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Primary and Secondary Metabolites Related to the Quality Potential of Table Grape Varieties (*Vitis vinifera* L.)

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Summary

The primary and secondary metabolites, in addition to the berry grape colouration, of eleven table grape varieties (*Vitis vinifera* L.) (white 'Aurora', 'Matilde', 'Perlette', 'Regina dei vignetti', and red 'Cardinal', 'Chasselas red', 'Muscat Hamburg', 'Michele Palieri', 'Perlon', 'Ribier' and 'Ribol') from sub-Mediterranean traditional wine production region of Slovenia were screened in the years 2004, 2005 and 2006. Phenols, carbohydrates, and organic acids in grapes were analysed using a high-performance liquid chromatograph (HPLC), while for the colour analysis, a colorimeter and an O.I.V. descriptor were used. In primary and secondary metabolite content levels, significant differences were observed among varieties. The screened phenol content showed differences, especially in the average (+)-catechin (0.8–57.3 mg kg^{-1} FW), (-)-epicatechin (1.1–3.1 mg kg^{-1} FW), M-3-G (27–170 mg kg^{-1} FW), *trans*-resveratrol (0.24–3.05 mg kg^{-1} FW) and kaempferol (2.8–20.2 mg kg^{-1} FW) contents. In terms of flavan-3-ols, anthocyanins, *trans*-resveratrol and kaempferol content levels, the most abundant phenol levels were quantified in the red varieties, especially in 'Michele Palieri'. The red varieties, compared to the white varieties had higher and statistically significant average total sugar content (154 g kg^{-1} FW) and total acid content (6.0 g kg^{-1} FW). Taking into account all the determined metabolites of grape quality, the 'Perlon' variety differed most, but the grape quality properties of all the screened varieties were satisfactory.

Key words. anthocyanin – carbohydrate – colour – flavan-3-ol – flavonol – grape (*Vitis vinifera* L) – organic acid – stilbene

Introduction

Despite of the flood of new interspecies with American hybrids, the table grapes varieties of *Vitis vinifera* L. are still an important crop traditionally produced in the Mediterranean, and in the last decades also all over the World in traditional wine producing regions (O.I.V. 2003).

Grape quality is determined by primary (carbohydrates and organic acids) and secondary metabolites (phenols); grapes, however, are also an important source of minerals, vitamins and amino acids, and are therefore used not only for fresh consumption, but also in the food, pharmaceutical and cosmetic industries (Winkler et al. 1974; Adams 2006; Kennedy et al. 2006).

The colouration, as well as the flavour – delicate, slightly astringent and bitter – of grape have been associated with the presence of phenol compounds (Fernández-López et al. 1998; Adams 2006; Kennedy et al. 2006). Phenolic compounds comprise a miscellaneous group of over 4000 natural plant products and presented as flavan-3-ols, anthocyanins, hydroxycinnamates, flavonols and stilbenes, and their abundance can be influenced by many environmental factors and viticultural practices as well as by genotype (Mazza et al. 1999; Adams 2006). Flavan-3-ols are the most abundant category of soluble polyphenols in grape berries, found predominantly in the hypodermal layers of the skin and in the soft parenchyma of the seeds. Catechin and epicatechin make up the most important units in grape flavan-3-ols, epicatechin usually being the more abundant of the two. Anthocyanins form the second important group of phenolic compounds, which are co-located with flavan-3-ols in the thick-walled hypodermal cells of the skin. The anthocyanidins found in the grape of *Vitis vinifera* are cyanidin, delphinidin, peonidin, petunidin, and malvidin as the most abundant (Yokotsuka et al. 1999; Adams 2006). Flavonols – such as kaempferol, quercetin, myricetin, rutin etc. – are the third most abundant group of phenols, and in grape they are present in the form of glycosides, galactosides and glucuronides (Formica and Regelson 1995; Adams 2006). The most frequently reported stilbene is resveratrol, which is produced by plants in response to fungal infection or abiotic stress and in the last few years it has been the most researched phenolic compound because of its benefits for human health (Mertens-Talcott and Percival 2005).

