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Content of total phenolic compounds, anthocyanins and spectral characteristics of Gamza red wines depending on the alcoholic fermentation conditions

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Abstract

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The study was focused on the influence of yeast strains, temperature and the inoculum yeast culture amount on the variation of the total phenolic substances and anthocyanins in the course of the alcoholic fermentation. It was also found the impact of these factors on the spectral characteristics of Gamza wines. Collection strains *Badachoni* and *24-6* of *Saccharomyces cerevisiae* species were used. The fermentation was carried out at 20°C, 24°C, 28°C and inoculum yeast culture ratio of 2%, 3%, 4%. The change in the concentration of the studied components was similar and reached its peak during the rapid fermentation (day 5th), thereafter started to slowly go down. As the temperature and the amount of yeast culture increased, the total phenolic compounds and anthocyanins rate went up. The optimal temperature for getting of more intensely coloured wines with a higher content of phenolic substances was 28°C. Samples of both strains fermented at 28°C/4% had more quantity of total phenols, flavonoid and non-flavonoid phenolic compounds and anthocyanins. The colour intensity IC' and the indicator dA%, determining the red colour brightness, corresponded to the amount of anthocyanins. The red colour involvement was the largest in the variants obtained at 28°C. The mathematical modeling and the presentation of the wines' organoleptic parameters in the form of surfaces showed that the tasting evaluation results of the samples obtained with *Badachoni* strain were more homogeneous, with more clearly defined zones of maximum compared to those of *24-6* strain.

Keywords: wine; *Saccharomyces cerevisiae;* alcoholic fermentation; phenolic compounds; anthocyanins; spectral characteristics; organoleptic profile; neural networks

Introduction

Phenolic compounds had an important place in the composition of red wines. They had an influence not only on their organoleptic profile (clarity, colour, taste), but also on their physical and chemical stability and antioxidant features. These indicators were determined both by the direct content of the phenolic components and by their transformations (Chobanova, 2012; Radonjic et al., 2019).

The wine phenolic complex had depended on a number of factors such as variety, terroir, harvest and technological practices. The grapes contained about 200 phenolic substances, localized mainly in the solid parts. The skins, seeds and rachis had been a source of flavonoid phenolic compounds, while the fleshy part was rich in non-flavonoid compounds (Gardin & Altindisli, 2015; Gundeşli et al., 2018; Jimenez-Moreno et al., 2019).

The technological practices used in grape processing

and vinification also had a significant impact on the content of phenolic components in wine (Kekelidze et al., 2014; Clodoveo et al., 2016; Banc et al., 2020). They included the manner of grapes pressing, the maceration regime, the alcoholic fermentation conditions and the storage. Increasing the temperature and the alcoholic concentration in the fermentation medium accelerated the extraction process (Chobanova, 2012; Tartian et al., 2017). The supplement of oenological tannins during the fermentation improved the colour, aromatic and taste features of the obtained wines (Stoyanov, 2007). The type of maceration applied depended on the grape variety, its quality and the style of wine that the wine-maker wished to achieve. The various maceration techniques affected the extraction of the phenolic components in different ways (Tartian et al., 2017). After the alcoholic fermentation completion, they underwent quantitative and qualitative changes that depended not only on the technological conditions, but were also strongly influenced by the specifics of the yeast strain (Stoyanov et al., 2004; Barra et al., 2005).

The phenolic compounds and mainly the anthocyanins participated in the formation of the colour and spectral features of wines. The anthocyanins had been the main component determining the red colour of young wines (Boyadjieva et al., 2016). These were the red pigments, localized mainly in the skins, and in some varieties in the flesh. The anthocyanins profile of wines had been determined mainly by the varietal specifics of the grapes (Burns et al., 2003; Otteneder and Marx, 2004; Leeuw et al., 2014), but also by the applied wine-making technology (Bai et al., 2013; Clodoveo et al., 2016; Banc et al., 2020). Typically, wines obtained from more coloured varieties also contained higher amounts of anthocyanins (Kilmister et al., 2014).

