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Fermentative Aroma Compounds and Sensory Descriptors of Traditional Croatian Dessert Wine Prošek from Plavac mali cv.

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Summary

Prošek is a traditional dessert wine from the coastal region of Croatia made from partially dried grapes. There is very little literature data about the chemical composition and sensory properties of Prošek, so an experimental production from the dried grapes of Plavac mali cultivar has been done using native and induced alcoholic fermentations. To determine the volatile compounds, gas chromatography with flame ionisation detector (GC/FID) was used on the samples prepared with solid phase microextraction (SPME). Higher alcohols, esters, carbonyl compounds and volatile acids were determined in the wine samples. Wines were grouped according to the production method using principal component analysis (PCA). It was found that Prošek wines produced with native and induced alcoholic fermentation differ in their volatile compounds. Descriptive sensory analysis was applied to show the sensory properties of Prošek wine, whose characteristic aromas include those of dried fruit (raisins), red berries, honey, chocolate and vanilla. A significant difference depending on the type of fermentation was determined in two sensory attributes, strawberry jam aroma and fullness.

Key words: Prošek, dessert wine, fermentation, volatile compounds, descriptive sensory analysis

Introduction

Dessert wines belong to a special category of high quality wines that are made from dried grapes, and their sensory properties differ from those of the wines made from fresh grapes. The production of dessert wines made from the over-ripe grapes is known in some European regions (Germany, France, Hungary and Greece) with specific climatic conditions (*1–3*). In some Mediterranean countries (Italy, Spain and Greece) dessert wines of similar type are produced from the grapes dried in the sun (*4,5*).

In the coastal region of Croatia, especially in Dalmatia, dessert wine Prošek has been known for centuries (*6*). Older literature data note the good potential of Plavac mali variety for drying and production of Prošek (*7*). Plavac mali is the most widespread and economically most important autochthonous variety for production of high quality wines in Dalmatia. However, in spite of the specific quality and significance of Prošek wine as a traditional product of Dalmatia, the literature indicators of its characteristics are pretty scarce. Prošek is produced by alcoholic fermentation of the dried grape pomace or the pomace of the grapes ripening on the vine for a longer time. In the process of drying, the sugar content is concentrated, which causes the change in the pH and total acidity, and it also modifies the content of the must (*8*). Alcoholic fermentation occurs under high sugar con-

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centration, and that influences the quality of the wine, which is why the analysis of the composition of fermentation components is of importance in the production of sweet wines.

Aroma is one of the most important quality factors in defining the characteristics of a product. Wine aroma is constituted of several hundreds of components derived from grapes; they are formed by biochemical reactions during alcoholic fermentation and by chemical and enzymatic reactions during maturation (*9*). During maceration, the processes of hydrolysis and oxidation liberate aromatic components from the grape skin (terpenes, C_{13} norisoprenoids), while volatile metabolites (higher alcohols, esters, carbonyl compounds, sulphur compounds, and volatile fatty acids) are synthesised by the activity of yeasts (*10,11*). Different research studies have shown that *Saccharomyces cerevisiae* wine yeasts significantly influence the composition of the wine aroma volatile components (*12–14*). In addition, stuck or sluggish fermentation often occurs during the production of sweet wines as a consequence of high osmotic conditions in the yeast cells and a rapid loss of intercellular water followed by cytoskeleton collapse, intracellular damage and subsequent arrest of yeast growth. Therefore, in high sugar musts osmotolerant yeasts are commonly used (*15*).

However, apart from the activity of yeasts, the composition of the must, grape variety, temperature and vinification also influence the production of volatile aroma components (*11,16*). While in the modern oenology alcoholic fermentation is done by inoculating the grape juice with selected yeasts, native alcoholic fermentation is still predominant in the traditional wine production (*17*). Varela *et al.* (*18*) reported about increased concentration of some higher alcohols and esters in wines produced with native alcoholic fermentation compared to the wines made with inoculated fermentation. Results about the impact that authochthonous yeasts have on the sensory properties of wines are very different, while some studies show positive, others show their negative influence on the chemical composition and sensory properties (*19,20*). Descriptive sensory analysis that was applied to characterise the wines (*21–25*) is one of the standard techniques used in the control of wine quality.

The aim of this research is to identify and quantify the fermentative aroma components of Prošek produced from Plavac mali cv. using GC/FID analyses, and to define descriptive sensory characteristics of the wines obtained using three different types of alcoholic fermentations (inoculation with two commercial yeasts and a native fermentation).

Materials and Methods

Grapes and drying process

In 2007 harvest, 360 kg of Plavac mali grapes at technological ripeness were gathered from the Pelješac winegrowing region, Croatia. The sugar concentration was 210 g/L, total acidity was 4.8 g/L and pH was 3.2. The grapes were dried in a greenhouse for 14 days (3–17 October). Daily temperature in the greenhouse was between 35 and 45 °C. A mass of 138 kg of dried grapes was obtained. After drying, the grapes contained 450 g/L of reducing sugars, total acidity was 6.6 g/L and pH was 3.58.