Grape quality is also influenced by primary metabolites, especially carbohydrate and organic acid contents and their ratios in grape berries (Amerine et al. 1965; Shiraishi 1993, 1995). The predominant sugars are glucose and fructose, with lower contents of sucrose, except in varieties of *Vitis rotundifolia* and hybrids between *Vitis labrusca* and *Vitis vinifera*. The 90 % content of total organic acids is consisted by tartaric and malic acids, which have important effects on the characteristics of grape quality, such as

Table 1. Content of phenolic compounds in grape skin (mg kg^{-1} FW) of different table grape varieties from the period 2004–2006. Means and standard errors are presented.

Variety	Colour	Catechin	Epicatechin	M-3-G	Rutin
'Aurora'	W	19.9 ± 3.1 c	2.1 ± 0.2 b	<LOQ	2.6 ± 0.3 ab
'Matilde'	W	4.7 ± 0.1 b	2.6 ± 0.3 b	<LOQ	3.8 ± 0.1 bc
'Perlette'	W	4.3 ± 0.3 b	1.1 ± 0.1 a	<LOQ	1.3 ± 0.0 a
'Regina'	W	0.8 ± 0.4 a	1.5 ± 0.1 a	<LOQ	4.4 ± 0.7 c
'Cardinal'	R	18.0 ± 0.7 b	2.5 ± 0.3 c	136 ± 2 d	4.8 ± 0.4 b
'Chasselas red'	R	16.0 ± 11.0 ab	3.0 ± 0.2 cd	27 ± 1 a	1.6 ± 0.3 a
'M. Hamburg'	R	45.9 ± 1.0 c	1.9 ± 0.1 b	130 ± 4 d	2.2 ± 0.3 a
'Michele Palieri'	R	51.4 ± 0.3 cd	3.1 ± 0.1 d	170 ± 3 e	4.9 ± 0.2 b
'Perlon'	R	8.8 ± 1.8 a	1.2 ± 0.1 a	49 ± 4 b	1.2 ± 0.1 a
'Ribier'	R	56.1 ± 4.4 d	2.9 ± 0.2 cd	134 ± 6 d	6.8 ± 0.1 c
'Ribol'	R	57.3 ± 3.7 cd	2.7 ± 0.2 cd	122 ± 6 c	4.1 ± 0.0 b
P<0.05	W	a	a	a	
	R	b	b	b	NS

		trans-Resveratrol	Myricetin	Kaempferol	Quercetin
'Aurora'	W	0.54 ± 0.07 b	3.8 ± 0.9	7.2 ± 0.2 b	2.1 ± 0.3 a
'Matilde'	W	1.93 ± 0.12 d	5.5 ± 1.2	2.8 ± 0.0 a	4.7 ± 1.0 b
'Perlette'	W	0.81 ± 0.04 c	3.5 ± 1.0	7.9 ± 0.1 b	2.7 ± 0.3 a
'Regina'	W	0.24 ± 0.12 a	5.1 ± 0.9	10.0 ± 0.2 b	1.0 ± 0.1 a
'Cardinal'	R	1.69 ± 0.48 b	7.8 ± 1.7 d	9.7 ± 0.1 cd	8.4 ± 1.8 d
'Chasselas red'	R	0.67 ± 0.47 a	2.5 ± 0.3 ab	16.8 ± 0.1 b	1.5 ± 0.5 a
'M. Hamburg'	R	0.71 ± 0.19 a	3.7 ± 0.5 bc	18.2 ± 0.1 cd	3.2 ± 1.0 b
'Michele Palieri'	R	0.83 ± 0.16 a	5.4 ± 0.7 c	20.2 ± 0.4 d	6.7 ± 1.0 c
'Perlon'	R	<LOQ	1.5 ± 0.1 a	12.1 ± 0.9 a	1.0 ± 0.1 a
'Ribier'	R	3.05 ± 0.09 b	1.2 ± 0.2 a	19.1 ± 1.3 cd	4.0 ± 0.2 b
'Ribol'	R	0.90 ± 0.35 a	5.1 ± 0.9 c	16.0 ± 0.2 bc	2.9 ± 0.2 b
P<0.05	W	a	NS	a	NS
	R	b		b	

W: white variety; R: red variety; <LOQ: less than limit of quantitation; NS: no significant difference.
The same letters indicate no statistical difference at P<0.05 (Duncan test); capital letters indicate statistically significant differences between groups of red and white varieties; small letters indicate statistically significant differences among varieties within white or red group.

colour stabilization and mouth-feel. High acidity also has a negative influence on the palatability of table grape.

