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Impact of different pure cultures of *Saccharomyces cerevisiae* on the volatile profile of Cabernet Sauvignon rosé wines

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Abstract: Grape juice of Cabernet Sauvignon was fermented with three axenic cultures of *Saccharomyces cerevisiae* (CS-V1, CS-V2, CS-V3) to determine the effect of yeast strain on the aroma of rosé wine. An analytical methodology based on headspace solid phase microextraction combined with comprehensive two-dimensional gas chromatography and high-resolution time-of-flight mass spectrometry was used for identification of volatile organic compounds (VOC) in resulting wines. This method allowed the identification of 97 VOC responsible for wine aroma which was strictly affected by the strain used for fermentation. Results of the statistical analysis showed that strains CS-V2 and CS-V3 had the highest similarity of VOC profiles while CS-V1 was significantly different. Wine fermented with yeast strain CS-V1 was characterized by a high concentration of hexyl octanoate, 2-phenylethyl octanoate and free terpenoids (farnesol, farnesyl acetate). Strain CS-V2 contributed to an increased relative concentration of 1-hexadecanol, 1-heptanol, 9-decenoic acid and nerolidol. Wine fermented with CS-V3 had a high level of benzaldehyde, hexyl hexanoate, benzeneacetaldehyde and terpenoids α-terpineol and nerol.

Keywords: comprehensive gas chromatography; high-resolution mass spectrometry; winemaking technologies, yeast

Rosé is a specific type of wine produced from grapes of red grapevine varieties using short maceration of grape must. Wines are characterized by light body, fruity odours and miscellaneous shades of pink colour (Dimitra et al. 2016). The aroma of rosé wine is a dominant attribute of their quality (Swiegers et al. 2005). Dominant volatile organic compounds (VOC) of rosé wines are mostly represented by ethyl esters, acetates (particularly 3-methylbutyl acetate and 2-phenylethyl acetate), furaneol and especially the polyfunctional thiols 3-mercapto-1-hexanol and 3-mercaptohexyl acetate (Wang et al. 2016). Terpenes, methoxypyrazines, norisoprenoids, volatile phenols and furans are present at significantly lower concentrations but have a very low odour threshold (Culleré et al. 2009).

Cabernet Sauvignon rosé wines have been scarcely researched, and there is an absolute lack of information on their VOC profiles. However, previous studies on corresponding red wines showed relevant differences in VOC profiles affected by geographical localities (Tao et al. 2009). Cabernet Sauvignon wines from France are often described as fruity or floral with roast-

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ed, wood smoke, cooked meat nuances and herbaceous aromas, Australian and Californian wines showed intensive fruity, caramel, green, and earthy aromas, Cabernets from Brazil are characterized by bell pepper, red fruits and jam-like aromas while blackcurrant, green pepper, smoke, redcurrant, hay, vanilla, bilberry and cinnamon flavours are typical of Chinese Cabernet Sauvignons (Allen et al. 1990; Allen et al. 1994; Gurbuz et al. 2006; Falcao et al. 2007; Tao et al. 2009). Besides the locality, VOC profiles of varietal wines are strongly affected by the strain of yeast used for fermentation. Each yeast strain produces significantly different concentrations of VOC which form an aromatic character of wine (Zott et al. 2011; Furdíková et al. 2014; Ugliano et al. 2016).

The aim of this work was to characterise VOC profiles of Cabernet Sauvignon rosé wines fermented with three different strains of the yeast *Saccharomyces cerevisiae* using solid phase microextraction and subsequent two-dimensional gas chromatography connected to a high resolution time-of-flight mass spectrometric detector (SPME-GCxGX-HRTOF-MS).

MATERIAL AND METHODS

Grape must and fermentation. In an experiment, grapes of Cabernet Sauvignon 2016 originated from the Central Slovak Wine Region (Slovak republic, Veľký Krtíš viticultural municipality) were used. Grapes were destemmed, crushed and grape must was macerated for 3 h at 18 °C. Pressed grape must was treated with a sanitizing dose of SO_2 (20 mg L^{-1}) and inoculated with axenic culture of *S. cerevisiae* (starting concentration 10^5 cells ml^{-1}). The fermentation was carried out in 30 L fermenters at a controlled temperature of 16–18 °C. After fermentation the wine was racked off gross lees, treated with SO_2 (35 mg L^{-1}) and aged in 20 L glass containers. After two months of maturing, the wine was filtered through a plate filter and treated with 50 mg L^{-1} of total SO_2.