In red wines, the effect of yeast was mainly on the anthocyanins rate. The different species and strains produced extracellular β-glucosidase of various activity. That enzyme affected the colour by catalyzing the hydrolysis of β-bonds in the glucoside forms of the anthocyanins (Ovalle et al., 2018). The higher enzyme activity did not reduce directly the amount of anthocyanins, but directly affected their colouring ability, converting them into aglucones prone to copolymerization (Spasov et al., 1998).

The influence of the phenolic compounds on the taste of red wines might be positive or negative, depending on their quantity and structure (Bai et al., 2013; Radonjic et al., 2019). The tannins from the grape skins were softer and gave the wine blandness, softness and colour, but extracted in larger quantities enhanced the bitter taste. The tannins from the seeds added to the wine structure and body, but in a higher ratio they made it tart (Abrasheva et al., 2008).

Recently in Bulgaria the interest of the wine-makers in the local grapevine varieties and their wines had been growing. Such a variety was Gamza, spread mainly in the North Western and Central Northern Bulgaria. Red wines with lively, not very dense ruby colour, pleasant aroma of red fruits, dominated by raspberries, and taste, characterized by light freshness and pleasant tannins, had been made from well-ripened and healthy grapes. The wines had been suitable for consumption as young (Donchev et al., 1982; Radulov et al., 2004; http://www.wikipedia.org; http://bg-shop.eu/info/2008/01/bg/). Previous studies had analyzed the phenolic composition (total flavonoids, catechin, epicatechin, syringic acid, vanilla acid), the antioxidant activity and the resveratrol content in wines from Gamza variety, but no direct correlation was found between the studied indicators ratio (Gülcü & Yoncheva, 2017; Yoncheva et al., 2018; Yoncheva et al., 2019).

The objective of the present study was to trace the influence of the technological factors – yeast strain, temperature and amount of inoculum yeast culture on the content of the total phenolic compounds, anthocyanins, spectral characteristics and the organoleptic profile of Gamza red wines.

Material and Methods

Grapes

The experimental work was carried out at the Institute of Viticulture and Enology – Pleven with grapes of Gamza variety. The grapes were harvested at technological maturity and processed in the conditions of micro-vinification according to the classic scheme for production of red wines (Abrasheva et al., 2008). Each experimental variant was crumbled and crushed separately and the uniformity of the raw material was ensured by even dividing of the bunches. The chemical composition of grapes is presented in Table 1.

The grape must chemical composition was determined according to the following methods (Ivanov et al., 1979): dry matter, % – refractometer of Abbe; sugars, % – hydrometer of Dujardin; glucose and fructose, g/l – iodometric methods; titratable acids (TA), g/l – titration with NaOH; pH – pH-meter; glucoacidometric index (GAI) – calculation method as the ratio of sugars (%) and TA (g/l).

Alcoholic fermentation – conditions and dynamics in the content of the total phenolic compounds and the anthocyanins

The alcoholic fermentation occurred under the following conditions:

- fermentation substrate – 4.0 kg of grape pulp, sulfated with 50 mg/kg SO_2,

Table 1. Chemical composition of grapes from Gamza variety

Indicators						
Dry matter, %	Sugars, %	Glucose, g/l	Fructose, g/l	Titratable acids, g/l	Glucoacidometric index	pH
21.60 ±0.84	21.10 ±0.57	95.86 ±0.11	114.14 ±0.11	6.80 ±0.58	3.62 ±0.11	3.31 ±0.06

- inoculum of 48-hour active yeast culture of collection strains *Badachoni* and *24-6* of *Saccharomyces cerevisiae* species, in quantity of 2%, 3%, 4% (the strains were provided from the collection of the Department of Wine and Beer Technology, University of Food Technologies (UFT) – Plovdiv, Bulgaria);
- Fermentation temperature – 20°C, 24°C, 28°C.

The dynamics in the content of the total phenolic compounds and total monomeric anthocyanins during the alcoholic fermentation was monitored. The recordings comprised four stages – onset (day 1st), rapid fermentation (day 5th), quiet fermentation (day 10th) and after the malolactic fermentation (day 20th). Their amount was analyzed in the clear part, after centrifugation of the samples, using a UV-Vis spectrophotometer Cary 50 Varian.