Vinification

Dried grapes were crushed and destemmed, after which Endozyme cultivar (30 g/100 kg) and potassium metabisulphite (15 g/hL) were added to the pomace. The pomace was divided into 6 equal parts and put into inox containers. Three different alcoholic fermentations were done, each in duplicate. Two of the fermentations were done using comercial yeasts (Lalvin EC-1118, *Saccharomyces cerevisiae* var. *bayanus*, 40 g/hL, Danstar Ferment AG, Zug, Switzerland; and Fermol Cryoaromae, *Saccharomyces cerevisiae* var. *uvarum*, 30 g/hL, AEB S.p.A., Brescia, Italy) prepared according to the manufacturer's instructions. The third fermentation was done with native yeasts or native microflora. On the second day of fermentation, yeast nutrient Fermaid E® (30 g/hL; Lallemand Inc, Montreal, Quebec, Canada) was added to the pomace. Maceration took 5 days and the pomace was punched down twice daily, after which it was pressed on the hydraulic press (pressure<2 bar). The must was put in 10-litre glass vials, where the alcoholic fermentation continued. The fermentation was controlled by measuring the temperature and determining the reducing sugars. Temperature during fermentation was between 22 and 24 °C. The first racking was done 29 days, and the second 184 days (6 months) after the beginning of fermentation. After the second racking, Prošek was bottled. Descriptive sensory analysis was done in June of the following year.

Headspace-solid phase microextraction (HS-SPME)

The SPME device used was a Supelco (Bellefonte, PA, USA) manual SPME holder 57330-U. Fused silica fibre coated with Carbowax-divinylbenzene, 65 μm film thickness (Supelco), was used for extraction and concentration of volatile compounds. The fibre was preconditioned at 250 °C for 1 h in the inlet of the GC prior to sampling, according to the manufacturer's instructions. The sample of wine (10 mL) was placed in a 20-mL vial containing internal standard *n*-amyl alcohol (180 ppm, by volume) and NaCl p.a. (3 g), and sealed with aluminium cover and Teflon-lined septum. HS-SPME was carried out under magnetic stirring. The SPME fibre was exposed to wine headspace at 25 °C for 15 min and immediately transferred to the GC injection port at 200 °C for 3 min in splitless mode. A liner with 0.75 mm i.d. (Varian Inc., Santa Clara, CA, USA) was used.

Gas cromatography

A Varian 3300 gas chromatograph equipped with a flame ionisation detector (FID) was used for GC analysis. Compounds were separated on a DB 624 column (30 m×0.32 mm, 1.8 μm i.d.; J&W Scientific, Folsom, CA, USA). Conditions of chromatographic analysis were in agreement with the method by Kovačević-Ganić *et al.* (*26*). Individual volatile compounds were identified by comparing their retention times with those of authentic standards. Quantitative determinations were performed using standard curves. All analyses were repeated three times, and the results were expressed as mean values in milligrams per litre of wine±standard deviation.

Descriptive sensory analysis

Descriptive analysis was used to evaluate the sensory characteristics of Prošek. It was done by the panel of 10 professionals (wine makers who are expert in the analysis of traditional Prošek wine), 6 female and 4 male. The evaluations were done at the Institute for Adriatic Crops and Karst Reclamation in Split, Croatia, where standard conditions for sensory evaluation were kept. Wine samples (25 mL) were served in standard wine tasting glasses coded with random 3-digit numbers at a temperature between 15 and 17 °C.

Preliminary sensory evaluation of Prošek aroma was done on 6 wine samples (3 different yeasts×2 repetitions) in order to select the sensory characteristics and to obtain a list of descriptive attributes of Prošek aroma. The attributes that were recognised by at least 50 % of the judges were put on the list. During evaluation, the judges had reference solutions of 54 wine aromas included in the Le Nez du Vin Master kit (Brizard and Co, York, UK).

In the second part of the evaluation, the judges were asked to evaluate with a number from 0 to 9 the intensity of the attribute from the descriptive list of Prošek. After that, sensory descriptors of wine such as fullness, acidity, sweetness, bitterness and astringency were also evaluated with a number from 0 to 9. In this part of the evaluation, each judge evaluated 6 samples of Prošek wine (3 different yeasts×2 repetitions).

Evaluations were done on the same day, with a break in between them. The panel supervisor did not take part in the evaluations.

Basic analytical parameters

Basic parameters of must and wine were determined according to the official methods of the European Union (*27*). The results are shown as the mean value of three determinations±standard deviation.

Statistical analysis

Statistically significant difference of the arithmetic means of volatile compounds and sensory characteristics between the wines produced with native and induced alcoholic fermentations was determined by the analysis of variance (ANOVA) and least significant difference (LSD) test.

Principal component analysis (PCA) was used to reduce the number of variables to latent dimensions in order to determine the connection between the volatile compounds and the wines produced with different yeasts. Statistical analysis was done using Statistica v. 8.0 software (*28*).

Results and Discussion

In the process of drying grapes, a concentrated must was obtained as a result of the loss of water in the grapes. The increase of pH from 3.2 to 3.58 in dried grapes is highly significant. The relative activity of microorganisms is much higher in the must with pH above 3.5 (*9*). However, the role of pH in the must also affected chemical and sensory quality of wine (*29*). This procedure of concentrating the must was done by Franco *et al.* (*4*) in the production of sweet wines, who dried the grapes off-vine directly exposed to the sun. Basic chemical parameters of Prošek wine obtained with native and induced (using Cryoaromae and EC-1118) alcoholic fermentations of partially dried grapes are shown in Table 1.

