Determination of physicochemical quality parameters of fruit wines produced in Republic of Serbia

Uroš Čakar[1*], Ivan Stanković[1], Brižita Đorđević[1]

[1]Department of Bromatology, Faculty of Pharmacy, University of Belgrade, Vojvode Stepe 450, 11000 Belgrade, Republic of Serbia

*Corresponding author: Uroš Čakar, e-mail: uros.cakar@pharmacy.bg.ac.rs

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Abstract

Fruit wines are products obtained after the processing of fruit crops which are not grapes. Water and alcohol are the most abundant constituents of fruit wines, along with biologically active compounds which are present in small amounts. Taken together, they significantly affect the physicochemical quality parameters. Before market placement, it is important to determine the physicochemical quality parameters of fruit wines.

This study deals with the determination of physicochemical quality parameters in blackberry and sour cherry fruit wines produced in Serbia. The total content of acids determined by titration was in the interval from 7.37 to 9.05 g/L express to mallic acid. The pH values were from 2.75 to 3.57. The content of free SO_2 is important to prevent spoilage induced by microorganisms, and it was in the range from 12.52 to 15.21 mg/L. The ethanol content of samples was in the interval from 6.87 to 13.57 % *v/v*. The obtained values for ethanol content were in accordance with the initial content of sugar in vinification, which was in the range from 13.8 to 24.2 ° Brix. Total phenolic content of fruit wines was from 1895.77 to 2417.21 mg/L expressed as gallic acid equivalents.

All the investigated physicochemical parameters of the analyzed fruit wines, except ethanol content, were in line with the National Regulations for Quality and Other Demands for Grape Wine (National Regulations). The obtained results indicate the quality of fruit and demonstrate that all the procedures applied during wine production were conducted properly to obtain a quality final product. Ethanol content was below the minimal limit in 5 of 11 analyzed samples according to the National Regulations. This can be explained by the fact that every fruit has a different composition of natural constituents, which is a crucial reason to adopt specific regulations related to quality and other requirements for fruit wines.

Key words: fruit wine, blackberry, raspberry, physicochemical quality parameters, polyphenols

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Introduction

Processing grapes and fruit into wine is a procedure which originates from the beginning of human civilization. The selection of grapes or fruit for wine production depended on the geographical location and climate conditions (1). Today the amount of all other produced fruit except grapes is increasing worldwide, and Serbia also contributes to these statistical results as a European and world leader in the production of high-quality raspberry, blackberry and plum (2).

The food which humans consume can be processed, semi-processed, and raw, with beverages such as wine also belonging to these groups, so according to the Codex Alimentarius wine is classified as a food (3). Wine is a product obtained after total or partial alcoholic fermentation of grape varieties which are allowed to be cultivated in Serbia (4), or any other fruit such as apple, plum, peach, apricot, strawberry, raspberry, blueberry and black chokeberry. Today, the most famous fruit wine is cider, which is produced from apples, and depending on the geographical origin alcohol content in cider could range from 1.5 to 14%. It is also important to highlight pear wine "poire," which is produced in France (5). There is also a long tradition of blackberry and plum wine production in the Republic of Korea (6, 7). There are also fruit wines with alcohol content from 18 to 20 vol%, usually sweet in taste and enriched with medicinal herbs. Those wines possess beneficial health effects, and are generally known as medicinal wines (8).

Processes applied during the production of fruit wine are same as those applied during the production of white and red wines (8). Alcoholic fermentation is a crucial reaction which occurs during vinification. It is important to highlight other biochemical reactions, since enzymes from yeasts are responsible for its kinetics, especially those from the *Saccharomyces cerevisiae* strain, which is a key initiator of alcoholic fermentation (9). Today, modern production of fruit wines is well-developed. This is supported by the fact that the production of cider increased from 2.3 billion liters in 2015 to 2.6 billion liters in 2022. (10). Berry fruit, especially raspberry, blackberry, blueberry and strawberry, showed good properties during the processing into wine. Studies of fruit wines in Serbia, which included those produced from blackberry as well as cherry, showed that a different technological approach during the controlled experimental microvinification procedure significantly affected the physicochemical properties (11, 12).