In fruit, colouration is the basic quality parameter (visual appreciation) and according to the O.I.V. descriptor code 225 the grape varieties could be divided into seven colour categories (O.I.V. 1983, 2001). For numerical evaluation of external skin colour, the CIE L*a*b* system can be used. The CIRG index ((180–h)/(L*+C*)) has been proposed, which is based on the parameters L* (lightness), h (hue angle) and C* (chroma). Using this index, skin colour can be classified into five groups (Carreño et al. 1997).

The quality properties of different table grape varieties (*Vitis vinifera* L.) have been poorly investigated, although some authors have reported results for other varieties; however, quantitative data are often missing, which is also confirmed by old references (Kliewer 1967; Kanellis and Roubelakis-Angelakis 1993). The main focus of this study is to present and critically analyse the primary and secondary metabolite abundances of identified grape quality in 11 different table grape varieties.

Material and Methods

Plant material

The study was carried out on 11 (4 white and 7 red) table grape vine varieties (*Vitis vinifera* L.) from the Ampelo-

Table 2. O.I.V. colour notes (O.I.V. 225; O.I.V. 1983, 2001), a*, b*, L*, chroma (C*), hue angle (h) and CIRG index according to variety from period 2004–2006. Means and standard errors are presented.

Variety	Variety colour	O.I.V. 225 note	a*	b*	L*
'Aurora'	W	1	−0.6 ± 0.3 c	8.6 ± 0.4 a	44.2 ± 0.5 b
'Matilde'	W	1	−3.0 ± 0.2 b	7.8 ± 0.5 a	45.6 ± 0.6 c
'Perlette'	W	1	−3.9 ± 0.3 a	17.5 ± 0.7 c	46.2 ± 0.5 c
'Regina'	W	1	−2.7 ± 0.1 b	12.1 ± 0.3 b	41.3 ± 0.3 a
'Cardinal'	R	4	4.7 ± 0.3 ab	1.0 ± 0.3 a	24.5 ± 0.2 a
'Chasselas red'	R	2	14.5 ± 0.3 e	7.8 ± 0.5 d	30.6 ± 0.5 c
'M. Hamburg'	R	4	8.1 ± 0.5 c	2.5 ± 0.3 b	27.5 ± 0.3 b
'Michele Palieri'	R	5	4.7 ± 0.5 ab	0.6 ± 0.2 a	24.1 ± 0.3 a
'Perlon'	R	2	12.6 ± 0.7 d	4.3 ± 0.3 c	27.1 ± 0.5 b
'Ribier'	R	5	5.7 ± 0.5 b	1.4 ± 0.2 a	25.1 ± 0.3 a
'Ribol'	R	4	4.2 ± 0.3 a	0.8 ± 0.1 a	24.5 ± 0.2 a
Average values	W		−2.5 ± 0.3 a	11.1 ± 0.4 b	44.2 ± 0.3 b
P<0.05	R		7.7 ± 0.2 b	2.6 ± 0.2 a	26.1 ± 0.2 a