Table 2 (*30–35*) shows volatile compounds identified in Prošek during three different types of alcoholic fermentations. Fermentation kinetics in all three types was very similar (data not shown). In all three types of Prošek, the following components were identified: acetaldehyde, 1-propanol, *i*-butanol, 1-hexanol, 2-phenylethanol, isoamyl alcohol, ethyl acetate, ethyl lactate, isoamyl acetate, 2-phenylethyl acetate, ethyl hexanoate, ethyl octanoate, ethyl decanoate and acetic acid.

Quantitatively the largest group of volatile components in all types of fermentations comprised higher alcohols, which is in agreement with the data for sweet wines (*2,5*). Concentration of higher alcohols in Prošek is higher than that in sweet Madeira wine, which is produced by the addition of natural grape spirit to the partly fermented wine (*30*). In addition, comparing the ratio and concentration of some individual higher alcohols in Prošek, it can be observed that it is different than in other sweet wines. In Prošek, the concentration of *n*-propanol is higher than the concentration of *i*-butanol, while the opposite ratio was reported in Malvasia delle Lipari (*5*). Also, the concentration of *n*-propanol is higher in Prošek than in sweet and ice wine (*5,31*). Higher alcohols, to-

Table 1. Basic chemical composition of dessert wine Prošek made with native and inoculated (using Cryoaromae and EC-1118) alcoholic fermentations

	Native yeast	EC-1118	Cryoaromae
φ(alcohol)/%	$(13.71\pm0.44)^a$	$(14.29\pm0.12)^a$	$(13.36\pm1.19)^a$
γ(total extract)/(g/L)	$(259.5\pm6.7)^a$	$(254.2\pm3.11)^a$	$(261.25\pm5.3)^a$
γ(reducing sugars)/(g/L)	$(214.2\pm6.8)^a$	$(205.2\pm2.6)^a$	$(206.6\pm5.3)^a$
γ(total acidity)/(g/L)	$(6.81\pm0.02)^a$	$(7.73\pm0.11)^b$	$(7.90\pm0.04)^b$
γ(volatile acidity)/(g/L)	$(1.47\pm0.11)^b$	$(1.57\pm0.03)^b$	$(1.87\pm0.01)^a$
γ(citric acid)/(g/L)	$(0.084\pm0.01)^a$	$(0.077\pm0.01)^a$	$(0.077\pm0.01)^a$
pH	$(3.78\pm0.01)^a$	$(3.76\pm0.01)^a$	$(3.74\pm0.02)^a$
m(ash)/(g/L)	$(3.79\pm0.05)^a$	$(3.80\pm0.03)^a$	$(3.92\pm0.16)^a$

[a,b]values indicated with different letters show statistically significant difference, $p<0.05$

Table 2. Composition and mass concentration of volatile components of dessert wine Prošek made with native alcoholic fermentation and the fermentations with Cryoaromae and EC-1118 yeasts

Compound	Aroma descriptor	γ(native yeast)/mg/L	γ(Cryoaromae)/mg/L	γ(EC-1118)/mg/L	Odour threshold/mg/L	Odour activity value		
						Native yeast	Cryo-aromae	EC-1118
acetaldehyde	fruity, green apple, oxidized	(120.87±1.29)[a]	(132.20±2.05)[a]	(135.70±0.70)[a]	110	1.1	1.2	1.2
Alcohols								
1-propanol	floral, fruity, candy, sweet	(43.04±1.99)[b]	(70.28±8.90)[a]	(76.92±6.19)[a]	306	0.1	0.23	0.3
i-butanol	nail polish	(28.92±2.34)[a]	(31.06±2.83)[a]	(26.15±0.92)[a]	75	0.4	0.41	0.3
i-amyl alcohol	squashed bug	(128.54±12.77)[a]	(122.12±7.76)[a]	(142.13±1.36)[a]	30	4.3	4.07	4.7
1-hexanol	green/grass	(0.59±0.01)[a]	(0.05±0.01)[a]	(0.55±0.01)[a]	1.1	0.5	0.05	0.5
2-phenylethanol	honey, rose, spice, lilac	(24.04±5.95)[a]	(11.52±0.42)[b]	(16.78±2.57)[b]	14	1.7	0.8	1.2
The sum of alcohols		225.12±19.08	235.03±19.93	262.52±11.06				
Esters								
ethyl acetate	fruity, nail polish	(80.73±2.17)[b]	(76.05±6.85)[b]	(88.30±2.44)[a]	12	6.7	6.3	7.4
i-amyl acetate	banana	(0.27±0.04)[a]	(0.17±0.10)[a]	(0.32±0.05)[a]	0.03	9.0	5.7	10.7
2-phenylethyl acetate	rose, honey, tobacco	(0.05±0.01)[a]	(0.02±0.00)[a]	(0.03±0.01)[a]	1.8	0.03	0.01	0.02
The sum of acetates		81.04±2.13	76.24±6.75	88.65±2.50				
ethyl lactate	lactic, raspberry	(18.84±1.03)[a]	(20.55±1.48)[a]	(22.20±3.81)[a]	150	0.1	0.1	0.1
ethyl hexanoate	apple, banana, violet	(0.05±0.00)[a]	(0.066±0.01)[a]	(0.05±0.01)[a]	0.014	3.6	4.7	3.6
ethyl octanoate	pineapple, pear, floral	(0.05±0.00)[a]	(0.02±0.01)[b]	(0.04±0.03)[a]	0.005	10.0	4.0	8.0
ethyl decanoate	sweet, fruity, dry fruits	(0.08±0.02)[a]	(0.02±0.00)[b]	(0.02±0.01)[b]	–	–	–	–
The sum of esters		100.05±3.13	96.87±8.24	110.94±6.36				
acetic acid	vinegar	(1091±41.04)[b]	(1126±40.65)[b]	(1376±19.80)[a]	–	–	–	–

