Influence of fermentation conditions on production of plum (*Prunus domestica* L.) wine: A response surface methodology approach

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Abstract

Plum (*Prunus domestica* L.) is the most important and most commonly grown fruit species in Serbia, one of the leading plum-producing countries. It is mainly used for table consumption, drying and fruit brandy production. The use of plums for wine production is not sufficiently investigated. The aim of this study was to investigate the influence of temperature, pH and duration of fermentation on the plum wine composition and quality, and to optimize these factors by response surface methodology (RSM). Second order polynomial equations, which represent fitted models for investigated responses, are shown as adequate (R^2 > 0.90 and P < 0.05). The average values of ethanol and glycerol content in plum wine were 6% and 5 g/L, respectively, while high methanol concentrations (above 1000 mg/L) were recorded in all wine samples. This requires further investigation of possible procedures to reduce the methanol content in the wines, according to its toxic properties to human. The optimal conditions for plum wine production, obtained by the application of RSM, were 18.3 °C, pH 3.0 and 7 days fermentation time. Apart from the problem of very high methanol concentrations, the plum wine produced with the optimal conditions had good sensory properties and acceptability.

Keywords: plum, wine, optimisation, fermentation conditions, methanol.

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Wine is a product of alcoholic fermentation of grape or any other fruit juice with a good proportion of sugar. In general, the main raw material for the wine production is grape, but the suitability of different fruits for the wine-making has been investigated significantly in the previous decade. Highly acceptable fruit wines are obtained from apple [1,2], mango [3,4], banana [5], peach [6], raspberry [7], blackberry [8], etc.

A plum is a common name for a large number of species belonging to the genus Prunus, generally cultivated in the temperate zones with numerous varieties and hybrids that are suitable for many soils and regions [9]. China is the leading plum producer with approximately 42% share of the total world production in 2003, followed by Romania and the United States. Plum (*Prunus domestica* L.) is the most important and most commonly grown fruit species in Serbia. With the average production of 577000 tonnes the Serbia is one of the leading plum-producing countries [9,10]. Plum trees are precocious and well cropping, have small requirements for ecological conditions and orchard management practices and can be grown at higher altitudes. The fruits are used for table consumption, drying, freezing and processing. The largest amount of plum fruits produced in Serbia (more than 75%) is processed into brandy [10].

Plum contains 10–16% (w/v) of sugar and 5–14 g/kg of total acids. Glucose, fructose and sucrose are the principal sugars in ripened plum, while malic, citric, succinic, quinic and fumaric acids are dominant organic acids [10,11]. The share of malic acid is up to 70% of total organic acids in ripened plums [12]. Plum juice is also good source of vitamins A (345 IU) and C (10 mg/L), as well as of potassium (157 mg/L) [9]. High content of natural phenolic phytochemicals, such as flavonoids and phenolic acids, is reported in plums. These compounds are effective natural antioxidants in human diet which reduce the risk of cancer and other chronic diseases [13]. Plums demonstrated high scavenger activity against oxygen-derived free radicals, such as hydroxyl and peroxyl radicals, and that activity is especially emphasized [14].

Research on plums' composition, their volatiles content and antioxidant potential were reported by many authors [11,12,15–17]. Furthermore, in European plum-producing countries, the special attention is paid to the production of the plum brandy, as a distillate of plum fermented must [18,19]. On the other hand, there are very few published studies about the production of plum wine [20]. There is a lack of relevant data about fermentation conditions for plum wine production and a need for characterization of the obtained wine. Hence, these factors must be studied in more detail in order to develop new vinification technologies

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which would ensure production of wine with the best sensory characteristics. Response surface methodology (RSM) is a statistical method widely used for optimization of fermentation medium and conditions, because it can simultaneously consider several factors at many different levels and corresponding interactions among these factors, using a small number of observations [3,21,22]. The aim of this research was to investigate the influence of temperature, pH and duration of fermentation on the plum wine composition and quality, and to optimize these factors by use of RSM and central composite design (CCD).

