Relationship between antiradical activity, polyphenolic antioxidants and free *trans*-resveratrol in grapes (*Vitis vinifera* L.)

M. Šulc, J. Lachman, A. Hejtmánková, M. Orsák

Faculty of Agrobiology, Food and Natural Resources, Czech University of Agriculture in Prague, Prague, Czech Republic

ABSTRACT: Contents of polyphenolic antioxidants as total polyphenols (TP), free *trans*-resveratrol (R) and their antiradical activity (ARA) in grape skins and seeds of grape varieties and TP in grape musts originating from 5 wine-growing Czech areas from the harvest 2003 were determined. TP content was determined spectrophotometrically with phenol Folin-Ciocalteau's reagent, R content by HPLC method, and ARA employing the 1,1-diphenyl-2-picrylhydrazyl stable free radical (DPPH·). Obtained results were evaluated statistically by Statistica programme. TP did not show any statistically significant differences between the analysed varieties ($p < 0.05$) in grape seeds and skins, but regarding wine-growing regions a significant difference in TP ($p < 0.10$) in grape skins was found. ARA ($p < 0.05$) was not significant either for grape seeds or for grape skins in relation to wine-growing regions and varieties. The highest TP contents were found in grape seeds (536.6 mg/g DM), whereas R contents were higher in the skins (av. 1.67 μg/kg DM). Blue grape varieties showed a higher TP content in grape skins and also in must as compared with white grape varieties. The assessment of ARA of extracts of model constituents of grapes tannin (T) and gallic acid (GA) revealed their higher antiradical activity in comparison with ascorbic acid (AA).

Keywords: vine; must; skins; seeds; polyphenolic antioxidants; *trans*-resveratrol; antiradical activity; varieties; wine-growing areas

Functional ingredients of grape seeds, skins and musts include phenolics such as monomeric flavanols catechin and epicatechin, dimeric, trimeric and polymeric procyanidins, phenolic acids (gallic acid and ellagic acid) or anthocyanins (Yilmaz, Toledo 2004a). Polyphenolic antioxidants of grape are very effective in preventing cancer and cardiovascular diseases (Bianchini, Vainio 2003). These phenolics were reported to exhibit antioxidant activity *in vivo* and *in vitro* in a number of studies (Karakaya et al. 2001; Borbalan et al. 2003; de Beer et al. 2003; Dugo et al. 2003) and are more effective than vitamin C and E (Matějková, Gut 2000; Bartolomé, Nuñez 2004). The highest values of antioxidant activity, inhibition of low-density lipoproteins and total polyphenols were determined in pomace, grapes and must (Yildirim et al. 2005). Grape skins proved to be rich sources of anthocyanins (Chicón et al. 2002), hydroxycinnamic acids, flavanols and flavonol glycosides, whereas flavanols are mainly present in seeds (Kammerer et al. 2004) and could exert antibacterial activities (Baydar et al. 2004). Katalinić et al. (2004) elucidated different reducing/antioxidant power of red and white wines in view of their different phenolic composition.

Another important compound contained in wine and grapes is resveratrol that is a free radical scavenger and inhibits the risk of cardiovascular diseases (Filip et al. 2003; Frémont 2000). Resveratrol is mainly contained in the skins of grapes (Matějková, Gut 2000; Schmandke 2002) meanwhile its low content was found in fresh musts (Kopec 1994). 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 (Filip et al. 2003). During the attack of *Botrytis cinerea* the plant forms a resveratrol barrier (Šmidrkal et al. 2001).

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Research Project MSM 6046070901.

The aim of this study was to determine the effect of grape variety and wine-growing area of Bohemia on total polyphenol (TP) and *trans*-resveratrol (R) content and antiradical activity (ARA) in grape must, skins and seeds regarding their radical scavenging potential and health effects.

MATERIAL AND METHODS

Biological material

The grapes were harvested three times during October 2003. After transport to a laboratory grape samples from vineyards were processed without delay by separation of grape skins, seeds and must. The samples were immediately stored in a freezer at –32°C and then lyophilised.

Preparation of samples

Juice was squeesed from grapes while 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 coarse filter and frozen. Samples after lyophilisation and stabilisation in an exsiccator were ground in the laboratory mill and then extracted with 80% water ethanol in Soxhlet apparatus for 20 hours. The weight of samples was 6–10 g. The extracts were converted into 250 ml volumetric flask and adjusted with 80% water ethanolic solution to the mark.