Microorganisms and preparation of inoculum. Three pure cultures of *Saccharomyces cerevisiae* (strains CS-V1, CS-V2 and CS-V3) were used. These strains originate from the yeast collection of the Institute of Biotechnology, Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava. In previous research, they were isolated from the same location as the grapes used for fermentation.

Yeast starters for grape must inoculation were prepared by aerobic cultivation of yeast strains in 100 mL of liquid YD broth (20 g L^{-1} glucose, 10 g L^{-1} yeast extract; pH 6.5) in 500 mL cultivation flasks. Aeration was maintained using an orbital shaker (2 Hz) and cultivation was carried out at 28 °C. After 24 h of cultivation, biomass was withdrawn, centrifuged (10 min, 1 370 g), washed with demineralized water and centrifuged again. Separated biomass was diluted with a small portion of demineralized water and concentration of biomass in suspension was determined by the Bürker chamber. Calculated aliquots of yeast suspension were added to grape must to achieve the starting biomass concentration of 10^5 cells mL^{-1}.

Analysis of basic oenological parameters. No extensive sample treatment was required for HPLC analysis. Grape juice and corresponding wines were centrifuged (10 min, 2 511 g) and the obtained supernatant was diluted five times with deionized water. Twenty microliters of prepared sample were injected into Agilent 1 100 (Agilent Technologies, Germany) equipped with diode array detector (210 nm) and refractive index detector.

Samples were analysed using Aminex II PX-87H (Bio-Rad Laboratories Hercules, USA) column which was tempered at 25°C. A five millimolar solution of H_2SO_4 with the constant flow rate of 0.6 mL min^{-1} was used as a mobile phase. The analyte (lactic, tartaric, malic, citric, acetic acid, ethanol, glucose, fructose) concentrations were calculated based on the standard addition method. For preparation of a standard solution, chemicals with purity higher than 99.5% obtained from Merck (Germany) were used.

Analysis by gas chromatography. The volatile organic compounds from grape juice and corresponding wines were analysed by comprehensive two-dimensional gas chromatography. This method was previously described by Furdíková et al. (2017). For semi-quantification purposes, relative concentrations (c_{rel}) of VOC were calculated by the ratio of each individual peak area to the area of internal standard (benzophenone) and converted to concentration equivalents based on internal mass added (Lima et al. 2017).

Statistical analysis. Concentrations of basic oenological parameters and relative concentrations of VOC of three wine samples were evaluated by one-way analysis of variance (ANOVA) to calculate Fisher's ratios and *P* values of each analyte. VOC were subjected to principal component analysis (PCA) to determine which analytes are responsible for the main differences between samples. Both ANOVA and PCA were performed using the Statistica 12 software (StatSoft, USA).

Sensory analysis. Sensory analysis of the aroma of final rosé wines was performed by 14 evaluators using

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quantitative descriptive analysis. A 10-point test was used to assess the intensity of flavours which are typical of the Cabernet Sauvignon variety. Flavours that did not show any intensity were rated by 0, and those with the highest intensity by 10 points. For corresponding aromas arithmetic averages were calculated and relevant aromagrams were constructed.

RESULTS AND DISCUSSION

Basic oenological analysis. ANOVA performed for the basic analysis of wine samples showed significant differences ($P < 0.05$) in all descriptors except the means of reducing sugar concentrations which were evaluated as not significantly different ($P > 0.05$) in all 3 cases (Table 1). From the statistical point of view, strains CS-V1 and CS-V2 were more similar than strain CS-V3.

Sensory analysis. Sensory analysis has shown that distinctive fruity and sweet tones prevailed in wines (Figure 1). Varietal typicity was evaluated by 5–6 points in the 10-point test. Herbal and green tones are typical of Cabernet Sauvignon; they were not rated higher in any sample. Wines fermented with strains CS-V2 and CS-V3 were characterized by intense strawberry aroma, aroma of wine fermented with CS-V1 was dominantly raspberry-like. Other identified main components of wine aroma were the aroma of apple compote, pomegranate, cherries and grapefruit.