MATERIALS AND METHODS

Plum pomace preparation and fermentation

Plum variety Čačanska lepotica resulted from the cross of Požegača and Wangenheims Fruhzwetsche in 1961. It was released in 1975 and patented in 1991 by the Fruit Research Institute, Čačak, Serbia. Today it is one of the most widely grown plum varieties in Serbia. The plums for this research were procured at commercial maturity in early September 2011 from the local market of Novi Sad, Serbia. Plums were halved and pits were carefully removed by hand after which plums were subjected to crushing. Obtained pomace was treated with $K_2S_2O_5$ (SO_2 level was set to 50 mg SO_2/kg pomace), to prevent contamination and oxidation processes, and with 0.02g/kg of commercial pectinase Lallzyme-oe (Lallemand S.A., St. Simon, France) for 3 h at 25 °C. The amount of pectinase was used according to the manufacturer's instructions. The plum juice sample was extracted by passing through cheesecloth and then subjected to analysis of total and reducing sugars, total acidity, pH and fermentable nitrogen.

The entire amount of pomace was divided into 5 L glass jars (3 kg of pomace in each) fitted with a fermentation bung for CO_2 release. The adjustment of pH to values 2.8, 3.0, 3.3, 3.6 and 3.8 was carried out by means of mixture solution of malic, citric and tartaric acid (1:1:0.5, respectively) and calcium carbonate. Alcoholic fermentation was conducted at desired temperatures (15–25 °C). All the runs were carried out according to the central composite design. Inoculation was performed with 0.25 g/kg of previously rehydrated commercial wine yeast *Saccharomyces cerevisiae* (Anchor WE372, South Africa). Wine was passed through the cheesecloth when the fermentation was finished. SO_2 level was adjusted to 50 mg/L and the wine was poured into 500 mL bottles, closed with screw caps and kept at 12–13 °C in the absence of light. After two months, during which clarification and stabilization processes took place, young plum wines were subjected to sensory analysis.

Analytical methods

Pomace samples taken for analysis were previously centrifuged (Tehtnica LC-321, Železniki, Slovenia) at 3500 rpm, 10 min and 20 °C. Total and reducing sugars, sucrose, total acidity and pH were determined using official methods [23]. The pH was measured directly in the pomace by the laboratory multi-parameter analyser Consort C860 (Consort, Turnhout, Belgium) with the glass electrode (SP10T). Fermentable nitrogen was determined using Formol titration [24]. Glycerol was estimated by the enzymatic method [25], using commercially available glycerol assay kit (Megazyme, Ireland).

Ethanol and methanol content in wine samples were determined by gas chromatography, using an HP 5890 Series II GC (Agilent Technologies Inc, Santa Clara, CA, USA) equipped with a flame ionization detector (FID) and Carbowax 20 M column. Chromatography conditions were set according to the previously described procedure [3].

Experimental design

Optimization of conditions for plum wine production was carried out using RSM. The experimental design and statistical analysis were performed using Stat-Ease software (Design-Expert 7.0.0 Trial, Minneapolis, MN, USA). Experiments with three independent variables, fermentation temperature (X_1), fermentation time (X_2) and pH (X_3), were carried out by full factorial central composite experimental design (CCD) [26]. CCD was used to evaluate the combined effect of the three independent variables. A 2^3 factorial experiment with 6 axial points (α = 1.682) and six replicates at the centre points (n_0 = 6) leading to a total of 20 experiments. Response parameters were ethanol, methanol and glycerol content. The levels of independent variables and design matrix are shown in Tables 1 and 2, respectively. Mean values of triplicate determinations were analysed to fit the following second-order polynomial model (1) which is used to calculate predicted responses:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{23}X_2X_3 + b_{13}X_1X_3 \quad (1)$$

where Y is the predicted response, X_1, X_2 and X_3 correspond to the independent variables, b_0 is intercept, b_1, b_2 and b_3 are linear effects, b_{11}, b_{22} and b_{33} are squared effects and b_{12}, b_{23} and b_{13} are interaction effects of the factors. The goodness of fitting and the

Table 1. Values of factors in central composite design (CCD)

Factor	Name	Low value	High value
X_1	Temperature, °C	15	25
X_2	Fermentation time, day	3	7
X_3	pH	3.0	3.6