Determination of total polyphenol (TP) content

For the determination of total polyphenols a modified method of Lachman et al. (1998) with Folin-Ciocalteau's reagent was used. 1 ml of sample was pipetted into 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-hour settling at laboratory temperature the absorbance of samples was measured on Helios γ spectrophotometer (Spectronic Unicam, GB) at a 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). Average results were obtained from three parallel determinations.

Determination of resveratrol (R) by HPLC

HPLC with isocratic elution on Waters™ chromatograph was used (Waters™ pump, Waters™ 717 plus autosampler, Waters™ PDA 996 UV-VIS detector) for the identification in UV and visible regions (Burns et al. 2000). A mixture of acetonitrile with water (75:25, V/V) as mobile phase was used; its pH value was adjusted to 1.5 with trifluoroacetic acid. Column ODS-Hypersil 250 × 4.6 mm, 5 µm was used, the flow rate was 1 ml/min. Detection was performed at a 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 standard. Calibration range was 0.05–10 µg/ml, calibration linearity min. 0.05–10 µg/ml, detection limit 0.034 µg/ml and critical level of signal was 0.017 µg/ml. Average results were obtained from three parallel determinations.

Determination of antiradical activity (ARA) by DPPH· method

ARA was measured after the reaction with free stable radical 1,1-diphenyl-2-picrylhydrazyl (DPPH·) according to Molyneux (2004). Fresh solution of DPPH in a concentration of 25 mg DPPH in 1 l of methanol should be prepared before the determination. 3 ml of violet DPPH· solution is pipetted into plastic cuvettes of 10 mm in length and absorbance

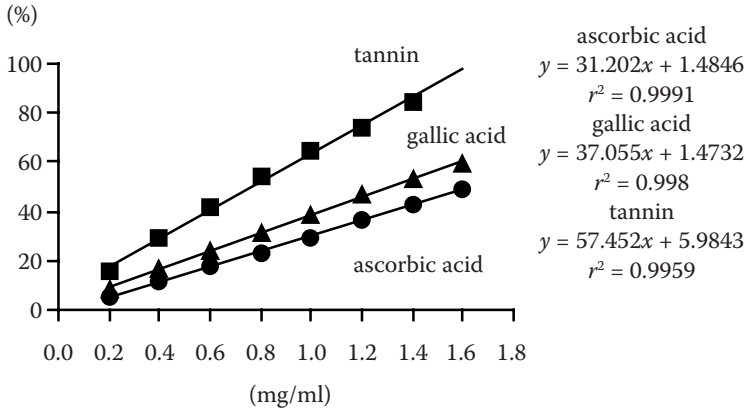

Fig. 1. Antioxidant activity of standard grape constituents and ascorbic acid at different concentrations

Table 1. TP content in grape skins, seeds and musts (mg/g DM or mg/l in musts) and ARA (% of inactivation or mg AA/ml) in grape skins and seeds of analysed varieties from five Czech winegrowing areas