The main constituent of fruit wine is water, while alcohols, organic acids, aromatic compounds, minerals and many other organic compounds are present too (13). The chemical composition of wine significantly contributes to the color, clarity and harmony between taste and aroma. The final alcohol content of wine depends on the sugar and acid content of fruit. Ethanol is a main product of alcoholic fermentation obtained after the transformation of sugar. Other compounds which are classified as alcohols, such as isoamyl alcohol, amyl alcohol and isobutyl alcohol, are present too (14, 15). Natural compounds present in wine are responsible for wine quality, which is important for the development of sensory properties.

Fruit wine quality depends on the chemical composition, which is responsible for organoleptic properties. The determination of physicochemical quality parameters of fruit wine is important, since results will indicate whether the final product (fruit wine) can be consumed. Unfortunately, in the Republic of Serbia there are no specific regulations related to the quality of fruit wines, which is why quality regulations related to grape wines are applied. The aim of this study was to determine the physicochemical quality parameters of fruit wines produced in Serbia which are available on the market, and to show whether fruit wine meets the quality conditions for grape wine.

Material and methods

Wine samples

In this study, 11 samples of fruit wine produced from blackberry and cherry were analyzed. The aforementioned fruit wines were obtained from local agricultural producers located in three different Serbian winegrowing sub regions (Table I). Thornfree cultivar was used for the production of blackberry wines, while cherry wines were produced from the Šumadinka cultivar. Immediately after being picked from an orchard, blackberries and cherries were processed into wine.

Table I Fruit wine samples and their geographical origin

Tabela I Uzorci voćnog vina i njihovo geografsko poreklo

Type of Fruit	Number of Sample	Winegrowing sub region	Abbreviation of Sample	Producer Number
Blackberry	1	Belgrade	B1B	1
Blackberry	2	Belgrade	B2B	1
Blackberry	3	Belgrade	B3B	1
Blackberry	4	Belgrade	B4B	1
Blackberry	5	Pocerje-Valjevo	B5PV	2
Blackberry	6	Pocerje-Valjevo	B6PV	2
Cherry	7	Belgrade	C7B	1
Cherry	8	Belgrade	C8B	1
Cherry	9	Belgrade	C9B	1
Cherry	10	Belgrade	C10B	1
Cherry	11	Knjazevac	C11K	3

Alcoholic fermentation of cherry wine (samples 1, 2, 3 and 4), as well as blackberry wine (samples 7, 8, 9 and 10), was conducted by the usage of the *S. cerevisie* yeast strain ICV D254 (Lallemand, Blagnac, France) in steel wats. Before the start of fermentation, potassium metabisulfite ($K_2S_2O_5$) was added in the amount of 10g/100kg in order to prevent the growth of unwanted microorganisms. In samples 1, 3, 8 and 10, sugar was added before the start of fermentation to increase the alcohol content in wine. All fermentations lasted for 12 days, after which the wine was bottled and kept in a cellar until further analysis. Samples 1, 2, 7 and 8 were from 2021, while 3, 4, 9 and 10 were from 2022.

Samples 5 and 6 were obtained after alcoholic fermentations conducted by the usage of the *S. cerevisie* yeast strain FX10 (Laffort, Bordeaux, France) in steel wats. Before the start of fermentation, $K_2S_2O_5$ was added in the amount of 10g/100kg. In sample 6, sugar was added before the start of fermentation in order to increase the alcohol content in wine. All the alcoholic fermentations lasted for 14 days, after which the wine was bottled and kept in a cellar until further analysis. The fruit wines were produced during 2022.

The process of alcoholic fermentation of sample 11 was conducted by the usage of the *S. cerevisie* yeast strain Qa23 (Lallemand, Montréal, Canada) in steel wats. Before the start of fermentation, $K_2S_2O_5$ was added in the amount of 10g/100kg. Sugar was added before the start of fermentation to increase the alcohol content in wine. Fermentation lasted for 16 days, after which the wine was bottled and kept in a cellar until further analysis. The fruit wine was produced in 2022.