Table 2. CCD matrix and responses

Temperature, °C	Fermentation time, day	pH	Ethanol content, vol.%	Methanol content, mg/L	Glycerol content, g/L
X_1	X_2	X_3	Y_1	Y_2	Y_3
11.59	5.00	3.30	1.11	387	1.3
15.00	3.00	3.60	0.64	787	2.53
15.00	3.00	3.00	0.4	580	2.1
15.00	7.00	3.60	4.35	1094	3.41
15.00	7.00	3.00	3.64	955	3.36
20.00	1.64	3.30	0.6	489	0.96
20.00	5.00	3.30	4.23	1207	4.25
20.00	5.00	3.30	3.97	1169	4.05
20.00	5.00	3.30	4.34	1222	4.4
20.00	5.00	3.80	4.42	1240	4.7
20.00	5.00	3.30	4.62	1199	4.3
20.00	5.00	3.30	4.41	1135	4.1
20.00	5.00	3.30	4.19	1188	4.39
20.00	5.00	2.80	3.72	1006	3.75
20.00	8.36	3.30	6.08	1204	4.95
25.00	3.00	3.60	3.74	1101	3.45
25.00	3.00	3.00	3.34	1028	3.4
25.00	7.00	3.00	5.9	1240	5.34
25.00	7.00	3.60	6.23	1265	5.72
28.41	5.00	3.30	5.96	1236	4.8

significances of all terms in the polynomial equations were determined through appropriate statistical methods (coefficient of determination (R^2), F-value at a probability (P) of 0.05).

Sensory analysis

Plum wine produced by the optimised conditions was subjected to sensory evaluation by the 20-point Bux-Baum method. A five-member panel evaluate following wine properties: colour (max. 2 points), clarity (max. 2 points), aroma (max. 4 points) and taste (max. 12 points). OIV Wine Descriptor Codes were used for the sensory description of the wines [27].

RESULTS AND DISCUSSION

Characteristics of plum pomace

The physicochemical characteristics of the base plum pomace were determined in order to evaluate a potential of plum, as a raw material, for fruit wine production. The total sugar concentration was 125 g/L, where the share of reducing sugars was 60% and the rest was mostly sucrose (35%). Total acidity was 7.1 g/L, expressed as malic acid, while an initial pH of plum pomace was 3.64. The content of fermentable nitrogen was 266 mg/L, which showed that additional nitrogen sources were unnecessary for normal fermentation process.

Statistical analysis

The most important parameters affecting the production of wine, in general, are temperature, pH and time of fermentation. In order to ensure the best quality characteristics of plum wine it is necessary to investigate and optimize fermentation parameters. The effects of these factors on ethanol, glycerol and methanol content in plum wine are shown in Table 2. Multiple regression analysis was performed to fit the

Table 3. Second-order polynomial models for investigated responses ($Y_{1–3}$); X_1: temperature (°C); X_2: fermentation time (day); X_3: pH; Y_1: ethanol content (vol.%); Y_2: methanol content (mg/L); Y_3: glycerol content (g/L); R^2: determination coefficient

Parameter	Equation	R^2
Ethanol	$Y_1 = -27.8149 + 0.9035X_1 + 1.8612X_2 + 7.6636X_3 - 0.0237X_1X_2 - 0.0183X_1X_3 + 0.0833X_2X_3 - 0.0114X_1^2 - 0.0884X_2^2 - 1.0631X_3^2$	0.987
Methanol	$Y_2 = -5550.7745 + 306.2226X_1 + 489.5587X_2 + 919.1365X_3 - 3.8250X_1X_2 - 20.6667X_1X_3 - 24.1667X_2X_3 - 4.5037X_1^2 - 25.0548X_2^2 - 27.3553X_3^2$	0.934
Glycerol	$Y_3 = -3.0893 + 0.6409X_1 + 0.9975X_2 - 3.3613X_3 + 0.0259X_1X_2 - 4.1667\text{E-}3X_1X_3 - 0.0104X_2X_3 - 0.0144X_1^2 - 0.0982X_2^2 + 0.6226X_3^2$	0.958

response functions ($Y_{1–3}$), and second order polynomial equations (Table 3) have been obtained. Regression coefficients (b_0,b_1,b_2,…,b_{13}) were used to generate response surface plots for investigated variables ($Y_{1–3}$). Response surface plots (Figures 1–3) are used to illustrate the effects of temperature, pH and fermentation time on the responses. Coefficient of determination (R^2) was used to evaluate the goodness of fitted models. The analysis of variance (ANOVA) is used to determine the adequacy and the significance of the quadratic models. The analyses were done by means of Fisher's *F*-test, and the results are shown in Table 4. The regression models were significant ($P < 0.05$) with a satisfactory value of determination coefficients ($R^2 > 0.90$), implying that at least 90% of the variability in the response could be explained by the second-order model equations.