Variety	Grape skins			Seeds			Must TP (mg/l)
	TP	ARA (%)	ARA	TP	ARA (%)	ARA	
Wine-growing area Roudnice nad Labem							
Kerner[W]	38.6 ± 0.3	5.49 ± 0.15	0.213	475.0 ± 0.9	18.92 ± 0.12	0.642	590.0 ± 2.1
Müller-Thurgau[W]	43.4 ± 1.7	4.19 ± 0.32	0.171	538.7 ± 2.1	23.15 ± 1.03	0.777	212.1 ± 1.0
Rhine (White) Riesling[W]	86.3 ± 0.4	3.73 ± 0.18	0.156	515.3 ± 1.5	25.44 ± 0.28	0.851	187.1 ± 0.9
Green Sylvaner[W]	44.4 ± 0.5	7.16 ± 0.11	0.266	575.5 ± 2.3	22.97 ± 0.21	0.771	93.8 ± 1.3
Blue Portugal[B]	161.5 ± 1.3	2.59 ± 0.20	0.120	525.7 ± 2.2	21.51 ± 0.25	0.726	124.5 ± 1.2
Saint Laurent[B]	488.5 ± 1.4	3.76 ± 0.31	0.157	666.6 ± 3.1	31.73 ± 0.12	1.053	140.3 ± 1.9
Wine-growing area Karlštejn							
Hibernal[W]	42.4 ± 0.9	6.13 ± 0.32	0.233	553.1 ± 3.2	19.42 ± 1.02	0.658	193.1 ± 1.7
Bianca[W]	158.6 ± 1.5	6.49 ± 0.13	0.245	529.0 ± 3.5	17.88 ± 0.45	0.607	217.2 ± 1.5
Müller-Thurgau[W]	31.5 ± 1.7	12.57 ± 0.51	0.440	426.4 ± 2.4	74.91 ± 0.51	2.436	412.8 ± 2.5
Wine-growing area Kutná Hora							
Müller-Thurgau[W]	49.1 ± 1.2	8.52 ± 0.20	0.310	385.1 ± 1.7	11.00 ± 0.21	0.390	326.8 ± 3.1
White Chrupka[W]	162.5 ± 2.1	13.90 ± 1.02	0.482	426.9 ± 5.3	56.66 ± 0.78	1.852	591.5 ± 1.8
Traminer[W]	133.9 ± 2.3	3.39 ± 0.10	0.145	484.6 ± 2.8	16.05 ± 0.09	0.549	107.9 ± 0.9
Blue Portugal (Blauer Portugieser)[B]	206.0 ± 1.3	4.51 ± 0.20	0.181	420.8 ± 3.1	68.24 ± 0.33	2.223	346.3 ± 1.2
Blue Burgundy (Blauburgunder, Pinot Noir)[B]	72.0 ± 0.8	1.28 ± 0.17	0.078	558.3 ± 3.2	21.53 ± 0.25	0.727	147.5 ± 1.8
Wine-growing area Most							
Müller-Thurgau[W]	69.6 ± 0.9	8.87 ± 0.11	0.321	471.6 ± 1.5	14.99 ± 0.21	0.514	171.9 ± 0.8
White Burgundy[W]	34.1 ± 0.5	4.04 ± 0.15	0.166	453.8 ± 3.2	21.65 ± 0.18	0.728	146.5 ± 0.7
Red Traminer (Roter Traminer)[W]	389.1 ± 3.1	18.02 ± 0.78	0.614	440.9 ± 2.5	16.94 ± 0.22	0.577	128.1 ± 0.9
Blue Franken (Lemberger, Blaufränkisch)[B]	318.6 ± 2.8	1.23 ± 0.03	0.076	513.3 ± 3.7	11.16 ± 0.15	0.391	299.6 ± 1.0
Zweigeltrebe[B]	615.1 ± 3.8	4.19 ± 0.08	0.171	573.2 ± 3.7	28.14 ± 0.54	0.937	357.8 ± 2.1
Alibernet[B]	400.9 ± 1.7	8.87 ± 0.10	0.321	737.9 ± 4.2	14.93 ± 0.23	0.514	874.3 ± 1.5
Wine-growing area Velké Žernoseky							
Müller-Thurgau[W]	53.4 ± 0.7	2.44 ± 0.07	0.115	858.0 ± 5.1	21.29 ± 0.32	0.718	164.1 ± 1.4
White Burgundy[W]	234.1 ± 1.6	6.38 ± 0.13	0.241	502.6 ± 4.3	20.94 ± 0.27	0.706	142.3 ± 1.1

Table 1 to be continued

Variety	Grape skins			Seeds			Must
	TP	ARA (%)	ARA	TP	ARA (%)	ARA	TP (mg/l)
Rhine (White) Riesling[W]	31.9 ± 0.9	5.56 ± 0.08	0.215	862.8 ± 5.0	20.08 ± 0.18	0.678	200.9 ± 2.0
Blue Portugal (Blauer Portugieser)[B]	63.3 ± 0.8	12.36 ± 0.21	0.433	341.4 ± 2.7	55.03 ± 0.62	1.799	253.9 ± 1.9
Saint Laurent[B]	218.7 ± 1.7	3.50 ± 0.08	0.149	579.5 ± 3.4	27.41 ± 0.50	0.914	396.3 ± 1.8
Average value of 25 samples	165.9 ± 1.44	6.37 ± 0.23	0.241	536.6 ± 3.1	27.21 ± 0.36	0.910	273.1 ± 1.5

[W] white, [B] blue

at a wavelength λ = 515 nm is measured on Heλios γ spectrophotometer (Spectronic Unicam, GB). Then 5 µl of sample extract is added and after stirring with the hand stirrer in cuvettes the reaction mixture is left to settle for 5 min. The absorbance is measured again and ARA is calculated from the decrease in absorbance in % according to the relation: % of inactivation = 100 $-[(A_{t5}/A_{t0}) \times 100]$. Calibration curves of ascorbic acid (Sigma), tannic acid (Fluka) and gallic acid (Merck) were constructed. Results were expressed as % of inactivation and calculated to the concentration of standard AA (mg/ml), which could provide the same inactivation as studied samples. Results were obtained from seven parallel determinations.