Analysis of VOC profile. Totally, 97 VOC were identified in analysed rosé samples: 64 in grape juice and 70 in wines. From these, 57 VOC were found in all analysed wines, while 13 were variable (Table 2). Identified VOC include 41 esters, 20 higher alcohols, 13 terpenoids, 8 carbonyl compounds, 7 volatile acids, 3 volatile sulphur compounds, 4 lactones and 1 naphthalene derivative.

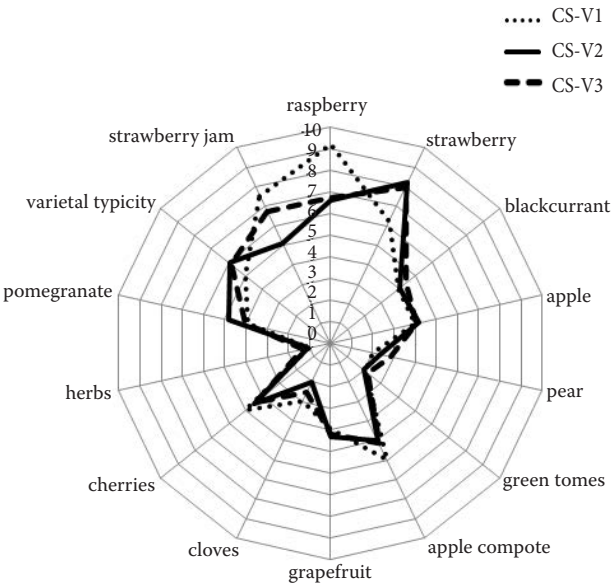

Figure 1. Aromagram of Cabernet Sauvignon rosé wines fermented with autochthonous pure cultures of *S. cerevisiae* CS-V1, CS-V2, CS-V3 (maximum SD ± 15%)

The total relative concentration of identified VOC in grape juice rose rapidly through the fermentation and the influence of yeast strain was significant. Esters, higher alcohols and terpenoids were quantitatively and qualitatively the most abundant groups of volatiles in wines.

Esters were the major group of identified VOC in wines. The highest c_{rel} was shown by ethyl esters of decanoic, octanoic and hexanoic acid. At the optimal concentrations, ethyl decanoate and octanoate bring the sweet and floral aroma to wine. It was published that these esters are commonly found in wines at a concentration of 0–3.8 mg L^{-1} (Swiegers et al.

Table 1. Basic chemical analysis of Cabernet Sauvignon rosé juice and wines fermented with 3 different strains of *Saccharomyces cerevisiae* (CS-V1, CS-V2 and CS-V3)

	Grape juice	CS-V1	CS-V2	CS-V3
Glucose + fructose	177.5 ± 8.8	20.8 ± 1.0*	19.1 ± 0.9*	19.1 ± 0.9*
Ethanol	ND	70.1 ± 3.5*	74.7 ± 3.7*^	81.7 ± 4.1^
Acetic acid	ND	0.32 ± 0.02	0.27 ± 0.01*	0.27 ± 0.01*
Tartaric acid	3.34 ± 0.10	2.51 ± 0.08	2.87 ± 0.09	2.14 ± 0.06
Lactic acid	ND	0.04 ± 0.01	ND	0.36 ± 0.01
Citric acid	0.73 ± 0.02	0.59 ± 0.02*	0.55 ± 0.02*	0.17 ± 0.01
Malic acid	5.22 ± 0.16	5.00 ± 0.15*	5.19 ± 0.16*	3.03 ± 0.09

The data (g L^{-1}) are mean values of triplicate samples; ANOVA was performed only for samples of wines; the same characters in the same row (*, ^) correspond to not statistically significant difference ($P \geq 0.05$); ND – not detected

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Table 2. Volatile compounds identified in samples of Cabernet Sauvignon rosé juice and wines fermented with 3 strains of *Saccharomyces cerevisiae* (CS-V1, CS-V2 and CS-V3)