Effects of fermentation temperature, time and pH

Optimal temperature and pH values for *Saccharomyces cerevisiae* activity are in the range of 25–30 °C and 4.5–6.5, respectively. However, wine fermentations are usually conducted at a relatively lower temperature (15–25 °C) and pH values (3.3–3.6), despite the risk of slower ethanol production, in order to

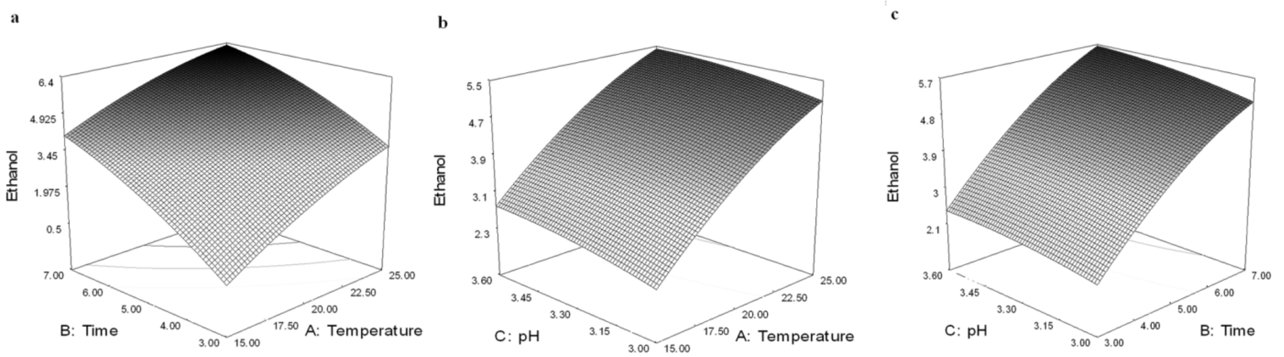

Figure 1. Response surface plots of the interaction of a) temperature– time (pH 3.3), b) temperature– pH (time = 5 days) and c) time–pH (temperature = 20 °C), and their influence on ethanol content.

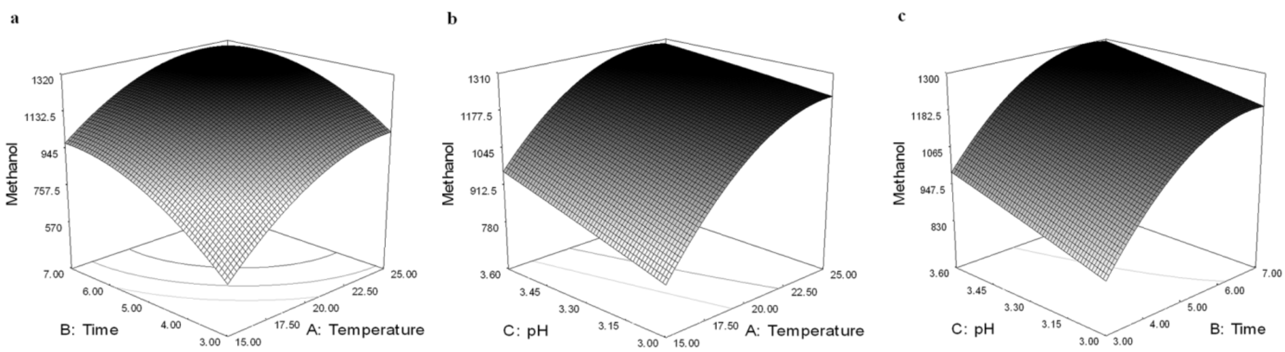

Figure 2. Response surface plots of the interaction of a) temperature–time (pH 3.3), b) temperature–pH (time = 5 days) and c) time–pH (temperature = 20 °C), and their influence on methanol content.