Statistical evaluation

Statistical evaluation of the results was done by Statistica programme at the level of statistical significance α = 0.05.

RESULTS AND DISCUSSION

The results of 25 analysed samples of grape must, skins and seeds are given in Tables 1 and 2. The average TP content was the highest in seeds (536.6 mg/g DM) and decreased in the order skins (165.9 mg/g DM) and must (273.1 mg/l). Seeds contained 3.2 times more TP than grape skins. This is in agreement with the results of Yildirim et al. (2005), who found that concentrations of gallic acid, monomeric catechin, and epicatechin were lower in the winery by-product grape skins than in seeds. Negro et al. (2003) also confirmed that grape seeds contained the highest quantities of proanthocyanidins. The tannins are considered superior antioxidants as their potential oxidation may lead to oligomerisation via phenolic coupling and enlargement of the number of reactive sites (Bors, Michel 2002). However, Kammerer et al. (2004) evaluated grape skins to be rich sources of anthocyanins, hydroxycinnamic acids, flavanols, and flavonol glycosides, whereas flavanols were major constituents present in seeds. Especially dimeric, trimeric, oligomeric or polymeric procyanidins account for the most of the superior antioxidant capacity of grape

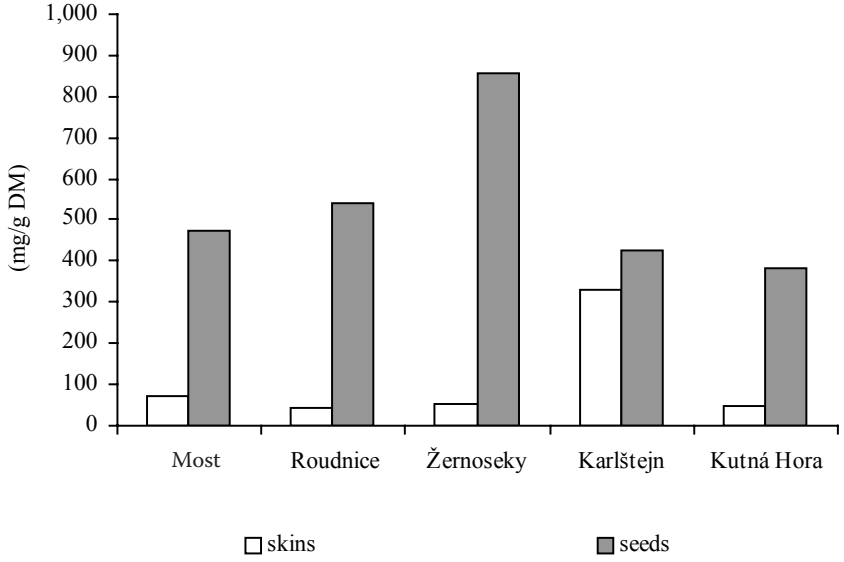

Fig. 2. Total polyphenol (TP) content in skins and seeds cv. Müller Thurgau

Table 2. Content of free *trans*-resveratrol (μg/kg DM)

Variety	Grape part	Wine-growing area	Content of *trans*-resveratrol
Blue Burgundy (Blauburgunder. Pinot Noir)	seeds	Kutná Hora	0.015*
White Burgundy	seeds	Most	0.025
Average value	**seeds**		**0.020**
Blue Burgundy (Blauburgunder. Pinot Noir)	skins	Kutná Hora	0.114
Blue Franken (Lemberger. Blaufränkisch)	skins	Kutná Hora	0.126
Zweigeltrebe	skins	Most	0.225
Bianca	skins	Karlštejn	0.009
Müller-Thurgau	skins	Velké Žernoseky	0.047
Müller-Thurgau	skins	Kutná Hora	0.038
White Burgundy	skins	Most	0.027
Saint Laurent	skins	Velké Žernoseky	9.630
Alibernet	skins	Most	4.798
Average value	**skins**		1.668

* The relative standard deviation (RSD %; $n = 3$) from the estimated concentration ranged for *trans*-resveratrol from 2.25 to 3.68% with average value 3.14%

Table 3. Analysis of variance of the content of total polyphenols

Grape part	Source of variability	*P*-values	Significance
Grape skins	wine-growing area	0.056704	*
	variety	0.292673	–
Grape seeds	wine-growing area	0.591718	–
	variety	0.757813	–

Table 4. Analysis of variance of antiradical activity

Grape part	Source of variability	*P*-values	Significance
Grape skins	wine-growing area	0.691572	–
	variety	0.828411	–
Grape seeds	wine-growing area	0.433584	–
	variety	0.818846	–

* significant differences ($p < 0.10$)

seeds (Yilmaz, Toledo 2004b). Contrary to TP the highest R content was found in grape skins (av. 166.818.10^{-5} mg/g DM) and it was 85 times higher in comparison with seeds (av. 1.969.10^{-5} mg/g DM). It is apparently related to *Botrytis* infection (Frémont 2000; Montero et al. 2003). Free *trans*-resveratrol was not found in musts in detectable amounts.