aroma descriptor and odour threshold reported in the literature (*30–35*)
odour activity value was calculated by dividing the concentration by odour threshold of the compound
[a,b]values indicated with different letters show statistically significant difference, $p<0.05$

gether with acetaldehyde, ethyl acetate and acetic acid, make almost half of the volatile compounds of wine, and are considered major fermentation products (*16*). Total concentration of higher alcohols was between 225.12 and 262.52 mg/L, which is within the limits that have a positive influence on the aroma. Namely, it is well known that higher alcohols are an important factor of wine aroma, but if they are in the concentrations above 350 mg/L, they have a negative effect (*36*). Among higher alcohols in Prošek, the highest concentration is that of isoamyl alcohol (122.12–142.13 mg/L), then follow 1-propanol (43.04–76.92 mg/L) and isobutanol (26.15–30.75 mg/L).

Aromatic alcohol 2-phenylethanol is considered important in the sensory aroma of wine. The content of 2-phenylethanol in Prošek was between 11.52 and 24.04 mg/L. Genovese *et al.* (*2*) determined that during drying of grapes, the concentration of 2-phenylethanol decreases. However, Prošek has higher concentration of 2-phenylethanol than reported in the literature for some other sweet wines (*2,30*), but lower than in Malvasia delle Lipari wine (*5*). 2-Phenylethanol brings out the odour of rose and honey in sweet wines.

Ethyl acetate, isoamyl acetate and 2-phenylethyl acetate are acetate esters that were identified and quantified in the samples of Prošek. The subtotal concentration of acetate esters in Prošek was 81.04–88.65 mg/L, among which ethyl acetate is the most prevalent ester. A small quantity of ethyl acetate is formed by the yeast during fermentation, but larger amounts result from the activity of aerobic acetic acid bacteria. Concentration of ethyl acetate contributes significantly to the volatile character of 'acetic nose' and levels of 150 to 200 mg/L impart spoilage character to wine. On the contrary, at very low concentrations (50–80 mg/L), ethyl acetate has a pleasant odour, which contributes to the olfactory complexity and has a significant influence on the quality of wine (*9,17*). Isoamyl acetate has an odour reminiscent of a banana. Van der Merwe and van Wyk (*37*) showed that isoamyl acetate is the compound that contributes most to the wine aroma and also positively influences the general quality of wine. Isoamyl acetate and ethyl hexanoate play a major role in the aroma of young white wines. Sample wines of Prošek showed that 2-phenylethyl acetate has the lowest concentration among the acetate esters of higher alcohols (0.03–0.05 mg/L). This compound has pleasant rose and honey flavour nuances and contributes to the aromatic complexity of wine (*9*).

Among ethyl esters of straight-chain saturated fatty acids, the ones that were identified were ethyl hexanoate, ethyl octanoate and ethyl decanoate. The concentration of these esters in wine is far above their sensory threshold, which is ten times lower, therefore these compounds are very important for the aroma of the wine. Ethyl hexanoate (odour threshold 0.014 mg/L, determined in synthetic wine consisting of 11 % (by volume) of ethanol, 7 g/L of glycerine, 5 g/L of tartaric acid, pH=3.4) has an odour reminiscent of apples and violets, ethyl octanoate (odour threshold 0.005 mg/L determined in synthetic wine consisting of 11 % (by volume) of ethanol, 7 g/L of glycerine, 5 g/L of tartaric acid, pH=3.4) of pineapple and pear, and ethyl decanoate has a floral odour (*32*,*33*). The most represented ethyl ester of straight--chain fatty acids in the samples is ethyl decanoate.

Ethyl lactate is the second most abundant ester in Prošek. Its formation in wine is linked to malolactic fermentation (*9*). Taking into account odour threshold of ethyl lactate (14 mg/L) and the determined concentration in the samples of Prošek, it can be considered that this compound influences fruity flavours of this dessert wine (*32*). Concentration of the most abundant esters in Prošek, ethyl acetate and ethyl lactate, is higher than the levels of these esters in sweet wines (*2*,*5*,*30*). Also, the concentration of ethyl lactate is higher than in ice wine (*31*). Favourable concentration of malic acid in must (1.3 g/L) and pH value (3.58) for spontaneous malolactic fermentation might be the reason for relatively high concentration of ethyl lactate in Prošek wine.

Among carbonyl compounds that influence the aroma, high concentration of acetaldehydes (120.9–135.7 mg/L) was observed in all samples of Prošek. This is partly due to the experimental production of small amounts of the wine, and to greater influence of oxygen, as acetaldehyde is a product of the oxidation of ethanol in the mechanism of alcoholic fermentation by the activity of enzyme dehydrogenase and in the presence of NAD^+. Taking into consideration the acetaldehyde threshold of 120 mg/L, it can be considered that the ratio of acetaldehyde in Prošek influences its sensory properties. High concentration of acetaldehydes gives a pungent character, typical for sherry wines, and directly contributes to the aroma with the smell of freshly cut apple, which was confirmed by Moreno *et al.* (*38*), who showed that with biological ageing of these wines, the concentration of acetaldehydes increases from 91 mg/L in the first year to 257 mg/L in the fifth year.