Determination of the phenolic compounds and anthocyanins content and the spectral characteristics of the experimental wines

After the end of the alcoholic fermentation (established by chemical analysis of the sugars) and the spontaneous malolactic fermentation (determined by paper chromatography), the experimental wines were decanted and by means of UV-Vis spectrophotometer Cary 50 Varian were analyzed for the content of:

- total phenolic compounds (TPC), g/l gallic acid – method of Singleton and Rossi with a Folin-Ciocalteu reagent and measurement of sample absorption spectrophotometrically at λ 750 nm (Ivanov et al., 1979).
- anthocyanins, mg/l – method of Gayon and Stonestreet by pH changing and using of buffer solutions with pH 0.6 and pH 3.5 and absorption of both samples was measured spectrophotometrically at λ 520 nm (Ivanov et al., 1979).
- flavonoid phenolic compounds (FPC), mg/l catechin equivalent and non-flavonoid phenolic compounds (NPC), mg/l caffeic equivalent – Somers method with analytical and calculation part – 0.2 cm^3 of the test sample was added to 10 cm^3 1n HCl and between 3rd and 4th hour the absorbance of the solution was measured at λ 280 and λ 320 nm (Chobanova, 2007).
- spectral characteristics by Glories method – determined by measuring the sample absorbance (d) in a 0.1 cm cuvette at λ 420, 520, 620 nm and equated to a 1 cm cuvette (Chobanova, 2007).

– colour intensity IC′ [abs. unit] – represented the sum of the absorbance measurements at the three wavelengths

$IC' = d_{420} + d_{520} + d_{620}$

– colour tint T – represented the absorbance at λ 420 nm and λ 520 nm ratio

$T = d_{420}/d_{520}$

– dA% – the indicator expressed the participation of free and bound flavylium forms of anthocyanins in the total wine colour

$dA\% = [1 - (d_{420} + d_{620})/2.d_{520}].100, \%$

– yellow colour ratio in the total wine colour – the absorbance measurement at λ 420 nm

$\%\ \text{yellow colour} = (d_{420}/ IC').100, \%$

– red colour ratio in the total wine colour – the absorbance measurement at λ 520 nm

$\%\ \text{red colour} = (d_{520}/ IC').100, \%$

– blue colour ratio in the total wine colour – the absorbance measurement at λ 620 nm

$\%\ \text{blue colour} = (d_{620}/ IC').100, \%$

The alcohol content of the test samples (vol. %) was determined by the distillation method, using a Gibertini distillation apparatus with a densitometer.

Organoleptic Profile

The organoleptic characteristics of the experimental wines were determined by a 5-member tasting panel, consisting of experts – oenologists from UFT – Plovdiv, on a 100-point scale (Tsvetanov, 2001) and by the method of the basic features (Prodanova, 2008). The analyzed indicators were: colour (clarity, nuance, intensity), aroma (purity, intensity, finesse, harmony), taste (purity, intensity, body, harmony, durability, aftertaste), general impressions. The presented results from the tasting were the arithmetic mean of the evaluations of all members, excluding the highest and the lowest ones.

Statistical analysis

Standard statistical methods from Excel 2016 (Microsoft Office) were used for mathematical and statistical processing of the experimental data.

The obtained results from the chemical analysis were the arithmetic mean value of two parallel samples. When a significant difference in the rates of the studied indicator was found, a third sample was made and the two closest values were taken into account. Statistical data processing was represented by mean and standard deviation (± SD).

The experimental data concerning the dynamics of the studied chemical components of the wine composition during the alcoholic fermentation, as well as the results of the organoleptic analysis of the samples were presented by neural networks (Cichoski & Unbehauen, 1993; Chen et al., 2006; Nicoletti et al., 2009). The software package "Statistica 8" with the standard software algorithms was used for modeling. The modeled layered neural networks described the influence of time, fermentation temperature and the amount of the yeast culture on the change of anthocyanins and total phenolic compounds during the fermentation process. In the training of neural networks, the experimental data from each group of the monitored indicators were divided in the ratio 80%: 20% (it was performed automatically according to the algorithm set in the program). The first 80% was used for network training, and the second 20% for its testing. The training procedure for both models was a second-order quasi-Newton algorithm minimizing the sum of the squares of the output error. For each model, the number of neurons in the input and output layer was determined by the number of input-output variables, respectively 3 for the input layer and 1 for the output. The number of neurons in the hidden layer was set to be changed from 3 to 15. As a result, the network that gave the highest correlation ratio with the experimental data was selected.