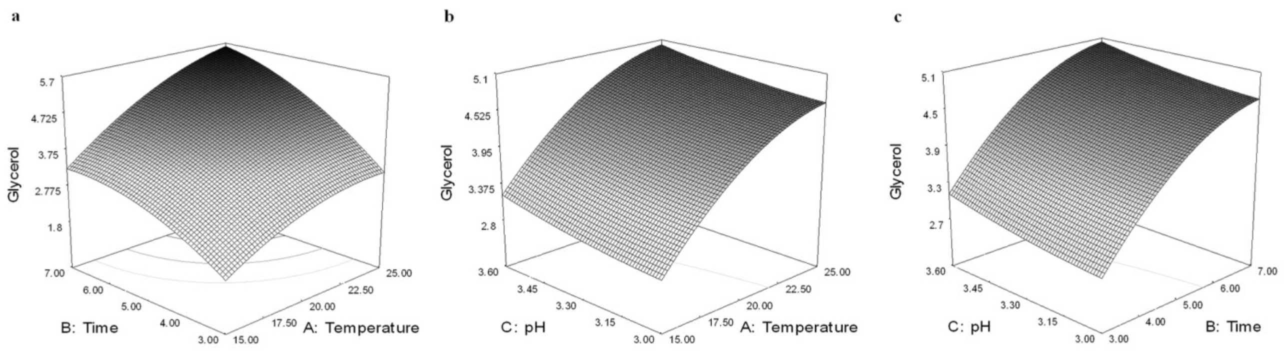

Figure 3. Response surface plots of the interaction of a) temperature–time (pH 3.3), b) temperature–pH (time = 5 days) and c) time–pH (temperature = 20 °C), and their influence on glycerol content.

*Table 4. Analysis of variance (ANOVA) for the experimental results; X_1: temperature (°C); X_2: fermentation time (day); X_3: pH; Y_1: ethanol content (vol.%); Y_2: methanol content (mg/L); Y_3: glycerol content (g/L); *significant at P < 0.05; **not significant*

Source	*F*-Value			*P*-Value		
	Y_1	Y_2	Y_3	Y_1	Y_2	Y_3
Model	152.02	15.76	25.67	< 0.0001*	< 0.0001*	< 0.0001*
X_1	548.74	57.63	90.62	< 0.0001*	< 0.0001*	< 0.0001*
X_2	734.62	42.06	100.59	< 0.0001*	< 0.0001*	< 0.0001*
X_3	13.32	5.77	3.71	0.0045*	0.0371*	0.0830**
X_1X_2	10.06	1.32	4.31	0.0100*	0.2780**	0.0645**
X_1X_3	0.13	0.86	2.5E-3	0.7211**	0.3744**	0.9610**
X_2X_3	0.45	0.19	2.5E-3	0.5195**	0.6729**	0.9610**
X_1^2	26.06	20.54	14.99	0.0005*	0.0011*	0.0031*
X_2^2	40.20	16.27	17.93	< 0.0001*	0.0024*	0.0017*
X_3^2	2.94	9.8E-3	0.36	0.1172**	0.9230**	0.5595**

decrease the risk of potential wine spoilage [28]. Hence, the influence of these levels of fermentation conditions on plum wine quality was investigated in this study.

Ethanol is the main product of the alcoholic fermentation of sugar in fruit juices and it contributes to the body and mouthfeel of a wine. As an organic solvent, ethanol helps to extract colour and phenolic compounds from the skins of fruit during fermentation. In addition to flavour, it also provides microbial stability to wine. We can notice (Figure 1) that the fermentations at 15 °C were not completed in the observed time (7 days), according to the ethanol content (3.64–4.35 vol.%) and the amount of available sugar in plum pomace (125 g/L). The maximum ethanol content (6.23%) was reached during fermentation at 25 °C and pH 3.6. Increase in temperature of fermentation has caused an intense increase in ethanol production, while the influence of pH was not so pronounced. Figure 1 shows the response surface plots for the effect of the independent variables on the ethanol content. The obtained model (Y_1), with a determination coefficient $R^2 = 0.987$ is proved as significant ($P < 0.05$), with only 1.13% of the total variations not explained by the model. The model terms X_1, X_2, X_3, X_1^2, X_2^2 and X_1X_2 are significant at 0.05 level ($P < 0.05$) while terms X_1X_3, X_2X_3 and X_3^2 do not have a significant effect on ethanol content (Table 4). Ethanol content was positively affected by the fermentation temperature, time and pH, and negatively by interactions between temperature and time, as well as by the quadratic terms of temperature and time of fermentation.