The concentrations of fermentation components (higher alcohols, esters and acetaldehyde) in Prošek are within the expected limits for dry wines (*16*,*26*). However, Genovese *et al.* (*2*) reported about lower concentration of basic fermentation components in sweet wines similar to Prošek, produced from grapes with higher sugar mass fraction (26 °Brix) and infected with *Botrytis cinerea*, than that in dry wine made from the same grape variety.

The influence of yeasts on the production of volatile components

Analysis of variance (ANOVA) showed statistically significant differences between the fermentations in these volatile components: 1-propanol, 2-phenylethanol, ethyl acetate, ethyl decanoate, ethyl octanoate and acetic acid, while no significant differences were determined among other volatile components.

In native fermentation, significantly lower concentration of 1-propanol ($p<0.05$) was observed, compared to the fermentations with EC-1118 and Cryoaromae, which did not differ significantly between them either. Bertolini *et al.* (*39*) found significant differences in the concentration of 2-phenylethanol produced in the fermentation with inoculated yeasts, while in the study of Varela *et al.* (*18*) the yeasts involved in the fermentation of Chardonnay wine did not influence its production. However, in this research, significantly more 2-phenylethanol was determined in the Prošek produced with native fermentation.

The content of ethyl acetate was significantly higher in the Prošek fermented with EC-1118 yeast, while other fermentations did not differ significantly. In the fermentation with EC-1118, there was also a significantly higher content of acetic acid than in the other two fermentations.

A significantly higher concentration of ethyl decanoate was determined in the Prošek produced with native fermentation, which is in agreement with the data of Varela *et al.* (*18*), who observed a significantly higher production of ethyl decanoate in the fermentation with native yeasts. Also, a higher content of ethyl octanoate was found in this Prošek.

Native yeast flora induces a significant and usually favourable effect on wine flavour, which has recently been demonstrated by Varela *et. al.* (*18*), but the risk of stuck or sluggish fermentations is higher when this yeast is used. The results of our study also demonstrate that native fermentation produces higher concentrations of some chemical components important for sensory implications and overall quality of Prošek. However, native fermentation might give undesirable effects and uneven quality of wine depending on the harvest season.

Although the population of yeasts was not studied here, the identified aroma compounds (Table 2) clearly show that Prošek wines produced with native and inoculated fermentations can be distinguished, both between the native fermentation and inoculation as well as between the inoculations. This was also confirmed with the PCA, which was done with the aim to establish the relationship between volatile chemical variables and the wine. Fig. 1 shows the relationship among the original variables on the basis of which the latent components PC1 and PC2 were obtained. These two components together comprise 61.9 % of the total chemical variability. Distribution of wine samples (3 types of yeast×2 repetitions) in the coordinate system defined by two latent components (PC1 and PC2) shows a clear distance between the wines produced with native and those produced with the induced (using Cryoaromae and EC-1118) alcoholic fermentation (Fig. 2). The distance between two repetitions of EC-1118 was relatively wider than expected, which suggests that more repetitions per fermen-

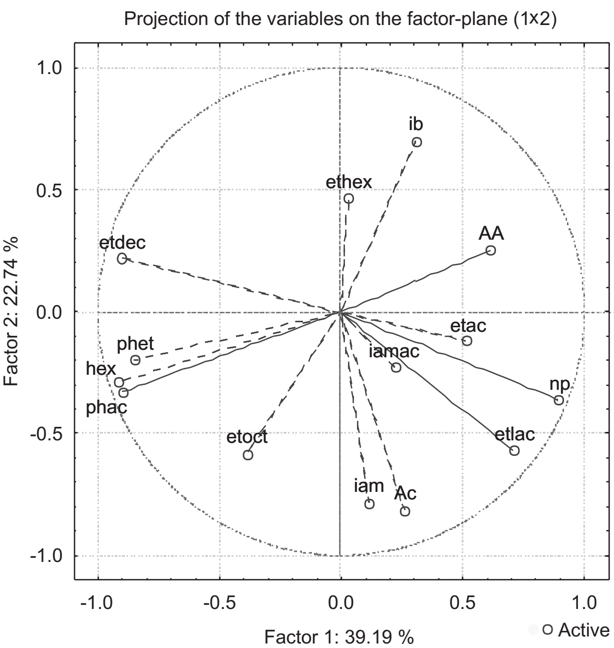

Fig. 1. Projection of latent factors (PC1 and PC2) obtained by reducing the 14 original variables: **AA** – acetaldehyde, **Ac** – acetic acid, **etac** – ethyl acetate, **etdec** – ethyl decanoate, **ethex** – ethyl hexanoate, **etlac** – ethyl lactate, **etoct** – ethyl octanoate, **hex** – 1-hexanol, **iam** – *i*-amyl alcohol, **iamac** – *i*-amyl acetate, **ib** – *i*-butanol, **np** – 1-propanol, **phac** – 2-phenylethyl acetate, **phet** – 2-phenylethanol

tation treatment in microvinification are necessary. PCA demonstrates that the Prošek wines produced with native and induced fermentations can be distinguished according to their volatile chemical components.