The results of the change of the monitored indicators, as well as the tasting evaluations of the experimental wines were presented in the form of 3-layer neural networks. The mathematical modeling presented the results through response surfaces that described the experimental data with high precision.

Results and Discussion

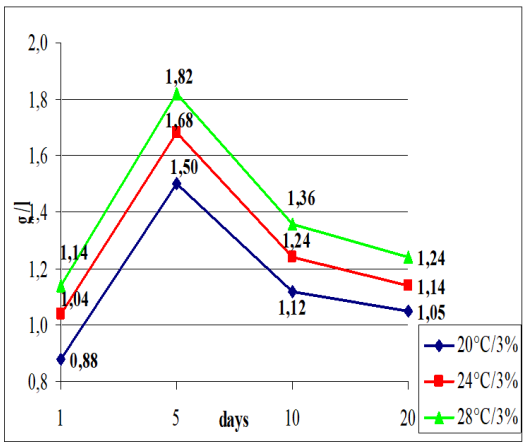
The studied yeasts had shown high fermentation activity, as the intensity with which they initiated the alcoholic fermentation and the time for its completion were in correlation with the technological factors. *Badachoni* and *24-6* strains revealed their best activity at 28°C. With the increase in the amount of the yeast culture (2%, 3%, 4%), at the same temperature, the process began and ended earlier.

In the course of the alcoholic fermentation, the change in the ratio of the total phenolic compounds and anthocyanins in the grape pulp fermenting with the studied yeast strains was observed. The correlation between the technological parameters of the process (time, temperature, inoculum amount of yeast culture) and the dynamics in the concentration of the studied components was established. Neural networks had been prepared for all variants and process models were presented, characterized by high accuracy of the experimental data description.

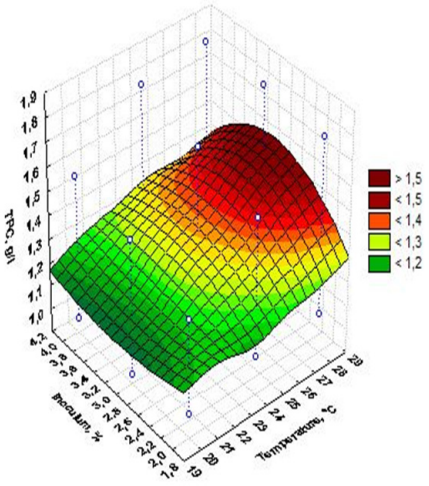
The obtained experimental data on the dynamics of TPC and the anthocyanins had confirmed the results found by other authors (Sims & Bates, 1994; Spranger et al., 1998). The accumulation reached a maximum during the exponential phase of the yeast development, followed by a decrease in their concentration due to the absorption by the cells or participation in the condensation processes. In the red wines production, the reduction in the phenolic substances content might reach 8 to 25% (Valujko, 1979). The effect of temperature on the TPC ratio and the anthocyanins had been more pronounced. The higher values, together with the increasing alcohol content in the medium, in the course of the fermentation, contributed to their better extraction from the grape pulp solid parts and their passing into the wine. The results from the dynamics monitoring had also shown a trend of increasing the concentration of the studied components with increasing the amount of the inoculum yeast culture, reaching the peak rates in the variant 28°C/4%.

Figures 1, 2, 3 and 4 depicted the changes in the content of TPC and the anthocyanins during the fermentation of grape pulp with *Badachoni* and *24-6* strains, under the conditions of 3% inoculum yeast culture and temperatures of 20°C, 24°C, 28°C. The results of the rest of the variants, fermented with 2% and 4% yeast culture, within the same temperature range, were similar and analogous. The mathematical models, presented as surfaces, described the influence of the three studied fermentation parameters on the dynamics of the investigated components. The data depicted in the form of a surface clearly reflected the moment of reaching the peak in their concentration during the rapid fermentation (day 5th), after which their amount started to slowly decrease.