Statistical analysis of variance of the results (Tables 3 and 4, Figs. 4 and 5) did not reveal any statistically significant differences between the wine-growing regions and varieties in total polyphenol content in grape skins and seeds. Regarding wine-growing regions only a significant difference in TP ($p < 0.10$) in grape skins was found. ARA ($p < 0.05$) was not significant either for grape seeds or for grape skins in relation to wine-growing regions and varieties (Table 1). The highest TP content was measured in the samples from Velké Žernoseky (858 mg/g DM grape seeds) and Karlštejn (426.4 mg/g DM grape seeds and 412.8 mg/l must) wine-growing areas. Applying the multivariate analysis to phenolic compounds Peña-Neira et al. (2000) found both qualitative and quantitative differences in polyphenolic antioxidants of red and white Spanish wines of different geographical origin.

As expected, we can confirm significant varietal differences and differences between blue and white grape varieties. All average TP contents were higher in blue varieties (282.7 mg/g DM in grape skins, 546.3 mg/g DM in seeds and 326.7 mg/l in must) when compared with white varieties (149.6 mg/g DM in skins, 531.2 mg/g DM in seeds and 242.9 mg/l in must). Blue grape varieties have 1.89 times higher TP content in grape skins and 1.35 times higher in must

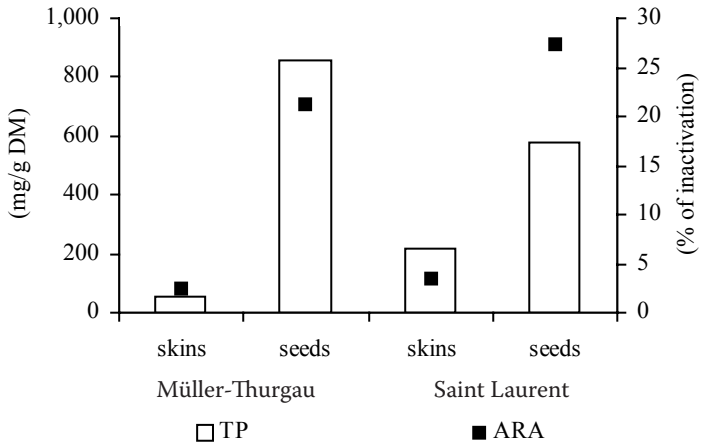

Fig. 3. Relationship between TP and ARA in V. Žernoseky wine-growing area

as compared with white grape varieties, whereas the content in seeds was practically the same. These results are in full accordance with the results of Peña-Neira et al. (2000) or Cantos et al. (2002). The highest TP contents were found in blue Zweigeltrebe from the wine-growing area Most (Table 1). Higher TP contents were found in blue grape varieties Alibernet and Saint-Laurent. On the contrary, lower TP contents were found out in white grape varieties such as Rhine (White) Riesling, Müller-Thurgau (Fig. 2), Kerner, Hibernal, and Green Sylvaner.

ARA was measured in grape skins and seeds (Table 1). It follows from the results that ARA expressed in AA equivalents was higher in grape skins of white grape varieties (0.271 AA mg/ml) in comparison with blue varieties (0.187 AA mg/ml), while in seeds the results were reciprocal (1.032 AA mg/ml in blue varieties and 0.841 AA mg/ml in white varieties). Regarding these results, it could be concluded that anthocyanins contained mainly in blue varieties contribute to ARA only to a lesser extent. Arnous et al. (2001) found that total flavanols contributed to hydroxyl free radical scavenging efficacy and to a lesser extent to antiradical and reducing ability, whereas there was a less significant relationship between the antioxidant properties and the total phenolics and only a weak relationship to total anthocyanin content. Kallithraka et al. (2005) also revealed a low and statistically insignificant correlation ($r^2 = 0.0724$, $p < 0.05$) between antiradical activity and total anthocyanin content. Thus, ARA will be dependent on special phenolics content, esp. in seeds (Fig. 3). The highest ARA values were found in Müller-Thurgau from the wine-growing area Karlštejn (2.436 AA mg/ml in seeds, 0.440 AA mg/ml in grape skins), Blue Portugal (2.223 AA mg/ml in seeds from Kutná Hora and 1.799 AA mg/ml in seeds and 0.433 AA mg/ml in grape skins from Velké Žernoseky), White Chrupka (1.852 AA mg/ml in seeds and 0.482 AA mg/ml in grape skins from Kutná Hora) and Saint Laurent (1.053 AA mg/ml in seeds from Roudnice nad Labem and 0.914 AA mg/ml from Velké Žernoseky). Durak et al. (1999) found that red wine, white wine and grape juices were characterised by strong antioxidant activity in a similar way.