Chemical analysis of fruit wines

The chemical analysis of fruit wines was conducted according to the official methods applied in enology. Specific regulations regarding the analysis of fruit wine do not exist in Serbia yet, so for this reason regulations related to wine produced from grapes were applied. The regulations for wine analysis in Serbia – the Rulebook on Quality and Other Requirements for Wine, 2016 (4), are in accordance with the regulations of the International Organisation of Vine and Wine (OIV), Paris, France (16). The physicochemical quality parameters prescribed for grape wines in Serbia are alcohol content, wine extract content, ash content, total titratable acidity, free sulphur-dioxide and total phenolic content. Organoleptic properties such as color, smell and aroma are also tested. If wine organoleptic properties are not in line for the specific wine, but meet the quality parameters, it is possible to conduct additional analyses, such as the determination of glycerol content, heavy metal content, methanol content, sorbic and citric acid content. In this paper, physicochemical methods for wine analysis were applied.

Total Titratable Acidity (TTA)

Total titratable acidity determination was conducted by titration with 0.25M NaOH, while titration endpoint was indicated by phenol phenolphthalein and pH meter (17). The obtained results were expressed as grams of malic acid per liter of fruit wine.

pH value

In the fruit wine samples, pH value was determined after potentiometric measurement conducted by microprocessor-based pH/mV/°C pH 212 instrument(Hanna Instruments, Woonsocket, RI, USA) (16).

Free sulphur-dioxide (SO_2)

The content of free SO_2 was determined in fruit wine directly after titration with a solution of iodine (18). The obtained result was expressed as mg of free SO_2 per liter of fruit wine.

Total Soluble Solids (TSS)

Total soluble solids were measured in fruit juice and represent the sugar content. For this purpose, refractometer PAL-87S (Atago, Tokyo, Japan) was used. The obtained results were expressed in °Brix (16).

Alcohol content

After the distillation of fruit wine, alcohol content was determined by the alcohol density meter DMA 35 (Anton Paar, Graz, Austria). The results were expressed as strength by volume (% v/v), after calculation during which 20°C/20°C tables were used (16).

Wine extract content

Wine extract content was measured in the liquid which was left in the balloon after fruit wine distillation. For this purpose, alcohol density meter DMA 35 was used (Anton Paar, Graz, Austria). The results were obtained after calculation, during which 20°C/20°C tables were used, and they were expressed as g/L (16).

Total phenolic content

Total phenolic content (TPC) of the analyzed fruit wines was determined by the Folin–Ciocalteu method (19). Gallic acid was used as a standard, and the results were expressed as mg/L of gallic acid equivalents (mg GAE/L). All analyses were conducted in triplicate.

Statistical analysis

The data were analyzed using the SPSS 21 statistical software. One-way analysis of variance (ANOVA) was used to compare the results of physicochemical quality parameters for blackberry and cherry wines. Statistical analysis was performed using the Tukey test to examine significant differences between the results for physicochemical quality parameters of different wines made from the same fruit (blackberry and cherry). *p* values lower than 0.05 ($p<0.05$) were consider to be statistically significant.

Results and Discussion

Total Titratable Acidity (TTA)

The obtained results for TTA (Table II) were in the interval from 7.37 to 9.05 g/L mallic acid. The lowest content was detected in blackberry wine sample B4B, while the highest was also in a blackberry wine sample, B6PV. Literature data indicate that the TTA of blackberry wine was 3.5 g/L (20), while in sour cherry it was 6.82 g/L (21). The regulations related to fruit wines from Republika Srpska (22) emphasized that TTA has to be higher than 3.5 g/L mallic acid. In comparison to the obtained results from this study, it is important to point out that the TTA content of grape wine is from 3.5 to 9.5 g/L tartaric acid (17). It is important to point out that fruit, due to its specific natural composition, is higher in organic acids content compared to grapes. This is the main reason for TTA higher values of fruit wine compared to grape wines. Mallic and citric acids are the most predominant compounds which are responsible for fruit acidity.