Descriptive sensory analysis

Descriptive sensory analysis was used to describe six wines with the aim to obtain sensory attributes of Prošek wine produced from Plavac mali cv. harvested in 2007. There were 54 sensory descriptors taken from the Wine Aroma Wheel (*40*), of which 11 (blackberry, raspberry, strawberry, black currant, cherry, raisin, prune, strawberry jam, honey, chocolate and vanilla) were agreed to define the aroma of Prošek. Olfactory properties of the wine were also evaluated (fullness, acidity, sweetness, bitterness and astringency).

Fig. 3 shows the sensory profile of the intensity of the selected descriptors for the Prošek wines produced with native and induced fermentations. The highest intensity was that of the sensory attribute of fullness (Cryoaromae=8.2, EC-1118=7.6, and native=7.0), while the lowest was that of bitterness (Cryoaromae=1.4, EC-1118=1.8, and native=1.6).

Regarding aroma, dominating attributes were of dried fruit (raisin, prune and strawberry jam), berries (blackberry, raspberry, strawberry, black currant, and cherry) and honey at almost equal intensities.

Significant difference ($p<0.05$) was determined for only two sensory attributes (strawberry jam aroma and fullness) between the wine produced with native and that with induced alcoholic fermentation. Prošek fermented with native yeasts had lower intensity of strawberry jam aroma and fullness than the other two wines, which did not differ significantly between themselves.

These results of sensory profile of Prošek wine from Plavac mali cv. are comparable with those of similar types of dessert wines from the Mediterranean area, which have the sensory attributes of dried fruit (raisin), honey, caramel and jam (*5,2,41*).

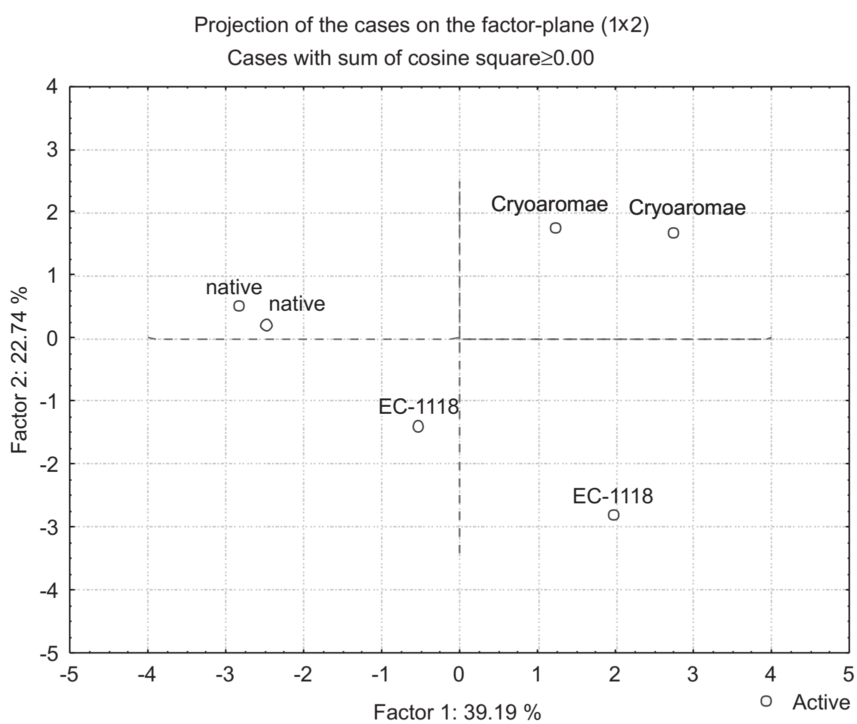

Fig. 2. Principal component analysis (PCA) of six Prošek wines produced with native and induced (using Cryoaromae and EC-1118) alcoholic fermentations

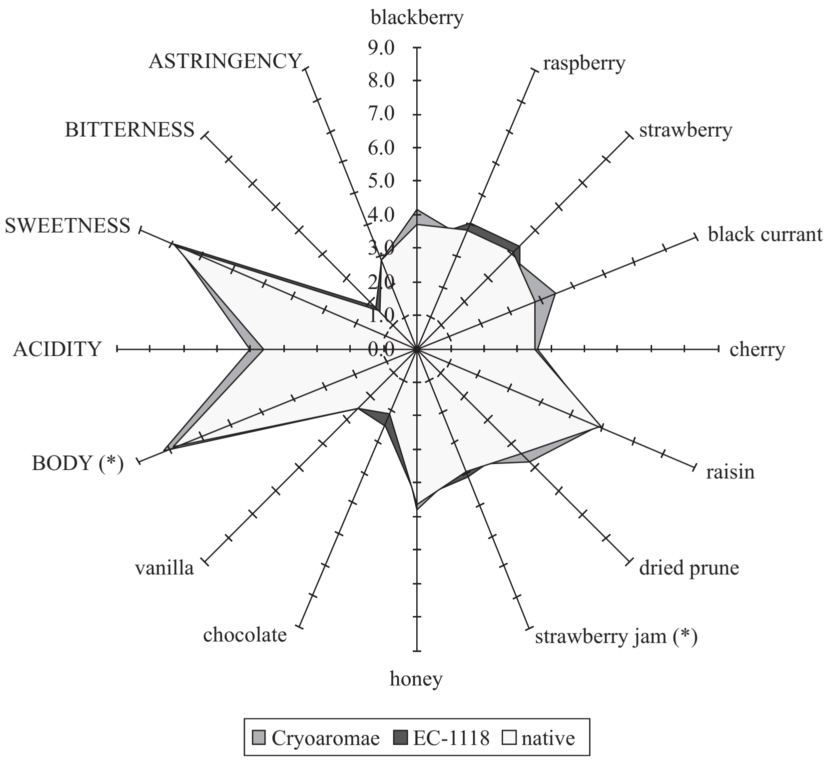

Fig. 3. Sensory profile of the intensity of the selected descriptors for the dessert wine Prošek produced with native and inoculated (using Cryoaromae and EC-1118) alcoholic fermentations. Aroma characteristics are written in lower case, while flavour characteristics are written in block capitals. *Significant difference of the arithmetic mean values ($p<0.05$)