LTPRI	ID	VOC	c_{rel}				FR
			Juice	CS-V1	CS-V2	CS-V3	
		Carbonyl compounds					
1 200	TI	2-Hexenal	1.6	ND	ND	ND	–
1 383	TI	2,4-Hexadienal	1.7	ND	ND	ND	–
1 495	ST	Decanal	1.1	1.6	ND	1.1	1 242.6
1 520	ST	Benzaldehyde	24.5	18.7	15.5	73.1	2 273.4
1 624	TI	3-Methylbenzaldehyde	ND	1.1	1.1	0.5	208.3
1 630	ST	Benzeneacetaldehyde	19.7	1.1	1.1	3.7	1 879.7
1 654	TI	4-Methylbenzaldehyde	33.6	45.3	43.7	39.5	2.0*
1 709	TI	Dodecanal	5.3	ND	ND	ND	–
		Sulphur compounds					
1 534	ST	3(2H)-Thiophenone,dihydro-2-methyl (Blackberry tiophenone)	1.6	6.9	5.9	4.8	242.6
1 705	TI	1-Propanol, 3-methylthio-	0.5	3.2	1.6	2.7	250.0
1 948	TI	1,3-Benzothiazole	ND	1.6	1.6	1.6	0.0*
		Volatile acids					
1 834	ST	Hexanoic acid	ND	616.5	433.0	560.0	36.1
1 956	TI	Heptanoic acid	1.1	ND	ND	ND	–
2 046	ST	Octanoic acid	294.9	1 501.8	1 415.4	1 429.8	4.4*
2 156	TI	Nonanoic acid	5.3	ND	ND	ND	–
2 254	ST	Decanoic acid	43.7	1 082.1	923.1	850.1	35.5
2 335	TI	9-Decenoic acid	17.6	ND	450.6	ND	2 500.0
2 485	TI	Dodecanoic acid	40.0	27.2	38.4	16.0	95.2
		Esters					
1 226	ST	Hexanoic acid, ethyl ester	ND	2 139.6	2 077.2	1 922.0	2.3*
1 270	ST	Acetic acid, hexyl ester	328.0	725.3	940.2	749.8	39.5
1 305	TI	Acetic acid, hex-3-en-1-yl ester	4.3	51.2	67.7	65.1	22.1
1 342	ST	Propanoic acid, 2-hydroxy-, ethyl ester	ND	ND	6.4	162.1	929.6
1 370	ST	Acetic acid, n-heptyl ester	ND	3.2	18.7	ND	1 923.4
1 388	ST	Octanoic acid, methyl ester	106.7	330.1	293.9	408.0	65.1
1 420	ST	Octanoic acid, ethyl ester	22.9	3 027.0	3 101.1	3 448.3	148.4
1 450	TI	Hexanoic acid, 3-methylbutyl ester	3.2	24.5	22.9	10.7	68.3
1 480	TI	Nonanoic acid, methyl ester	ND	ND	ND	3.2	612.2
1 515	TI	Pentanoic acid, 2-hydroxy-4-methyl-, ethyl ester	ND	ND	ND	11.2	1 578.9
1 541	ST	Nonanoic acid, ethyl ester	ND	49.6	42.1	88.5	1 18.7
1 551	ST	Octanoic acid, 2-methylpropyl ester	3.2	3.2	38.9	46.9	818.0
1 572	TI	Propanoic acid, 2-hydroxy-, 3-methylbutyl ester	ND	ND	ND	24.5	1 071.4
1 580	ST	Decanoic acid, methyl ester	193.6	1 434.0	377.6	1 558.8	389.9
1 580	TI	Hexanoic acid, hexyl ester	5.3	1.1	1.1	19.7	2 052.1