			C*	h	CIRG
'Aurora'	W	1	8.8 ± 0.4 a	78.5 ± 1.4 b	1.92 ± 0.03 b
'Matilde'	W	1	8.5 ± 0.5 a	66.4 ± 1.7 a	2.10 ± 0.03 c
'Perlette'	W	1	18.0 ± 0.7 c	77.6 ± 0.9 b	1.60 ± 0.03 a
'Regina'	W	1	12.5 ± 0.3 b	76.9 ± 0.8 b	1.92 ± 0.20 b
'Cardinal'	R	4	4.6 ± 0.3 a	7.6 ± 0.7 ab	5.84 ± 0.10 de
'Chasselas red'	R	2	6.1 ± 0.3 e	26.1 ± 1.1 e	3.38 ± 0.07 a
'M. Hamburg'	R	4	8.5 ± 0.5 c	4.6 ± 1.0 c	4.64 ± 0.13 c
'Michele Palieri'	R	5	4.5 ± 0.4 a	6.3 ± 0.7 a	6.05 ± 0.12 e
'Perlon'	R	2	14.3 ± 0.6 d	19.3 ± 0.4 d	3.82 ± 0.09 b
'Ribier'	R	5	5.9 ± 0.4 b	9.7 ± 0.5 b	5.58 ± 0.11 d
'Ribol'	R	4	4.7 ± 0.3 b	9.1 ± 0.7 b	5.74 ± 0.11 d
Average values	W		11.6 ± 0.4 b	74.8 ± 0.8 b	1.9a ± 0.0 a
P<0.05	R		8.3 ± 0.3 a	13.3 ± 0.5 a	5.0 ± 0.1 b

W: white variety; R: red variety; NS: no significant difference.
The same letters indicate no statistical difference at P<0.05 (Duncan test); capital letters indicate statistically significant differences between groups of red and white varieties; small letters indicate statistically significant differences among varieties within white or red group.

graphic vineyard owned by the University of Ljubljana, Biotechnical Faculty, belonging to a sub-Mediterranean winegrowing region in Slovenia. The grapes from 10 plants of each white grape variety – 'Aurora' ('Reine des Vignes' x 'Perla di Csaba'), 'Matilde' ('Italia' x 'Cardinal'), 'Perlette' ('Reine des Vignes' x 'Thompson Seedless'), 'Regina dei vigneti' ('Reine des Vignes'; 'Regina Elisabetta' x 'Perla di Csaba') – and of red varieties – 'Cardinal' ('Flame Tokay' x 'Ribier'), 'Chasselas red' ('Gutedel'), 'Muscat Hamburg' ('Muscat de Alexandria' x 'Trollinger'), 'Michele Palieri' ('Ribier' x 'Red Malaga'), 'Perlon' ('Emperor' x 'Perlette'), 'Ribier' ('Alfonse Lavallée'; 'Bellino' x 'Lady Downes Seedling') and 'Ribol' ('Ribier' x 'Olivetta blanc') – were sampled in the years 2004, 2005 and 2006. The bunches harvested at the ripening stage, were picked randomly, and 100 berries per variety were included in the experiment. The vines were grown under the same agricultural practices and geographical and climatic conditions. After picking, the grape samples were frozen and stored as rapidly as possible in PE bags in darkness at −20 °C.

Sample preparation

First, as soon as possible after sampling, the colouration of grape skin was determined on fresh samples according to variety. On 30 fresh berries, five colour measures per berry (around berry) and per variety were done. The extractions for phenols were prepared according to the method described by Escarpa and González (2000) with

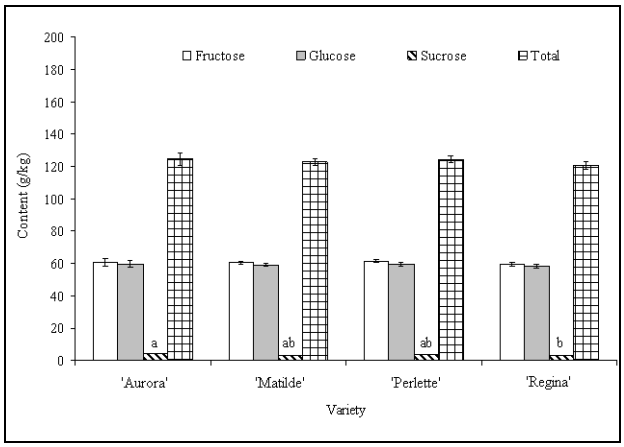


Fig. 1. The average carbohydrate contents (g kg^{-1} FW) in grape of studied white table grape varieties from period 2004–2006. The means and standard errors are presented. The different letters indicate statistical difference for individual sugars at P<0.05 (Duncan test).