The presented models for the change of TPC and the anthocyanins demonstrated that in the variants of both strains the peak rates of the studied components were found in the variant 28°C/4%, and the minimum – in 20°C/2%. This result for the studied technological factors impact had shown that in the conditions of the experiment, 28°C was the optimal temperature for the production of more intensely coloured wines of Gamza variety, with a higher content of



a



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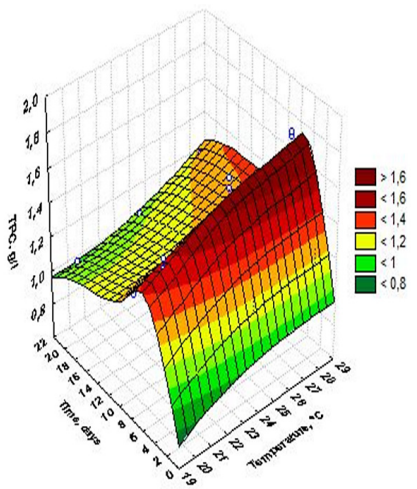

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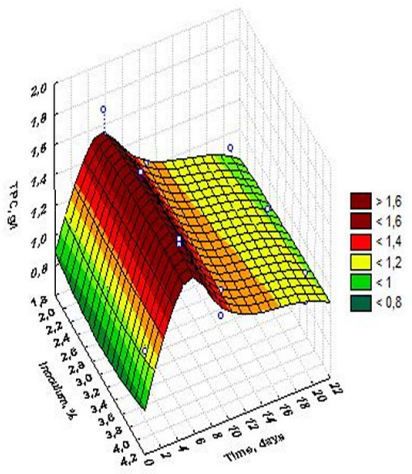


d

Fig. 1. Change in the concentration of total phenolic compounds during alcoholic fermentation with the strain *Saccharomyces cerevisiae Badachoni: a*) change in TPC at different fermentation temperatures; *b*) influence of temperature and inoculum yeast culture amount; *c*) influence of temperature; *d*) influence of inoculum yeast culture amount

phenolic substances. This was a confirmation of other authors' findings that in the production of red wines the optimal temperature for extraction of the phenolic substances and the anthocyanins was 28-30°C and the influence of this factor could not be substituted by extending the maceration time (Getov, 2002).

During the rapid fermentation, the amount of TPC in the variants of the *Badachoni* strain varied from 1.42±3.53 to 1.84±4.05 g/l, and at the end of the process – from 1.12±2.54 to 1.35±1.83 g/l (Figure 1). With *24-6* strain the change was from 1.28±3.86 to 1.75±6.02 g/l (rapid fermentation) and from 1.10±2.53 to 1.40±2.12 g/l (quiet fermentation), respectively (Figure 2).

The yeast strain influence was more pronounced on the quantitative change of the anthocyanins during the alcoholic fermentation. The reduction of the anthocyanins had been associated with the active development of the yeast during the logarithmic phase, when the cells secreted a significant amount of enzymes, including glucosidases that attacked their molecules (Kanev & Patokova, 2004). The various strains manifested different β-glucosidase activity. In previous studies, *Badachoni* strain was found to have higher