Table II Physicochemical quality parameters (total titratable acidity, pH and free SO_2) of blackberry and cherry wine

Tabela II Fizičko-hemijski parametri kvaliteta (ukupna kiselina određena titracijom, pH i slobodni SO_2) vina od kupina i višnje

Blackberry (B)			
Fruit wine sample	**Total Titratable Acidity (g/L)**	**pH**	**Free sulphur-dioxide (mg/L)**
B1B	8.45 ± 0.08^{a}	2.75 ± 0.01^{c}	12.95±1.25
B2B	7.57 ± 0.07^{b}	2.81 ± 0.01^{c}	14.15±1.47
B3B	8.53 ± 0.08^{a}	2.87 ± 0.02^{d}	13.52±1.18
B4B	7.37 ± 0.09^{b}	2.85 ± 0.01^{d}	14.23±1.57
B5PV	8.00 ± 0.07^{c}	2.91 ± 0.02^{c}	12.87±1.07
B6PV	9.05 ± 0.11^{c}	2.95 ± 0.01^{c}	12.52±1.21
Cherry (C)			
Fruit wine sample	**Total Titratable Acidity (g/L)**	**pH**	**Free sulphur-dioxide (mg/L)**
C7B	8.31 ± 0.08^{e}	3.38 ± 0.01^{h}	13.45±1.37
C8B	7.25 ± 0.09^{f}	3.42 ± 0.02^{i}	13.77±1.41
C9B	8.17 ± 0.08^{e}	3.35 ± 0.02^{j}	14.53±1.57
C10B	7.40 ± 0.09^{f}	3.43 ± 0.01^{f}	15.21±1.71
C11K	7.80 ± 0.08^{g}	3.57 ± 0.02^{g}	14.47±1.25

Requirements for grape wines according to regulations in Serba			
Total Titratable Acidity (g/L)	**pH**	**Free sulphur-dioxide (mg/L)**	
more than 4.5	/	Red wine with sugar content up to 4g/L	max 150
		White and rose wine with sugar content up to 4g/L	max 200
		White and rose wine with sugar content more than 4g/L	max 250

a-(sig. dif. from samples 2, 4, 5, 6; $p<0.05$); b-(sig. dif. from samples 1, 2, 5, 6; $p<0.05$); c-(sig. dif. from all cherry wine samples within the same column; $p<0.05$); d-(sig. dif. from samples 1, 2, 5, 6; $p<0.05$).

e-(sig. dif. from samples 8, 10, 11; $p<0.05$); f-(sig. dif. from samples 7, 9, 11; $p<0.05$); g-(sig. dif. from samples 7, 8, 9, 10; $p<0.05$); h-(sig. dif. from samples 10, 11; $p<0.05$); i-(sig. dif. from samples 9, 11; $p<0.05$); j-(sig. dif. from samples 8, 10, 11; $p<0.05$).

During alcoholic fermentation, some acids such as acetic, lactic, propionic, butyric and succinic acids could be generated. The degradation or generation of the abovementioned organic acid is responsible for the different values of total titratable acidity of fruit wine (14). It is important to point out that every fruit possesses its specific profile and content of organic acids. The TTA and pH are significant parameters which are responsible for the aroma, color, stability and maturity of fruit wine (16, 23). The determination of TTA is an important analysis, since the presence of organic acids in fruit wines is responsible for preservation from spoilage.

pH value

The pH values of the samples (Table II) were from 2.75 to 3.57. The lowest pH was detected in blackberry wine sample B1B, while the highest was in cherry wine sample C11K. Compared to fruit wines, the pH values of grape wines are in the interval from 2.8 to 4 (24). The values for this parameter depend on the content of organic acids in wine and its dissociation ability. The highest dissociation ability was shown by tartaric, mallic, and then other acids present in wine. Wine quality significantly depends on the pH value, since this parameter affects biochemical processes during wine maturation and aging. During sensory analysis of wine, the sour taste which we feel in our mouth is proportional to the pH value.

The pH values of fruit wines are different and depend on the fruit used for wine production. It is interesting to highlight the pH values of wines produced from black plum – pH 2.7 (25), banana – pH 3.3 (26), blueberry – pH 3.3-4.3 (27), and pineapple – pH 3.7 (28). When the pH value is over 3.6, fruit wine instability is higher, while lower pH values contribute to better stability. This can be explained by the fact that lower pH values prevent spoilage, bacteria growth and increased amounts of free SO_2. Fruit wine color and aroma significantly depend on the pH value (24). According to the fruit wine regulations in the USA (29), the allowed pH value is from 2.8 to 4.5.