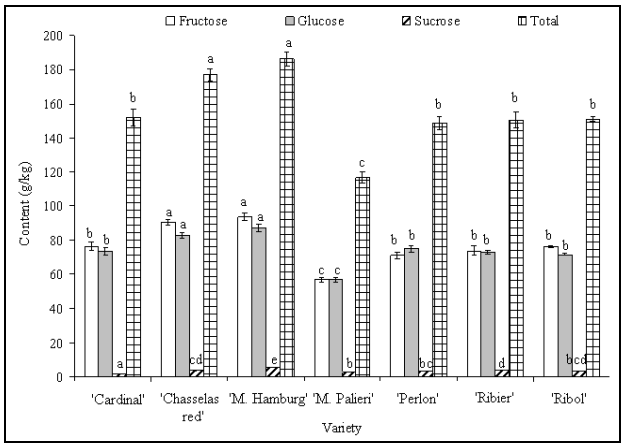


Fig. 2. The average carbohydrate contents (g kg^{-1} FW) in grape of studied red table grape varieties from period 2004–2006. The means and standard errors are presented. The different letters indicate statistical difference for individual sugars at P<0.05 (Duncan test).

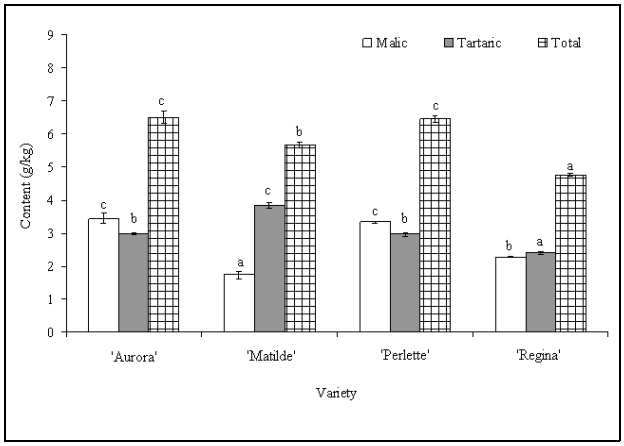


Fig. 3. The average organic acid contents (g kg^{-1} FW) in grapes of studied white table grape varieties from period 2004–2006. The means and standard errors are presented. The different letters indicate statistical difference for individual sugars at P<0.05 (Duncan test).

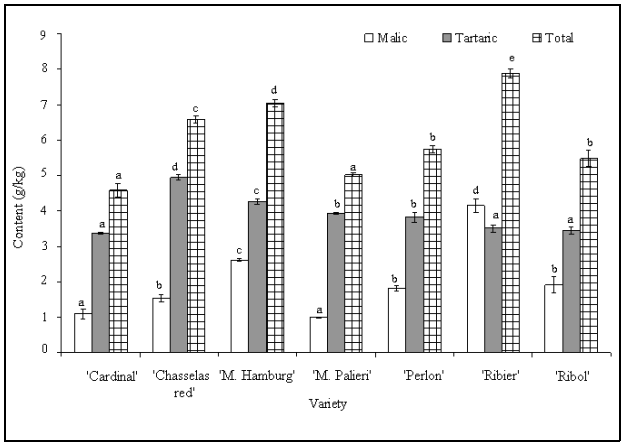


Fig. 4. The average organic acid contents (g kg^{-1} FW) in grapes of studied red table grape varieties from period 2004–2006. The means and standard errors are presented. The different letters indicate statistical difference for individual sugars at P<0.05 (Duncan test).

minor modifications in sample weight. The frozen berries were peeled, and 5 g of skin was weighed and directly extracted in 98 % methanol containing 1 % BHT using an ultrasonic bath (Iskra Pio, Slovenia). The samples were extracted first with 10 mL for 1 h, then with another 10 mL for 30 min and with another 5 mL for 30 min. The extract fractions were joined and filtered through a 0.45 μm syringe filter (Chromafil AO-45/25; Macherey-Nagel) prior to injection. BHT was added as antioxidant and did not interact with the extracted phenols or interfere with the subsequent HPLC analyses (Henderson and Slickman 1999).