In Fig. 1 we compared ARA of tannin >> gallic acid > ascorbic acid. In accordance with the hypothesis of Bors and Michel (2002) the tannins are considered superior antioxidants as their potential oxidation may lead to oligomerisation via phenolic coupling

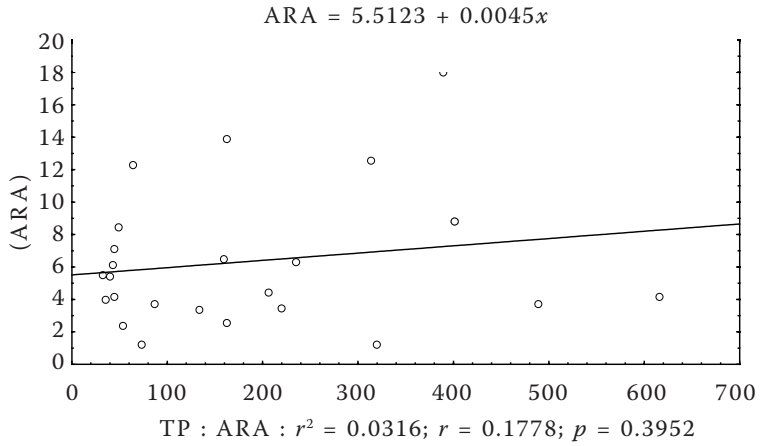

Fig. 4. Regression correlation between ARA and TP in grape skins

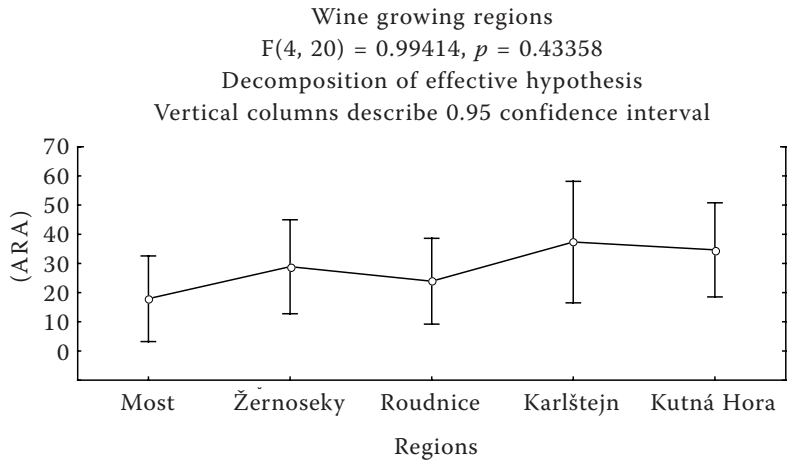

Fig. 5. Analysis of variance of ARA of grape seeds and wine-growing regions

and enlargement of the number of reactive sites. Gallic acid, monomeric catechin and epicatechin – three major phenolic constituents of grape seeds – also contribute to antioxidant capacity to a larger extent (Yilmaz, Toledo 2004b). Peroxyl radical scavenging activities of phenolics present in grape seeds or skins in decreasing order were resveratrol > catechin > epicatechin = gallocatechin > gallic acid = ellagic acid. Thus, functional ingredients of grape seeds – monomeric flavanols (catechin and epicatechin), dimeric, trimeric and polymeric procyanidins and tannins, and phenolic acids (gallic acid and ellagic acid) seem to be major contributors to antioxidant and antiradical activity (Yilmaz, Toledo 2004b; Makris et al. 2003). Resveratrol also has a stronger ability to inhibit lipid peroxidation as compared with other antioxidants: resveratrol > propyl gallate > tripolyphosphate > vanillin > phenol > butylated hydroxytoluene > α-tocopherol (Murcia, Martinez-Tome 2001). Antioxidant and vasodilatation activities are correlated with the total phenol content and they are associated especially with gallic acid, total resveratrol and total catechin (Burns et al. 2000).

