mg/kg sušiny v semenech, zatímco obsah *trans*-resveratrolu v moštu byl téměř zanedbatelný. Získané výsledky byly statisticky zhodnoceny programy Statgraphic a Anova. Byly nalezeny statisticky významné rozdíly mezi ročníky, odrůdami a obsahy v semenech a slupkách hroznů. U obsahu *trans*-resveratrolu byly nalezeny staticky významné rozdíly mezi ročníky.

Klíčová slova: vinná réva; hrozny; mošt; semena; slupky; polyfenolické antioxidanty; *trans*-resveratrol; vliv odrůdy, ročníku, části rostliny

Corresponding author:

Prof. Ing. JAROMÍR LACHMAN, CSc., Česká zemědělská univerzita v Praze, Agronomická fakulta, 165 21 Praha 6-Suchdol, Česká republika
tel.: + 420 222 382 717, fax: + 420 234 381 840, e-mail: lachman@af.czu.cz