Conclusion

Chemical and sensory characteristics of a traditional Dalmatian dessert wine Prošek produced from partially dried grapes of Plavac mali cv. were done because of the significance of that cultivar for this region. There were 15 volatile components identified and quantitatively determined. Significantly higher content of ethyl acetate and acetic acid was determined in the Prošek fermented with inoculated yeasts *S. cerevisiae bayanus* EC-1118, while the Prošek produced with native fermentation had significantly lower content of 2-propanol, but higher content of 2-phenylethanol, ethyl decanoate and ethyl octanoate. PCA showed clear distinction among the Prošek wines produced with three different fermentations. Prošek made from Plavac mali cv. is characterised by the aroma of dried fruit (raisin, prune), red berries, jam, honey and vanilla.

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References

1. E. Miklósy, Z. Kalmár, Z. Kerényi, Identification of some characteristic aroma compounds in noble rotted grape berries and Aszù wines from Tokaj by GC-MS, *Acta Aliment. 33* (2004) 215–226.
2. A. Genovese, A. Gambuti, P. Piombino, L. Moio, Sensory properties and aroma compounds of sweet Fiano wine, *Food Chem. 103* (2007) 1228–1236.
3. C. Thibon, D. Dubourdie, P. Darriet, T. Tominaga, Impact of noble rot on the aroma precursor of 3-sulfanylhexanol content in *Vitis vinifera* L. cv. Sauvignon blanc and Semillin grape juice, *Food Chem. 114* (2009) 1359–1364.
4. M. Franco, R.A. Peinado, M. Medina, J. Moreno, Off-vine grape drying effect on volatile compounds and aromatic series in must from Pedro Ximénez grape variety, *J. Agric. Food Chem. 52* (2004) 3905–3910.
5. G. Muratore, C.N. Asmundo, C.M. Lanza, C. Caggia, F. Licciardello, C. Restuccia, Influence of *Saccharomyces uvarum* on volatile acidity, aromatic and sensory profile of Malvasia delle Lipari wine, *Food Technol. Biotechnol. 45* (2007) 101–106.
6. M. Jelaska: *Tasting, Consumption, Serving Wine*, Agricultural Publishing Bureau, Zagreb, Croatia (1955) p. 23 (in Croatian).
7. S. Bulić: *Dalmatian Ampelography*, Agricultural Publishing Bureau, Zagreb, Croatia (1949) (in Croatian).
8. M.P. Serratosa, A. Lopez-Toledano, M. Medina, J. Merida, Drying of Pedro Ximenez grapes in chamber at controlled temperature and with dipping pretreatments. Changes in the color fraction, *J. Agric. Food Chem. 56* (2008) 10739–10746.
9. P. Ribereau-Gayon, Y. Glories, A. Maujean, D. Dubourdieu: Handbook of Enology. In: *The Chemistry of Wine Stabilization and Treatments, Vol. 2*, John Wiley & Sons Ltd, Chichester, UK (2006) pp. 59–61,205–206.
10. N. Loscos, P. Hernandez-Orte, J. Cacho, V. Ferreira, Release and formation of varietal aroma compounds during alcoholic fermentation from nonfloral grape odorless flavor precusors fractions, *J. Agric. Food Chem. 55* (2007) 6674–6684.

11. J.H. Swiegers, E.J. Bartowsky, P.A. Henschke, I.S. Pretorius, Yeast and bacterial modulation of wine aroma and flavour, *Aust. J. Grape Wine Res. 11* (2005) 139–173.

12. S. Patel, T. Shibamoto, Effect of 20 different yeast strains on the production of volatile components in Symphony wine, *J. Food Compos. Anal. 16* (2003) 469–476.

13. D.J. Erasmus, M. Cliff, H.J.J. van Vuuren, Impact of yeast strain on the production of acetic acid, glycerol, and sensory attributes of icewine, *Am. J. Enol. Vitic. 55* (2004) 371–378.

14. M. Vilanova, I. Masneuf-Pomarède, D. Dubourdieu, Influence of *Saccharomyces cerevisiae* strains on general composition and sensorial properties of white wines made from *Vitis vinifera* cv. Albariño, *Food Technol. Biotechnol. 43* (2005) 79–83.

15. S. Hohmann, Osmotic stress signaling and osmoadaptation in yeasts, *Microbiol. Mol. Biol. Rev. 66* (2002) 300–372.

16. J.A. Regodón Mateos, F. Pérez-Nevado, M. Ramírez Fernández, Influence of *Saccharomyces cerevisiae* yeast strain on the major volatile compounds of wine, *Enzyme Microb. Technol. 40* (2006) 151–157.

17. M.G. Lambrechts, I.S. Pretorius, Yeast and its importance to wine aroma – A review, *S. Afr. J. Enol. Vitic. 21* (2000) 97–129.