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Table 2 to be continued

LTPRI	ID	VOC	c_{rel}				FR
			Juice	CS-V1	CS-V2	CS-V3	
1 600	TI	Benzoic acid, methyl ester	16.5	ND	ND	ND	–
1 620	TI	4-Decenoic acid, methyl ester	16.5	ND	276.3	ND	1 578.9
1 633	ST	Decanoic acid, ethyl ester	230.4	1 463.4	3 216.3	3 804.6	707.4
1 645	TI	Octanoic acid, 3-methylbutyl ester	23.5	205.3	221.3	253.9	27.2
1 652	ST	Benzoic acid, ethyl ester	ND	1.6	1.6	2.1	11.6
1 666	ST	Butanedioic acid, diethyl ester	ND	11.7	11.7	68.3	1 494.5
1 675	TI	9-decenoic acid, ethyl ester	34.1	262.9	1 316.2	104.0	695.3
1 679	ST	Acetic acid, decyl ester	ND	7.5	ND	ND	625.0
1 690	TI	Acetic acid, phenylmethyl ester	0.5	ND	ND	ND	–
1 734	TI	Undecanoic acid, ethyl ester	ND	89.6	73.6	132.8	87.6
1 750	TI	Decanoic acid, 2-methylpropyl ester	ND	ND	24.0	3 520.0	608.1
1 755	TI	Benzoic acid, 2-hydroxy-, methyl ester	3.2	6.9	5.9	7.5	20.5
1 770	TI	Benzeneacetic acid, ethyl ester	ND	16.0	11.2	16.0	51.6
1 785	ST	Dodecanoic acid, methyl ester	105.1	291.2	276.3	162.1	184.1
1 791	ST	Benzoic acid, 2-hydroxy-, ethyl ester	ND	1.1	0.5	1.1	850.7
1 799	TI	Acetic acid, 2-phenylethyl ester	27.2	315.2	250.1	308.3	63.9
1 800	TI	Octanoic acid, hexyl ester	14.9	10.1	ND	ND	1 428.6
1 825	ST	Dodecanoic acid, ethyl ester	50.7	508.8	1 058.6	521.6	111.8
1 864	TI	Decanoic acid, 3-methylbutyl ester	ND	ND	296.0	115.2	4 965.1
1 989	ST	Tetradecanoic acid, methyl ester	6.9	11.7	28.3	12.3	347.8
2 011	TI	Decanoic acid, hexyl ester	ND	4.8	7.5	4.8	34.4
2 043	ST	Tetradecanoic acid, ethyl ester	9.1	225.1	374.4	189.3	79.7
2 050	TI	Dodecanoic acid, 3-methylbutyl ester	ND	32.0	34.1	ND	791.1
2 177	ST	Hexadecanoic acid, methyl ester	ND	ND	40.5	ND	1 428.6
2 235	ST	Hexadecanoic acid, ethyl ester	45.3	400.0	454.9	398.4	14.8
2 376	TI	Octanoic acid, 2-phenylethyl ester	ND	4.3	ND	ND	1 578.9
		Higher alcohols					
1 210	ST	1-Butanol, 3-methyl-	160.5	1060.7	1033.0	1171.7	2.8*
1 313	ST	2-Heptanol	1.1	ND	ND	ND	–
1 348	ST	1-Hexanol	523.6	362.6	330.1	453.8	39.5
1 355	ST	3-Hexen-1-ol	45.3	ND	0.5	1.1	642.9
1 388	ST	2-Hexen-1-ol	3.2	ND	ND	ND	–
1 405	ST	3-Octanol	1.6	ND	ND	ND	–
1 423	ST	2-Octanol	1.1	ND	ND	ND	–
1 442	ST	1-Octen-3-ol	11.2	ND	ND	ND	–
1 449	ST	1-Heptanol	19.6	1.1	13.3	ND	2 124.3
1 467	ST	2-Ethyl-1-hexanol	22.4	6.9	5.3	5.9	41.4
1 510	ST	2-Nonanol	1.6	3.7	ND	4.8	736.3
1 529	ST	2,3-Butanediol	ND	68.3	93.9	104.0	96.7
1 545	ST	1-Octanol	9.6	22.9	12.8	40.5	474.9
1 647	ST	1-Nonanol	3.7	2.1	5.9	1.6	557.7