Free sulphur-dioxide (SO_2)

The amount of SO_2 which is not bounded to biomolecules is defined as free SO_2 (17). This is a significant parameter, since the content of free SO_2 is important during wine production. The content of SO_2 in wine depends on fruit ripeness, pH value and temperature. The obtained results (Table II) indicate that the values for free SO_2 ranged from 12.52 to 15.21 mg/L. The lowest value was detected in blackberry wine sample B6PV, while the highest was in cherry wine sample C10B. The obtained results indicate different ability of biomolecules to bond to SO_2, which is responsible for the different amount of free SO_2 in various fruit wine samples. During wine production, additive potassium metabisulfite (E224) was used, from which SO_2 was obtained after alcoholic fermentation.

During the production of wine, the main role of SO_2 is to prevent the growth of unwanted yeast and bacteria responsible for wine spoilage, which results in an unpleasant smell and aroma (30). Besides the prevention of the growth of unwanted microorganisms, SO_2 is a source of elemental sulphur, which is important for the growth of *S. cerevisiae* yeast, which is responsible for controlled alcoholic fermentation. At the beginning of alcoholic fermentation, $K_2S_2O_5$ is added in fruit must, and during alcoholic fermentation free SO_2 is generated. According to wine regulations in Serbia (4), the content of SO_2 is limited to 250 mg/L. Moreover, the content of SO_2 in red wines with sugar amount up to 4g/L is limited to 150 mg/L. For white and rose wines with sugar amount up to 4g/L, it is limited to 200 mg/L, while in those with sugar amount higher than 4g/L it is limited to 250 mg/L. Higher amounts of SO_2 could result in headaches after wine consumption, while in some cases the effects could be more severe, such as allergy, vomiting and diarrhea. Regulations in Republika Srpska (22) related to fruit wines indicate that SO_2 is limited to 200 mg/L.

Total soluble solids (TSS) (sugar)

The values for TSS (sugar) of fruit juice (Table III) before the start of alcoholic fermentation were in the interval from 13.8 to 24.2 ° Brix. The lowest value was detected in blackberry wine sample B4B, while the highest was also in blackberry wine, but in sample B6PV. The determination of TSS of fruit juice was conducted to obtain the sugar content, which is important to predict the potential ethanol amount in the final product at the end of fermentation. Ethanol is a solvent of natural origin, obtained after fermentation, which is responsible for the extraction of phenolic compounds from solid parts of fruit (skin and seeds). The sugar content of fruit juice and alcohol amount in the final product are important for the stability and preservation of wine during maturation. It is important to point out that, compared to grapes, it is hard to extract sugars and other compounds from specific fruits. Compared to grapes, the juice obtained from most of fruit is lower in sugar, but high in acid content (8, 31).

Alcohol content

Alcohol content (ethanol) of the analyzed samples was in the interval from 6.87 to 13.57% *v/v* (Table III). The lowest alcohol content was in blackberry wine sample B4B, while the highest was also detected in blackberry wine, sample B6PV. This parameter of wine quality depends on the sugar content in fruit before the start of alcoholic fermentation. Ethanol is generated from sugars in anaerobic conditions under yeast cells activity. Higher sugar content results in higher alcohol content of wine. Based on the obtained results for sugar content of fruit juice (TSS), it was possible to predict alcohol content in the final product (wine). Besides sugar content, alcohol content depends on the type of yeast used during alcoholic fermentation and temperature.

Fruit wine alcohol content depends on the technology applied during production, and it is mostly from 5 to 15% v/v. Compared to grapes, the sugar content of fruit is mostly lower, and in such cases it is not possible to achieve the necessary alcohol content in wine. To avoid this problem, it is allowed to add sugar to fruit before the start of alcoholic fermentation. During the production process of cider, it is necessary to add sugar to achieve alcohol content of 5% v/v., which is the average value of this parameter for European ciders. Observing the data from fruit wine industry, alcohol content is a parameter which differs worldwide. In Great Britain, alcohol content is from 4 to 22% v/v (32), in the USA up to 14% *v/v* (29), while in Brazil it ranges from 4 to 14% v/v (33).