Methanol has no organoleptic impact on wine. It is not formed by alcoholic fermentation, but exclusively from enzymatic hydrolysis of the methoxyl groups of pectins during fermentation [29]. From Figure 2 it can be seen that most of the methanol is formed in the first 4 days of fermentation when the activity of pectin methylesterase is highest. Furthermore, exponential increase in methanol concentration is observed with the increase of fermentation temperature. Increase in pH values of plum pomace has caused a slight increase in its content. Hence, the maximum methanol content (1265 mg/L) is obtained when process parameters were 25 °C and pH 3.6, after 7 days of fermentation. Generally, the high methanol content was obtained in all wine samples. This is a problem because methanol is toxic to human through ingestion and inhalation. Its oxidation leads to production of formic aldehyde and formic acid, both toxic to the central nervous system [29]. Oral lethal dose of methanol for human ranges from 340 µg to 1 mg/kg of body weight [30]. A possible explanation for these results can be found in the fact that plums have high pectin content (2.0–3.5 mass%) and the high degree of esterification [31]. For instance, mango has 0.7–1 mass% of pectins [32] and its wine can contain up to 800 mg/L of methanol [33]. Wine from apples, another fruit that has high content of pectins – 0.7–0.84 mass% [34], can have high methanol concentrations (up to 700 mg/L) [35]. The addition of pectinase in pomace is also causing an increase in methanol level [33,36]. According to the Serbian regulations on alcoholic drinks quality, the maximal dose of methanol in fruit wines is 250 mg/L and in fruit brandies 10–14 g on the litre of absolute ethanol. From the regression model (Y_2) of methanol concentration, the value of determination coefficient ($R^2 = 0.934$) indicates that only 6.6% of the total variance could not be explained by the model. Among the model terms X_1, X_2, X_3, X_1^2, X_3^2 are significant with the probability of 95% (Table 4). The interactions between X_1, X_3 and X_3, as well as quadratic term X_3^2 however, did not have significant influence on methanol production. The influence of pH is less significant compared to the influence of temperature and time. Production of methanol was positively affected by the linear effects of temperature, time and pH, while quadratic terms of the first two factors had a negative influence.

Glycerol is a non-volatile compound, without aromatic properties, but which significantly contributes to wine quality by providing sweetness and fullness [29,37]. It can be noticed (Figure 3) that glycerol content increased with the increase of fermentation temperature and pH of pomace. The highest glycerol content (5.72 g/L) was obtained during fermentation at 25 °C and pH 3.6. Production of glycerol was more intensive during first 4 days of fermentation, especially at the higher temperatures (25 °C). As already mentioned, a temperature of 15 °C delayed the fermentation and left residual sugars, but according to the fact that glycerol production is connected with the first 50 g of sugar fermented [29], extension of fermentation would not increase significantly its concentration. The previous studies have also shown that an increase in temperature resulted in greater glycerol production [3,4,37]. It was reported that a pH increase from 2.8 to 3.7 has only a slight effect on glycerol yield [38]. The amount of this parameter in plum wine was lower than in wines produced from grapes (4–9 g/L), mango (5.5–8.4 g/L) and raspberry (5–10 g/L) [4,7,38]. The possible explanation may be found in the fact that higher concentrations of glycerol are obtained in mediums with higher content of glucose [39]. According to the determination coefficient of glycerol $R^2 = 0.958$ it can be concluded that only 4.2% of the total variance could not be explained by the model Y_3, which is proved to be significant ($P < 0.05$). The significance at 0.05 level ($P < 0.05$) is associated with following model terms: X_1, X_2, X_1^2, X_2^2; on the other hand, terms X_3, X_1X_3, X_1X_3, X_2X_3 and X_3^2 are insignificant ($P > 0.05$). It can be seen that the glycerol content was positively affected by fermentation temperature and time. Furthermore, quadratic terms of temperature and time of fermentation negatively affected glycerol production.