18. C. Varela, T. Siebert, D. Cozzolino, L. Rose, H. McLean, P.A. Henschke, Discovering a chemical basis for differentiating wines made by fermentation with 'wild' indigenous and inoculated yeasts: Role of yeast volatile compounds, *Aust. J. Grape Wine Res. 15* (2009) 238–248.

19. K. Povhe Jemec, N. Cadez, T. Zagorc, V. Bubic, A. Zupec, P. Raspor, Yeast population dynamics in five spontaneous fermentations of Malvasia must, *Food Microbiol. 18* (2001) 247–259.

20. M. Combina, A. Elía, L. Mercado, C. Catania, A. Ganga, C. Martinez, Dynamics of indigenous yeast populations during spontaneous fermentation of wines from Mendoza, Argentina, *Int. J. Food Microbiol. 99* (2005) 237–243.

21. T. Ohkubo, A.C. Noble, C.S. Ough, Evaluation of California Chardonnay wines by sensory and chemical analyses, *Sci. Aliment. 7* (1987) 573–587.

22. I.L. Francis, M.A. Sefton, P.J. Williams, Sensory descriptive analysis of the aroma of hydrolysed precursor fractions from Semillon, Chardonnay and Sauvignon Blanc grape juices, *J. Sci. Food Agric. 59* (1992) 511–520.

23. N.A. Abbot, B.G. Coombe, P.J. Williams, The contribution of hydrolyzed flavor precursors to quality differences in Shiraz juice and wines: An investigation by sensory descriptive analysis, *Am. J. Enol. Vitic. 42* (1991) 167–174.

24. E. Falqué, A.C. Ferreira, T. Hogg, P. Guedes-Pinho, Determination of aromatic descriptors of Touriga Nacional wines by sensory descriptive analysis, *Flavour Fragr. J. 19* (2004) 298–302.

25. M. Vilanova, F. Vilarino, Influence of geographic origin on aromatic descriptors of Spanish Albariño wine, *Flavour Fragr. J. 21* (2006) 373–378.

26. K. Kovačević-Ganić, M. Staver, Đ. Peršurić, M. Banović, D. Komes, L. Gracin, Influence of blending on the aroma of Malvasia istriana wine, *Food Technol. Biotechnol. 41* (2003) 305–314.

27. Community Methods for the Analysis of Wines, Commission Regulation (EEC) No. 2676/90, *Off. J. Eur. Comm. L 272* (1990).

28. STATISTICA (Data Analysis Software System) v. 8.0, StatSoft, Inc., Tulsa, OK, USA.

29. A. Morata, M.C. Gómez-Cordovés, F. Calderón, J.A. Suárez, Effects of pH, temperature and SO_2 on the formation of pyranoanthocyanins during red wine fermentation with two species of *Saccharomyces*, *Int. J. Food Microbiol. 106* (2006) 123–129.

30. R. Perestrelo, A. Fernandes, F.F. Albuquerque, J.C. Marques, J.S. Câmara, Analytical characterization of aroma of Tinta Negra Mole red wine: Identification of the main odorants compounds, *Anal. Chim. Acta, 563* (2006) 154–164.

31. M. Cliff, D. Yuksel, B. Girard, M. King, Characterization of Canadian ice wines by sensory and compositional analyses, *Am. J. Enol. Vitic. 53* (2002) 46–53.

32. M. Vilanova, C. Martínez, First study of determination of aromatic compounds of red wine from *Vitis vinifera* cv. Castañal grown in Galicia (NW Spain), *Eur. Food Res. Technol. 224* (2007) 431–436.

33. V. Ferreira, R. López, J.F. Cacho, Quantitative determination of the odorants of young red wines from different grape varieties, *J. Sci. Food Agric. 80* (2000) 1659–1667.

34. R.S. Jackson: *Wine Science. Principles and Aplications*, Academic Press Inc., San Diego, CA, USA (1994).

35. R.A. Peinado, J.C. Mauricio, J. Moreno, Aromatic series in sherry wines with gluconic acid subjected to different biological aging conditions by *Saccharomyces cerevisiae* var. *capensis*, *Food Chem. 94* (2006) 232–239.

36. A. Rapp, H. Mandery, New progress in vine and wine research, *Experientia, 42* (1986) 873–884.

37. C.A. van der Merwe, C.J. van Wyk, The contribution of some fermentation products to the odor of dry white wines, *Am. J. Enol. Vitic. 32* (1981) 41–46.

38. J.A. Moreno, L. Zea, L. Moyano, M. Medina, Aroma compounds as markers of the changes in sherry wines subjected to biological ageing, *Food Control, 16* (2005) 333–338.

39. L. Bertolini, C. Zambonelli, P. Giudici, L. Castellari, Higher alcohol production by cryotolerant *Saccharomyces* strains, *Am. J. Enol. Vitic. 47* (1996) 343–345.

40. A.C. Noble, R.A. Arnold, J. Buechsenstein, E.J. Leach, J.O. Schmidt, P.M. Stern, Modification of a standardized system of wine aroma terminology, *Am. J. Enol. Vitic. 38* (1987) 143–146.

41. N. Guarrera, S. Campisi, C. Nicolosi Asmundo, Identification of the odorants of two Passito wines by gas chromatography-olfactometry and sensory analysis, *Am. J. Enol. Vitic. 56* (2005) 394–399.