The regulations set by the Association of the Cider and Fruit Wine Industry of the European Union highlighted alcohol content from 1.2 to 14% *v/v* (34). The results of physicochemical analysis of fruit wine indicate that the alcohol content of blackberry and blueberry wines ranged from 9% to 12% v/v (20), plum wine from 6% to 13.5% (35), while in sour cherry it was from 10% to 13% (36). However, in the Republic of Korea it is possible to find fruit wines with much higher alcohol content, almost up to 15% v/v (37), while in peach wine it was 8.1% v/v (38).

Table III Physicochemical quality parameters (total soluble solids, alcohol content, wine extract content and total phenolic content) of blackberry and cherry wine

Tabela III Fizičko-hemijski parametri kvaliteta (ukupne rastvorljive materije, količina alkohola, količina ekstrakta vina i ukupan sadržaj polifenola) vina od kupina i višnje

Fruit wine sample	Total soluble solids (° Brix)	Alcohol content (% *v/v*)	Wine extract content (g/L)	Total Phenolic Content (mg GAE/L)
Blackberry (B)				
B1B	18.7±0.31^{a}	9.85±0.21^{a}	22.3±0.3^{f}	2185.57±25.0^{g}
B2B	14.5±0.17^{b}	7.27±0.15^{d}	21.2±0.7^{f}	2281.23±27.3^{b}
B3B	19.1±0.25^{a}	10.27±0.27^{a}	25.7±1.1^{e}	2173.32±29.5^{g}
B4B	13.8±0.21^{c}	6.87±0.10^{d}	18.7±0.5^{e}	2357.81±21.4^{h}
B5PV	14.1±0.15^{d}	7.21±0.07^{d}	28.3±0.7^{e}	2235.58±22.5^{i}
B6PV	24.2±0.24^{e}	13.57±0.23^{e}	38.0±1.5^{e}	2417.21±19.2^{h}
Cherry (C)				
Fruit wine sample	**Total soluble solids (° Brix)**	**Alcohol content (% *v/v*)**	**Wine extract content (g/L)**	**Total Phenolic Content (mg GAE/L)**
C7B	15.7±0.18^{j}	7.85±0.07^{l}	22.7±0.7^{l}	1918.81±25.8^{n}
C8B	19.5±0.22^{j}	10.55±0.17^{j}	26.8±1.2^{m}	1895.77±28.4^{o}
C9B	14.8±0.14^{j}	7.75±0.08^{l}	22.3±1.1^{l}	1995.32±23.8^{p}
C10B	20.3±0.23^{k}	11.17±0.14^{j}	27.3±0.8^{o}	1843.72±22.2^{m}
C11K	20.7±0.25^{k}	11.88±0.18^{l}	30.2±1.2^{j}	1987.51±24.1^{p}

Requirements for grape wines according to regulations in Serbia

Total soluble solids (° Brix)	Alcohol content (% *v/v*)	Wine extract content (g/L)	Total Phenolic Content (mg GAE/L)
/	8.5-15	White more than 15 Rose more than 16 Red more than 18	100-500 500-1500 More than 1500

a-(sig. dif. from samples 2, 4, 5, 6; p<0.05); b-(sig. dif. from samples 1, 3, 4, 6; p<0.05); c-(sig. dif. from samples 1, 2, 3, 6; p<0.05); d-(sig. dif. from samples 1, 3, 6; p<0.05); e-(sig. dif. from all blackberry wine samples within same column p<0.05); f-(sig. dif. from samples 3, 4, 5, 6; p<0.05); g-(sig. dif. from samples 2, 4, 6; p<0.05); h-(sig. dif. from samples 1, 2, 3, 5; p<0.05); i-(sig. dif. from samples 4, 6; p<0.05);

j-(sig. dif. from all cherry wine samples within the same column p<0.05); k-(sig. dif. from samples 7, 8, 9; p<0.05); l-(sig. dif. from samples 8, 10, 11; p<0.05); m-(sig. dif. from samples 7, 9, 11; p<0.05); n-(sig. dif. from samples 9, 10, 11; p<0.05); o-(sig. dif. from samples 9, 11; p<0.05); p-(sig. dif. from samples 7, 8, 10; p<0.05);