Optimisation

The obtained response surfaces (Figures 1–3) were used as guidelines in the optimisation of investigated parameters for plum wine production. According to the general winemaking practices, it is expected that the optimisation should be aimed to maximise ethanol, glycerol and minimise methanol yield. Methanol is a limiting factor in this study because of the very high values of its content obtained in all wines. The optimisation was made by use of desirability function concept which combines multiple responses into one response by assigning a value from 0 (one or more characteristics are unacceptable) to 1 (all process characteristics are on target). After the transformation of estimated responses into individual desirability values (from 0 to 1), the overall desirability of the process is calculated as geometric mean of the individual desirability functions [21]. The final optimised fermentation conditions, obtained with RSM, were 18.3 °C, pH 3.0 and 7 days fermentation time, which should ensure the production of 4.72 vol.% of ethanol, 1122 mg/L of methanol and 4.23 g/L of glycerol. The predicted optimum was verified and the models were proven as adequate after a repeated experiment (triplicate set), with the optimal fermentation conditions, was done (4.95% of ethanol, 1087 mg/L of methanol and 4.10 g/L of glycerol were obtained). The obtained desirability function value was 0.558. This value is relatively low because of the strong limiting effect of the high methanol content. Reduction of the methanol content could lead to an increase of the overall desirability function value.

Sensory evaluation of the plum wine produced with optimized fermentation conditions showed good quality and overall acceptability, according to the assigned average values for colour (1.9), clarity (2.0), aroma (3.4) and taste (9.1), in total 16.4.

CONCLUSION

The results of this study are significant for improvement of plum wine production, primarily in terms of optimisation of fermentation conditions. From the results it can be seen that changes in ethanol, methanol and glycerol during fermentation are well described by the obtained second order equations, according to the high coefficients of determination ($R^2 > 90\%$) and statistical significance ($P < 0.05$). It has been shown that fermentation at 15 °C could not be completed in the observed time (7 days). Considering the content of ethanol and glycerol, the average values of 6% and 5 g/L, respectively, were obtained. Generally, high methanol concentrations (above 1000 mg/L) were recorded in all wine samples. The optimal conditions for plum wine production were 18.3 °C, pH 3.0 and 7 days within which the production of 4.72% of ethanol, 1122 mg/L of methanol and 4.23 g/L of glycerol should be ensured. This was confirmed through the validation experiment. Apart from the problem of very high methanol concentrations, plum wine produced with the optimal conditions has good sensory properties and acceptability. Future studies will have to deal with the investigation of possible procedures to reduce the methanol content in plum wines. Furthermore, the suitability of other plum varieties for wine production should be checked.

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IZVOD

Ispitivanje uticaja uslova fermentacije na proizvodnju vina od šljiva (*Prunus domestica* L.) primenom metode odzivne površine

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(Naučni rad)

Šljiva (*Prunus domestica* L.) predstavlja najvažniju i najzastupljeniju vrstu voća u Srbiji koja je ujedno i jedan od najvećih proizvođača ovog voća u svetu. Njena upotreba je uglavnom vezana za potrošnju u svežem stanju, sušenje i proizvodnju voćne rakije šljivovice. Upotreba šljiva u proizvodnji vina nije uobičajena, ali ni dovoljno istražena. Cilj ovog rada bio je da se ispita uticaj temperature, pH i trajanja fermentacije na hemijski sastav i kvalitet vina od šljiva, kao i da se optimizuju pomenuti faktori procesa fermentacije upotrebom metode odzivnih površina (RSM). Pokazano je da dobijene jednačine drugog reda adekvatno predstavljaju fitovane modele za ispitivane parametre kvaliteta vina (R^2 > 0,90 i P < < 0,05). Prosečna vrednost za sadržaj etanola u proizvedenim vinima je bila 6 zapr.%, glicerola 5 g/l, dok je koncentracija metanola bila veoma visoka (iznad 1000 mg/l) u svim uzorcima. S obzirom na toksična svojstva metanola, ovakvi rezultati zahtevaju opsežna ispitivanja mogućih postupaka za smanjenje sadržaja ovog jedinjenja u vinu od šljiva. Optimalni uslovi fermentacije za proizvodnju vina šljive dobijeni su primenom metode funkcije poželjnosti, koja je bila usmerena na postizanje maksimalnog prinosa etanola i glicerola i minimalnog prinosa metanola. Primenom pomenute metode dobijene su sledeće optimalne vrednosti: 18,3 °C (temperatura ferementacije), pH 3,0 i 7 dana trajanja fermentacije. Ako se zanemari nedostatak usled visokih koncentracija metanola, vino od šljiva proizvedeno pri optimalnim uslovima imalo je dobre senzorne karakteristike i sveukupnu prihvatljivost.

Ključne reči: Šljiva • Vino • Optimizacija • Uslovi fermentacije • Metanol