The extraction of carbohydrates and organic acids followed the method citied by Šturm et al. (1999). The grapes were pressed, and samples of 1 mL of grape juice were diluted with MilliQ purified water (grape juice : water = 1:10 (*v/v*)). The mixtures were centrifuged for 7 min at 4200 rpm at room temperature (Eppendorf 5810 R, Hamburg, Germany). The supernatant was used and filtered through a 0.45 μm syringe filter (Chromafil A-25/25, Macherey-Nagel) and stored at −20 °C prior to injection.

Chemicals

The following standards prepared in aqueous or methanol solutions were used for the determination and quantification of quality parameters; (-)-epicatechin, quercetin, rutin, fructose and tartaric acid from Fluka Chemie GmbH [Buchs, Switzerland], (+)-catechin, *trans*-resveratrol, kaempferol, myricetin, sucrose, glucose and malic acid from Sigma Chemical Co. [St. Louis, MO]. Malvidin-3-glucoside (M-3-G) was from Extrasynthese S.A. [Genay, France].

The methanol used as an extraction solvent and the acetonitrile used as an elutant in the HPLC system were purchased from Merck KgaA [Darmstadt, Germany] and were of HPLC grade. Butylated hydroxytoluene (2,6-di-*tert*-butyl-4-methylphenol; BHT), which was used as an antioxidative agent in the extraction solution, was obtained from Sigma Chemical Co. [St. Louis, MO]. The water was additionally purified using the Milli-Q water purification system [Millipore; Bedford, MA].

Analytical methods

The analysis of phenols and the HPLC analysis were performed using a Thermo Finnigan Surveyor HPLC system (Thermo Finnigan, San Jose, CA) with a diode array detector scanning the spectra of wavelength at 280 nm. The system was controlled using the ChromaQuest 4.0 chromatography workstation software system. Separations were carried out using a Chromsep HPLC column SS (250 x 4.6 mm, Hypersil 5 ODS HPLC) from Chrompack (Middleburg, The Netherlands), maintained at 25 °C. The volume of injection was 20 μL and the flow rate was 1 mL min^{-1}. The chromatographic conditions were as previously described by Escarpa and González (2000). Gradient elution was used, consisting of solvent A: aqueous solution of phosphoric acid (0.01 M) and solvent B: methanol (Escarpa and González 2000). The elution programme was: 5–50 % B (10 min), 50–70 % B (5 min), 70–80 % B (5 min) and 80–100 % B (5 min).

The samples for carbohydrates and organic acids were analysed using a Thermo Separation Product with the HPLC system and a UV detector set at 210 nm for organic acids and with a differential RI detector for detection of carbohydrates. A Phenomenex (Rezex RCM-Monosaccharid Ca^+; 300 x 7.80 mm) column for carbohydrates and a Phenomenex (Rezex ROA-Organic acid H^+; 300 x 7.8 mm) column for acids were used and operated at 65 °C. The mobile phase for organic acids was an aqueous solution of H_2SO_4 (4 mM) and MilliQ purified water for carbohydrates. The volume of injection was 20 μL and the flow rate was 0.6 mL min^{-1}.

Identification and quantification of phenols, carbohydrates, and organic acids

The investigated and quantified phenolic compounds in grapes were flavan-3-ol monomers ((+)-catechin and (-)-epicatechin), anthocyanin (malvidin-3-glucoside), flavonols (kaempferol, quercetin, myricetin and rutin) and stilbene (*trans*-resveratrol). The individual phenols were identified by comparing their UV-vis spectra with those obtained from standards in combination with retention times, as well as by the addition of standard solutions. Quantification was achieved according to the concentrations of the corresponding external standard. Absorbance was monitored at 280 nm. The carbohydrates (sucrose, glucose and fructose) and organic acids (malic and tartaric) were quantified using standard solutions with known concentrations additionally combined with retention times as well as by the addition of external standard solutions in samples. The phenols were expressed in mg per kg of fresh weight (mg kg^{-1} FW), but carbohydrate and organic acid contents as g per kg of fresh weight (g kg^{-1} FW).