CONCLUSION

It was clearly demonstrated that TP contents differed significantly between the wine-growing areas at the level of significance $p < 0.05$. In the total number of 25 grape samples it was not possible to determine *trans*-resveratrol in must and its content in grape seeds and skins was also low. The highest R content was found in grape skins (av. 1.668 μg/kg DM) and it was higher than in seeds (av. 0.020 μg/kg DM). The average TP content was the highest in seeds (536.6 mg/g DM) and decreased in the order skins (165.9 mg/g DM) and must (273.1 mg/l). Seeds contained more TP as compared with grape skins. All average TP contents were higher in blue grape varieties (282.7 mg/g DM in grape skins, 546.3 mg/g DM in seeds and 326.7 mg/l must), when compared with white grape varieties (149.6 mg/g DM in skins, 531.2 mg/g DM in seeds and 242.9 mg/l must). Blue grape varieties have higher TP content in grape skins and must as compared with white grape varieties. Statistically significant differences were found between the varieties ($p < 0.05$). ARA expressed in AA equivalents was higher in the grape skins of white grape varieties (0.271 AA mg/ml) in comparison with blue varieties (0.271 AA mg/ml), while in seeds the results were reciprocal (1.032 AA mg/ml in blue varieties and 0.841 AA mg/ml in white varieties) suggesting only a lesser contribution of anthocyanins to antioxidant activity. The assessment of ARA of extracts of model constituents of grapes tannin (T) and gallic acid (GA) revealed their higher antiradical activity in comparison with ascorbic acid (AA).

References

ARNOUS A., MAKRIS D.P., KEFALAS P., 2001. Effect of principal polyphenolic components in relation to antioxidant characteristics of aged red wines. Journal of Agricultural and Food Chemistry, *49*: 5736–5742.

BARTOLOMÉ B., NUÑEZ V., MONAGAS M., GÓMEZ-CORDOVÉS C., 2004. *In vitro* antioxidant activity of red grape skins. European Food Research and Technology, *218*: 173–177.

BAYDAR N.G., ÖZKAN G., SAĞDIÇ O., 2004. Total phenolic contents and antibacterial activities of grape (*Vitis vinifera* L.) extracts. Food Control, *15*: 335–339.

BIANCHINI F., VAINIO H., 2003. Wine and resveratrol mechanisms of cancer prevention? European Journal of 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. Journal of Chromatography A, *1012*: 31–38.

BORS W., MICHEL C., 2002. Chemistry of the antioxidant effect of polyphenols. Alcohol & Wine in Heath and Disease Annals of the New York Academy of Sciences, *957*: 57–69.

BURNS J., GARDNER P.T., O´NEIL J., CRAWFORD S., MORECROFT I., Mc PHAIL D.B., LISTER C., MATTHEWS D., Mac LEAN M.E.J., DUTHIE G.G., CROZIER A., 2000. Relationship among antioxidant activity, vasodilatation capacity, and phenolic content of red wines. Journal of Agricultural and Food Chemistry, *48*: 220–230.

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

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. Journal of Agricultural and Food Chemistry, *50*: 5691–5696.

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. Journal of Agricultural and Food Chemistry, *51*: 902–909.

DUGO G., SALVO F., DUGO P., LA TORRE G.L., MONDELLO L., 2003. Antioxidants in Sicilian wines: Analytic and compositive aspects. Drugs under Experimental and Clinical Research, *29*: 189–202.

DURAK I., AVCI A., KACMAZ M., BUYUKKOCAK S., CIMEN M.Y.B., ELGUN S., OZTURK H.S., 1999. Comparison of antioxidant potentials of red wine, white wine, grape juice and alcohol. Current Medical Research and Opinion, *15*: 316–320.

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

FRÉMONT L., 2000. Minireview. Biological effects of resveratrol. Life Sciences, *66*: 663–673.

KALLITHRAKA S., MOHDALY A.A.A., MAKRIS D.P., KEFALAS P., 2005. Determination of major anthocyanin pigments in Hellenic native grape varieties (*Vitis vinifera* sp.): Association with antiradical activity. Journal of Food Composition and Analysis, *18*: 375–386.

KAMMERER D., CLAUS A., CARLE R., SCHIEBER A., 2004. Polyphenol screening of pomace from red and white grape varieties (*Vitis vinifera* L.) by HPLC-DAD-MS/MS. Journal of Agricultural and Food Chemistry, *52*: 4360–4367.

KARAKAYA S., EL S.N., TAS A.A., 2001. Antioxidant activity of some foods containing phenolic compounds. International Journal of Food Sciences and Nutrition, *52*: 501–508.