The most important parameter of fruit wine quality is alcohol content, since it significantly affects the values for other quality parameters. The regulations in Republika Srpska (30) indicate that the lowest alcohol content of fruit wine has to be 1.2% *v/v*. According to these regulations, besides regular fruit wine, there are desert and aromatic fruit wines with alcohol content up to 22% *v/v*. On the contrary, in Serbia the maximum alcohol content of fruit wine is limited to 15% v/v (4). High alcohol content up to 16% *v/v* and pH 2.9 could prevent the growth of unwanted bacteria, while in wines with lower alcohol content and pH above 3.7 there is greater possibility for spoilage. This problem may be overcome if wine is kept at temperatures lower than 15°C (39).

Wine extract content

The values for wine extract content of the samples (Table III) were in the interval from 18.7 up to 38 g/L. The lowest value was in blackberry wine sample B4B, while the highest was also detected in blackberry wine, sample B6PV. Wine extract content indicates wine quality. The minimal value for extract content of white wine is 11 g/L, while in red wine it is 13g/L. The components of wine extract are non-volatile compounds which are left in the balloon after the end of fruit wine distillation. The main components of fruit wine extract are organic compounds and minerals. This parameter is very important for fruit wine quality (40). Alcohol content in fruit wine indicates wine extract content. Higher amounts of sugar in fruit wine are responsible for higher amounts of ethanol and many other side products of alcoholic fermentation, such as glycerol. It is important to highlight that glycerol is the most important constituent of wine extract (41). Wine extract is a complex mixture of many different natural compounds. Beside sugar content and pH, organic acid content also significantly contributes to wine extract content. The balance between acidic and tannic compounds of fruit wine also affects wine extract content. Wine extract content depends on the fruit type and its cultivar used for wine production (42). It is important to point out that specific fruit cultivars are used for processing wine and other products, while other cultivars are consumed in the raw form.

Total Phenolic Content

The TPC values of the analyzed samples (Table III) were in the interval from 1895.77 to 2417.21 mg GAE/L. The lowest value was in cherry wine sample C8B, while the highest was in blackberry wine sample B6PV. Total phenolic content is a physicochemical quality parameter of grape wines, and its values are in the interval from 100 to 500 mg GAE/L for white wine, while for red wines they have to be higher than 1500 mg GAE/L. The TPC of fruit wines depends on the fruit type, its ripeness level and the technological approach applied during wine production. TPC value is also significantly dependent on the climate, soil and agro-technical approach during the growing. It is important to highlight that, during the processing of fruit into wine, compounds which have beneficial health effects are preserved and pass into the final product (40). The TPC of fruit wines significantly contributes to their quality, since phenolic compounds are responsible for organoleptic properties such as color and bitterness (43). Phenolic compounds are localized in the skin and seeds of fruit, which is particularly characteristic of berry fruit. It is important to highlight that berry fruit wines are a rich source of different classes of phenolic compounds such as flavonoids, flavan-3-ols and phenolic acids. The synergistic activity of all those compounds contributes to the antioxidant activity and beneficial health effect of fruit wines (44). Berry fruit skin colors are different, ranging from almost black (chokeberry and blackberry) to dark blue (blueberry) and red (raspberry and currants), which is due to the varying phenolic content of berries. Fruit which has darker skin possesses a higher amount of phenolic compounds, which have to be extracted to wine. For the extraction process, alcoholic fermentation is crucial, during which the skin and seeds are in contact with fruit juice which enables the maceration of phenolic compounds (11, 12). Alcoholic fermentation controlled by the selected pure yeast culture applied during wine production significantly increases TPC in comparison with unfermented product. Higher amounts of ethanol, which is obtained during fermentation, are responsible for better extraction of phenolic compounds (45).

Limitation of research

The findings of this research may be limited due to the number of analyzed samples – 11, since we could only obtain this number of samples for analysis from commercial producers.