Fruit colour determination

The skin colour of each sample berry was first classified according to O.I.V. code number 225 (O.I.V. 1983, 2001). Surface colour of grape berries was also recorded with a Minolta CR-300 Chroma portable colourimeter (Minolta Co, Osaka, Japan), where the colour was expressed in L*, a* and b* colour space coordinates (CIE L*a*b*) and by calculating the CIRG index defined as CIRG = (180−h)/(L*+C*), where L* is lightness and represents the dark-light axis (0 % = black; 100 % = white), h is the hue angle, and $C^*=(a^{*2}+b^{*2})^{0.5}$ is the chroma and represents colour intensity. The colorimeter was calibrated before use with a standard white calibration plate (Carreño et al. 1997).

Statistical analyses

Data are presented as means with standard errors (milligrams or grams per kilogram of fresh material). The one-way analysis of variance (ANOVA) to test the significance of the observed differences was performed using the Statgraphic plus 4.0 software. The differences in quantified contents were evaluated using Duncan's test at $P<0.05$ and were considered to be statistically significant.

Results and Discussion

Content of phenols in grape skins

The identified phenol levels of abundance in grape skin are shown in Table 1. The statistical differences between white and red varieties were observed in (+)-catechin, (-)-epicatechin, M-3-G, *trans*-resveratrol and in kaempferol contents. The average (+)-catechin ranged from 0.8 in white to 57.3 mg kg^{-1} FW in red varieties and lower contents of average (-)-epicatechin from 1.1 in white to 3.1 mg kg^{-1} FW in red varieties, what confirmed the findings of Bonilla et al. (1999); Sakkiadi et al. (2001); Herrmann (2001) and of Tsanova-Savova et al. (2005). Generally, these data are in agreement with the findings of Bonilla et al. (1999), especially for red varieties and of Sakkiadi et al. (2001) with some exceptions. Compared to the data mentioned by Herrmann (2001) and by Tsanova-Savova et al. (2005), the contents of (+)-catechin and (-)-epicatechin in our study were lower, but higher for (+)-catechin compared to data by Núñez et al. (2004) especially for red varieties.

Malvidin-3-glucoside contents differed statistically among red varieties and ranged from 27 mg kg^{-1} FW in 'Chasselas red' to 170 mg kg^{-1} FW in 'Michele Palieri', a result which was expected considering the CIRG index and observations by Fernández-López et al. (1998). The determined M-3-G contents in our study were lower than those cited by González-Neves et al. (2004), Mori et al. (2005) and Kallithraka et al. (2005), who determined the average contents at ripe stage for around 360 mg kg^{-1} FW of grape skin; on the other hand, a M-3-G content several times higher, 1060 mg kg^{-1} was determined bf Stafford (1999), which could be explained by a difference in variety and by the method of quantification.

The most abundant and statistically different flavonols in the sampled skins were kaempferol followed by rutin, myricetin, and quercetin. The average values of kaemp-

ferol and quercetin in grape skin could be compared with the values cited by Bonilla et al. (1999) and by Rodríguez-Montealegre et al. (2006) especially for red varieties, with some exceptions (Table 1). But quite different quercetin contents in grape juice were citied by Mertens-Talcott and Percival (2005). The myricetin content ranged between 1.2 and 7.8 mg kg^{-1} FW, and this did not differ statistically between groups of white and red varieties. According to values cited by Rodríguez-Montealegre et al. (2006) that quantified levels of myricetin considerably lower, but Wang and Huang (2004), Volikakis and Efstathiou (2005), Tsanova-Savova and Ribarova (2002), Gambelli and Santaroni (2004) and Ho et al. (1999) citied the average myricetin in red wines, which cannot serve as an appropriate comparison with fresh grapes. The content of rutin varied from 1.2 to 6.8 mg kg^{-1} FW, where statistical differences were not observed between white and red varieties, but only among varieties with the same colour. Sakkiadi et al. (2001) citied rutin contents from 0.8 to 12.4 mg kg^{-1} only in red wine. Data on the rutin content in grape, especially in table grapes, was not observed in previous research.