KATALINIĆ V., MILOS M., MODUN D., MUSIĆ I., BOBAN M., 2004. Antioxidant effectiveness of selected wines in comparison with (+)-catechin. Food Chemistry, *86*: 593–600.

KOPEC K., 1994. Resveratrol – a chemoprotective component of grapes and wine. Horticultural Science (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. In: Proceedings of Conference Human Health and Preventive Nutrition. Brno, 7.–11. 7. 1998: 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 Research International, *36*: 805–814.

MATĚJKOVÁ Š., GUT I., 2000. Polyfenoly v potravě jako protektivní látky v aterosklerotickém procesu. Remedia, *10*: 272–281.

MOLYNEUX P., 2004. The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. Songklanakarin Journal of Science and Technology, *26*: 211–219.

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 Physiology, *131*: 129–138.

MURCIA M.A., MARTINEZ-TOME M., 2001. Antioxidant activity of resveratrol compared with common food additives. Journal of Food Protection, *64*: 379–384.

NEGRO C., TOMMASI L., MICELI A., 2003. Phenolic compounds and antioxidant activity from red grape marc extracts. Bioresearch Technology, *87*: 41–44.

PEÑA-NEIRA A., HERNÁNDEZ T., GARCÍA-VALEJJO C., SUAREZ J.A., 2000. A survey of phenolic compounds in Spanish wines of different geographical origin. European Food Research and Technology, *210*: 445–448.

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

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

YILDIRIM H.K., AKCAY Y.D., GUVENC U., ALTINDISLI A., SOZMEN E.Y., 2005. Antioxidant activities of organic grape, pomace, juice, must, wine and their correlation with phenolic content. International Journal of Food Science and Technology, *40*: 133–142.

YILMAZ Y., TOLEDO R.T., 2004a. Health aspects of functional grape seed constituents. Trends in Food Science and Technology, *15*: 422–433.

YILMAZ Y., TOLEDO R.T., 2004b. Major flavonoids in grape seeds and skins: Antioxidant capacity of catechin, epicatechin, and gallic acid. Journal of Agricultural and Food Chemistry, *52*: 255–260.

Received for publication May 6, 2005
Accepted after corrections May 20, 2005

Vztah mezi antiradikálovou aktivitou, polyfenolickými antioxidanty a volným *trans*-resveratrolem v hroznech révy vinné (*Vitis vinifera* L.)

ABSTRAKT: Byly stanoveny obsahy polyfenolických antioxidantů jako celkové polyfenoly (TP), resveratrolu (R) a jejich antiradikálová aktivita (ARA) ve slupkách a semenech hroznů odrůd vinné révy a TP v moštech z pěti vinařských oblastí českého regionu ze sklizně r. 2003. Obsah TP byl stanoven spektrofotometricky s Folin-Ciocalteuovým činidlem, obsah R pomocí HPLC a ARA za použití 1,1-difenyl-2-pikrylhydrazylového stabilního volného radikálu (DPPH). Získané výsledky byly vyhodnoceny statisticky programem Statistica. TP nevykázaly statisticky významné rozdíly mezi analyzovanými odrůdami ($p < 0,05$) u semen i slupek bobulí, ale ve vztahu k vinařským oblastem se podařilo u TP ($p < 0,10$) prokázat významný rozdíl jen u slupek bobulí. ARA ($p < 0,05$) byla neprůkazná jak pro semena, tak i pro slupky bobulí ve vztahu k oblastem i odrůdám. Nejvyšší obsahy TP byly nalezeny v semenech hroznů (536,6 mg/g sušiny), zatímco obsahy R byly vyšší ve slupkách (průměr 1,67 μg/kg sušiny). Modré odrůdy obsahovaly vyšší obsah TP ve slupkách hroznů i v moštu ve srovnání s bílými odrůdami. Vyhodnocení ARA extraktů modelových složek taninu (T) a gallové kyseliny (GA) potvrdilo jejich vyšší antiradikálovou aktivitu ve srovnání s askorbovou kyselinou (AA).

Klíčová slova: réva vinná; mošt; slupky; semena; polyfenolické antioxidanty; *trans*-resveratrol; antiradikálová aktivita; odrůdy; vinařské oblasti

Corresponding author:

Ing. Miloslav Šulc, Česká zemědělská univerzita v Praze, Fakulta agrobiologie, potravinových a přírodních zdrojů, 165 21 Praha 6-Suchdol, Česká republika
tel.: + 420 224 382 721, fax: + 420 234 381 840, e-mail: sulc@af.czu.cz