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Table 2 to be continued

LTPRI	ID	VOC	c_{rel}				FR
			Juice	CS-V1	CS-V2	CS-V3	
1 749	ST	1-Decanol	1.6	122.7	52.8	96.5	196.7
1 840	TI	1-Undecanol	0.5	ND	ND	ND	–
1 869	ST	Benzyl alcohol	13.3	37.9	17.6	51.7	857.2
1 896	ST	2-Phenylethanol	113.1	460.8	252.8	464.5	54.8
1 940	TI	1-Dodecanol	2.1	11.2	14.9	7.5	63.3
2 387	TI	1-Hexadecanol	ND	1.6	5.3	ND	1 144.4
		Naphthalene compounds					
1 901	TI	α-Calacorene	3.7	19.2	10.7	13.3	123.7
		Terpenoids					
1 539	ST	Linalool	1.6	9.6	2.1	11.7	9 757.3
1 560	TI	α-Ionene	ND	ND	1.6	ND	612.2
1 594	ST	Terpinen-4-ol	10.1	2.7	6.9	7.5	267.4
1 648	ST	Citronellyl acetate	ND	4.8	4.8	6.4	22.6
1 663	TI	α-Terpineol	1.1	ND	ND	1.1	1 578.9
1 692	TI	α-Farnesene	0.5	6.4	3.2	5.9	1 029.9
1 740	TI	β-Farnesene	ND	25.1	19.2	21.9	8.6
1 755	TI	β-Citronellol	1.1	9.6	3.2	11.2	144.5
1 773	TI	β-Damascenone	136.0	168.0	113.6	107.7	48.3
1 780	ST	Nerol	ND	ND	ND	4.8	1 071.4
2 030	ST	Nerolidol	3.2	26.1	40.0	23.5	834.2
2 248	TI	Farnesyl acetate	ND	4.3	ND	ND	2 500.0
2 350	ST	Farnesol	ND	17.6	ND	ND	2 307.7
		Furans and lactones					
1 457	ST	Furfural	ND	0.5	ND	1.1	295.1
1 599	TI	2-Furancarboxylic acid, ethyl ester	ND	11.7	16.5	10.7	88.0
1 616	ST	γ-Butyrolactone	1.6	28.8	27.7	43.7	82.0
1 745	ST	2(5H)-Furanone	ND	ND	ND	0.5	769.2

The data are mean values of the triplicate samples (SD < 5%); LTPRI – linear temperature programmed retention index; VOC – volatile organic compound; ID – identification of VOC; ST – VOC confirmed by authentic standard; TI – tentatively identified VOC; c_{rel} – relative concentrations expressed as units of the internal standard benzophenone (μg L^{-1}); FR – Fisher's ratio calculated for triplicate samples; *$P \geq 0.05$; ND – not detected

2005). In wine fermented with *S. cerevisiae* CS-V3, the highest c_{rel} of ethyl decanoate (3.8 mg L^{-1}) and ethyl octanoate (3.4 mg L^{-1}) was found. Ethyl hexanoate, which imparts the characteristic flavour of green apple, was determined in all samples and its c_{rel} was 1.9–2.1 mg L^{-1}. Presence of these esters corresponded with results of sensory analysis. Also, their calculated odour activity values (OAV) confirmed their relevant contribution to the aroma of wines: based on values of the odour threshold of particular compounds (Guth 1997) OAV of ethyl decanoate in wine fermented with strain CS-V3 was 19, OAV of ethyl octanoate 1 700 and OAV of ethyl hexanoate –380. In consequence of fermentation, total concentration of identified esters increased more than 10-times on average. In all samples, many esters which are char-

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acterized by strong fruity flavours were identified, which correlates with sensory analysis.

Higher alcohols were the second most abundant group of VOC in wines. According to the type of higher alcohol, they are produced either by microbial metabolism or synthetized by grapevine. C_6–C_8 alcohols are typical products synthetized by grapevine and their concentration decreases during the fermentation process. They are formed via the lipoxygenase metabolic pathway, which is specific to plants (and missing