The average contents of *trans*-resveratrol differed statistically between groups of white and red varieties, which were comparable to values citied by Sakkiadi et al. (2001) and by Martens-Talcott and Percival (2005) with some exceptions.

Determination of external skin colour

The mean values of the figures obtained according to the O.I.V. descriptors (1983, 2001) and the average values of L*, a*, b*, C*, h and of the CIRG index for the eleven grape varieties being studied are presented in Table 2. According to O.I.V. descriptor code 225, all white varieties were classified in category 1, the varieties 'Chasselas red' and 'Perlon' in 2 and 'Michele Palieri', 'Ribier' and 'Cardinal' received the highest value at 5, where 'Cardinal' is also mentioned as the standard variety for colour determination. Some of that data is comparable with values mentioned by Carreño et al. (1995, 1996).

The statistically lightest (L*) grape colour was recorded by whites varieties compared to red, especially by 'Perlette' and 'Matilde'. The average CIRG indices were statistically different among varieties and comparable with the results of Carreño et al. (1995) (Table 2).

Content of carbohydrates in grape juice

Separate figures for carbohydrate and total sugar contents of studied table grapes varieties are given in Fig. 1 and 2. The average total sugar content of white varieties was 123 g kg^{-1} FW, and statistical differences were observed only in sucrose content between 'Aurora' and 'Regina', although these varieties are genetically related.

In comparison with white varieties, the red table grapes had statistically higher average fructose (77.0 g kg^{-1} FW), glucose (74.3 g kg^{-1} FW) and total sugars (154.6 g kg^{-1} FW), but less sucrose (3.4 g kg^{-1} FW) (Fig. 2). The varieties 'Muscat Hamburg' and 'Chasselas red' had the highest total sugar, fructose and glucose contents. Comparison of 'Ribier', 'Cardinal' and 'Ribol' showed that they did not differ statistically in total sugar, fructose or glucose content, which can be explained with parental relationships. That did not work for 'Michele Palieri'. Many statistically significant differences were observed for sucrose content. The highest sucrose content was determined in 'Muscat Hamburg' (5.3 g kg^{-1} FW) and the lowest in 'Cardinal' (1.9 g kg^{-1} FW). The average carbohydrate content levels fell in range of values mentioned by Cosmo et al. (1974a, b) and Huai-Feng et al. (2006).

Content of organic acids in grape juice

The organic acid content in table grape juices is shown in Fig. 3 and 4. Statistically significant differences in acid contents were observed among table grape varieties. The lowest malic but the highest tartaric acid contents were found in 'Matilde', but the highest malic content in 'Aurora' and 'Perlette'. The total acid content was statistically different; 'Regina' had the lower values while the genetically related varieties 'Aurora' and 'Perlette'. 'Aurora' and 'Perlette', with the higher malic acid content, also had higher total acid content (Fig. 3).

In juices of red table grape varieties, the average content of malic acid (2.0 g kg^{-1} FW), tartaric acid (3.9 g kg^{-1} FW) and citric acid (0.1 g kg^{-1} FW) was established (Fig. 4). The highest malic acid content was found in 'Ribier' and the lowest in its hybrid 'Michele Palieri'. The 'Chasselas red' had the highest tartaric acid content, which was expected according to Huai-Feng et al. (2006). Lower tartaric acid content was determined in 'Ribier' and its genotype related varieties 'Cardinal', 'Ribol' and, to a lesser extent in 'Michele Palieri'.

According to the statistics for all varieties, the quality parameters could be difficult to explain by genotype relation, as has been suggested by many researchers (Kliewer 1967; Kanellis and Roubelakis-Angelakis 1993; Shiraishi 1995) but not confirmed in our study. The differences among content levels could be also explained by differences in grape variety, ecological conditions, viticulture practice or maturity stage, but also by extraction methods and solvents.

The study showed the importance of screened primary and secondary metabolites in relation to the quality of table grape, a finding which could be crucial not only for the varieties evaluated, but also applicable to wider table grape production in sub-Mediterranean regions.

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