Conclusions

Fruit wine production is a unique multidisciplinary process which encompasses knowledge and skills from physics, chemistry and biotechnology which are practically applied in solving problems to obtain a high-quality final product. From this point of view, the analysis of fruit wines in this paper showed important findings related to physicochemical quality parameters. All the investigated physicochemical parameters of the analyzed fruit wines, except alcohol content, were in line with the National Regulations. The alcohol content in 3 samples of blackberry and 2 samples of cherry wines was below the minimal limit according to the National Regulations, which could be explained by the fact that the initial content of sugar in fruit was lower compared to grapes. The obtained results for blackberry and cherry wine analysis indicate their high quality. Compared to the required values for grape wines, different values for some of analyzed parameters of fruit wines can be explained by the different natural composition of the cherry and blackberry fruit. This is a crucial reason to adopt specific regulations related to quality and other requirements for fruit wines.

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Declaration of Competing Interest

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Author contributions

For transparency, we require corresponding authors to provide co-author contributions to the manuscript using the relevant CRediT roles. The CRediT taxonomy includes 14 different roles describing each contributor’s specific contribution to the scholarly output. The roles are: Conceptualization-U.Č. ; Data curation-U.Č. ; Formal analysis-U.Č. ; Funding acquisition-B.Đ. ; Investigation-U.Č. ; Methodology-U.Č ; Project administration-I.S. ; Resources-B.Đ. and I.S. ; Supervision-B.Đ. and I.S. ; Visualization-U.Č. ; Roles/Writing - original draft-U.Č. ; and Writing - review & editing-B.Đ. and I.S. Note that not all roles may apply to every manuscript, and authors may have contributed through multiple roles.

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Ispitivanje fizičko-hemijskih parametara kvaliteta voćnih vina proizvedenih u Republici Srbiji

Uroš Čakar[1*], Ivan Stanković[1], Brižita Đorđević[1]

[1]Katedra za bromatologiju, Farmaceutski fakultet, Univerzitet u Beogradu, Vojvode Stepe 450, 11000 Beograd, Republika Srbija

*Autor za korespondenciju: Uroš Čakar, e-mail: uros.cakar@pharmacy.bg.ac.rs

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Kratak sadržaj

Voćna vina su proizvodi koji se dobijaju preradom voća koje nije grožđe. Voda i alkohol su najzastupljeniji u sastavu, dok su u malim količinama prisutna i biološki aktivna jedinjenja. Svi oni zajedno utiču na fizičko-hemijske parametre kvaliteta. Da bi voćna vina mogla da se nađu na tržištu, bitno je da se ispitaju fizičko-hemijski parametri kvaliteta.

U ovom radu ispitani su fizičko-hemijski parametri kvaliteta voćnih vina od kupine i višnje koja su proizvedena u Srbiji. Sadržaj ukupnih kiselina određen titracijom je bio od 7.37 do 9.05 g/L jabučne kiseline. Vrednosti za pH vina su bile u intervalu od 2.75 do 3.57. Količina slobodnog SO_2, koji je važan da zaštiti vino od mikrobiološkog kvarenja, bila je 12.52 do 15.21 mg/L. Količina alkohola u vinima bila je u intervalu od 6.87 do 13.57 % *v/v*. Upravo ove vrednosti su bile u skladu sa inicijalnim sadržajem šećera u vinifikacijama, koji je bio od 13.8 do 24.2 ° Brix. Sadržaj ukupnih polifenola u vinima je bio 1895.77 do 2417.21 mg/L ekvivalenata galne kiseline.

Svi rezultati analize kvaliteta voćnih vina, osim sadržaja alkohola, bili su u skladu sa Pravilnikom o kvalitetu i drugim zahtevima za vino od grožđa (Pravilnik), što ukazuje na kvalitet voća i na to da je postupak proizvodnje sproveden tako da se dobije dobar krajnji proizvod. Sadržaj alkohola u 5 od 11 uzoraka analiziranih vina je bio ispod najniže vrednosti propisane Pravilnikom, što se može objasniti različitom prirodom samog voća u odnosu na grožđe. Upravo to je glavni razlog da se usvoje posebni zakonski propisi koji će se odnositi na kvalitet i druge zahteve za voćna vina.

Ključne reči: voćno vino, kupina, malina, fizičkohemijski parametri kvaliteta, polifenoli

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