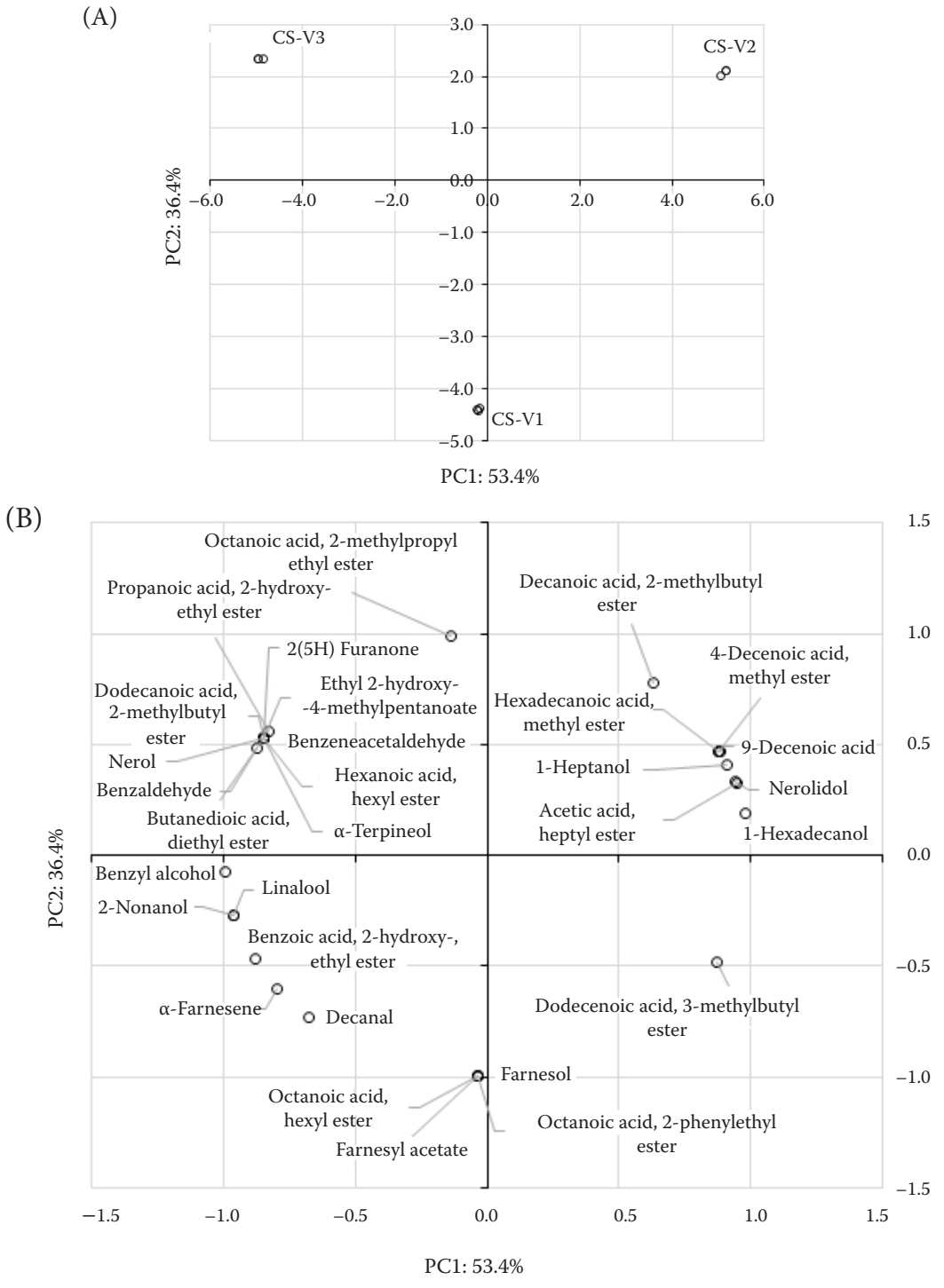

Figure 2. Score plot (A) and loading plot (B) of the first and second principal components

PC – Principal component

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in *Saccharomyces cerevisiae* metabolism) (Baysal & Demirdoven 2007), and donate green and vegetal odours typical of Cabernet Sauvignon. Among these alcohols, 1-hexanol, 1-heptanol, 3-hexen-1-ol, 1-octen-3-ol, 1-undecanol, 2-ethylhexanol, 2-heptanol, 2-octanol, 3-octanol, 2-hexen-1-ol were identified. 1-Hexanol showed the highest c_{rel} (523 μg L^{-1}) in grape juice and its concentration in wines slightly decreased. Calculated OAV for 1-hexanol was 0.07 (Guth 1997). Total concentration of identified higher alcohols rose due to fermentation but their increase was less intense than that of esters. Compared with other strains, *S. cerevisiae* CS-V3 showed the most intense production of higher alcohols (3-methylbutanol, 2-phenylethanol, 2,3-butanediol, 2-nonanol, etc.) while the lowest production was found in wine fermented with CS-V2.

In grapes, terpenoids are present both in free and glycosidically bound forms (Michlmayr et al. 2012). Compared with esters and higher alcohols, concentrations of terpenoids in wines are significantly lower. Nevertheless, their impact on sensory profile is high because of very low odour thresholds. Until now, more than 50 terpenoids have been identified in wines and their presence and concentration strongly depend on the grapevine variety (Furdíková et al. 2014). Cabernet Sauvignon belongs to non-aromatic grapevine varieties and does not have a rich terpenoid profile. Fourteen terpenoids were identified in samples of grape juice and rosé wines, while β-damascenone (aroma of rose, cooked apple or honey) was the most dominant. Its concentration in wines reached 107.7–168.0 μg L^{-1}, which corresponds to the odour activity value of 2 154–3 360. This C13 norisoprenoid is formed by oxidation of carotenoids and was found in most varietal wines, including the Cabernet Sauvignon (Black et al. 2015). β-Damascenone showed the highest c_{rel} in a wine sample fermented with CS-V1. The highest c_{rel} of farnesenes (α, β) and the presence of farnesol and farnesyl acetate were also characteristic of this strain. In the case of CS-V2 yeast, a significant concentration of nerolidol (floral flavour) and α-ionene was determined. The higher c_{rel} of nerol (rose aroma) and terpinen-4-ol (must, sweet) was typical of a wine fermented with CS-V3. Generally, strain CS-V1 was characterized by the higher total c_{rel} of terpenoids (274.1 μg L^{-1}) in comparison with CS-V2 (194.7 μg L^{-1}) and CS-V3 (201.6 μg L^{-1}).

VOC profiles determined in three rosé wines were compared using ANOVA and PCA (Figure 2). ANOVA showed significant differences for 73 volatiles ($P < 0.001$). Thirty VOC with the highest Fisher's ratios (FR > 730) served as input data for PCA. Wine fermented with yeast strains CS-V1 and CS-V2 showed higher similarity in comparison with the strain CS-V3 (Figure 2). The correlation matrix calculated for all VOC had total variability of 99.8% (63.4% for PC1 and 36.4% for PC2). As shown in Figure 2, these VOC could distinguish and characterise three rosé wines based on the used strain. The PC1 axis separates strains CS-V1 and CS-V2 and the PC2 axis separates them from more different strain CS-V3. Farnesol, farnesyl acetate, hexyl octanoate and 2-phenylethyl octanoate (green, floral, sweet flavours) negatively correlate with PC1 and separate strain CS-V1 from the two others. This result also correlates with sensory analysis in which wine fermented with CS-V1 differed in strawberry aroma from wines fermented with CS-V2 and CS-V3, which were characterized by raspberry odour. Strains CS-V2 and CS-V3 expressed smaller differences in volatile profiles. Benzaldehyde, hexanoic acid, hexyl acetate, benzeneacetaldehyde, α-terpineol and nerol showed the highest negative correlation with PC2 and distinguished strain CS-V1 from CS-V2. On the other hand, the highest positive correlation with PC2 was recorded in 1-heptanol, nerolidol, heptyl acetate and 1-hexadecanol.

CONCLUSION

In this work the influence of pure cultures of *Saccharomyces cerevisiae* on the sensory profile of varietal rosé wine Cabernet Sauvignon was studied. Chemical analysis enabled to characterize basic oenological parameters of rosé wines fermented with different strains of yeast. Statistical analysis showed the similarity of wines fermented with strains CS-V2 and CS-V3 in terms of basic parameters. Sensory evaluation showed that the wines were overall candy-like, less spicy and characterized by sweet, fruity, strawberry and raspberry flavours.

Number and overall concentrations of VOC determined in wines increased because of fermentation. The most abundant chemical groups in all rosé wine samples were esters, higher alcohols and terpenoids. Statistical analysis showed significant differences in the VOC profiles of wines and enabled to specify VOC defining the most important differences between wines according to the used *Saccharomyces cerevisiae* strain. Every wine had its own specific character that points to the importance of yeast strain selection.

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