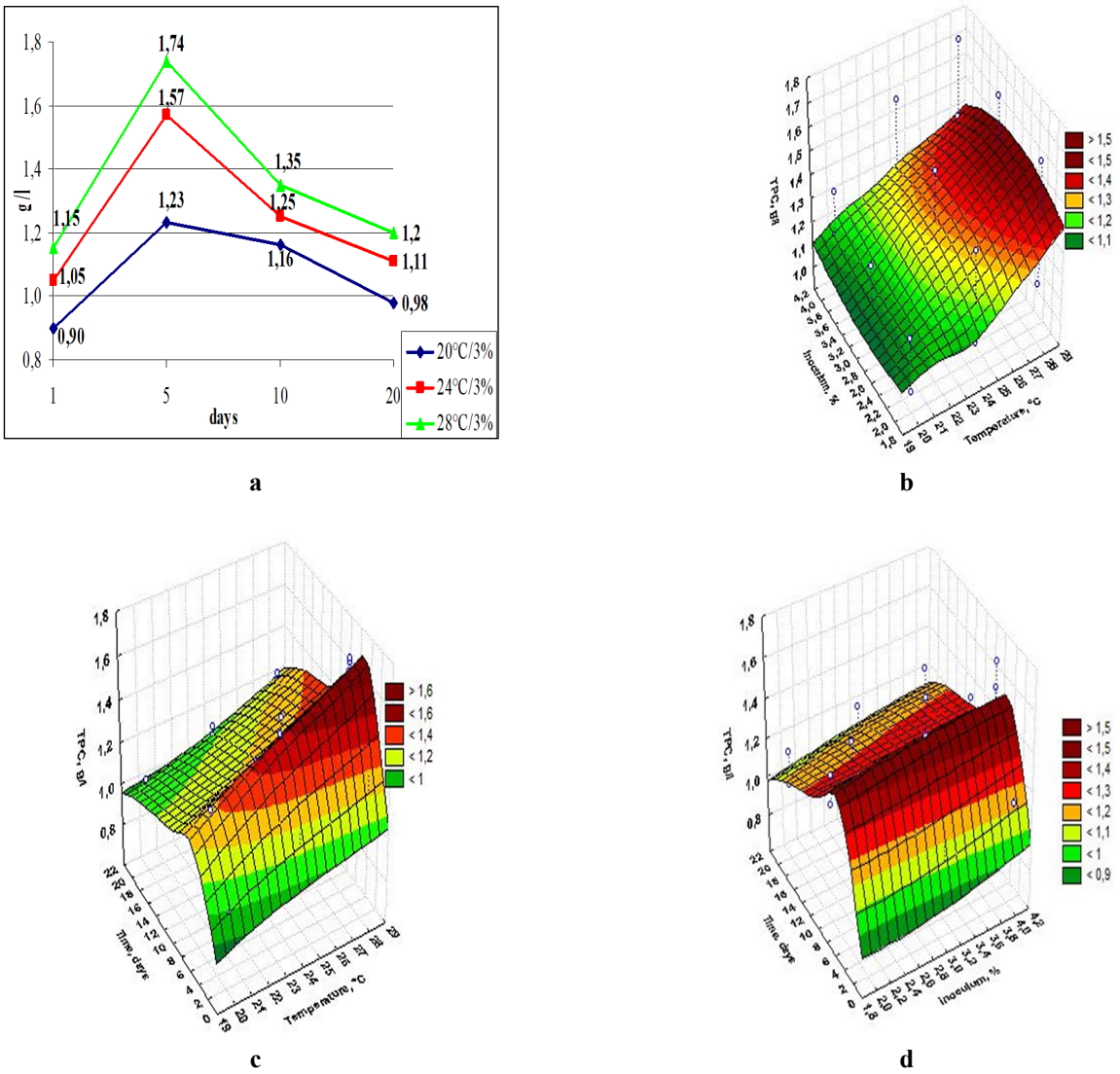


Fig. 2. Change in the concentration of total phenolic compounds during alcoholic fermentation with the strain *Saccharomyces cerevisiae 24-6: a*) change in TPC at different fermentation temperatures; *b*) influence of temperature and inoculum yeast culture amount; *c*) influence of temperature; *d*) influence of inoculum yeast culture amount

β-glucosidase activity than *24-6* strain (Yoncheva et al., 2007). However, in the variants of *Badachoni* strain a higher content of anthocyanins and correspondingly higher colour intensity was found, as that was not a strict correlation and their values depended on other factors in the wine-making process.

During the rapid fermentation, the anthocyanins ratio in the variants of *Badachoni* strain varied from 267.25±18.25 to 337.79±23.70 mg/l, and at the end of the process – from 210.52±10.12 to 282.48±9.25 mg/l (Figure 3). In *24-6* strain, the change was from 248.77±21.30 to 296.58±15.52 mg/l (rapid fermentation) and from 178.50±11.36 to 255.50±17.24 mg/l (quiet fermentation), respectively (Figure 4). Under the created experimental conditions, within the same temperature range, the anthocyanins concentration went up with increasing the yeast culture amount. In the samples of both strains their quantity was the smallest in the variants fermented with 2% inoculum yeast culture.

In the course of the trial, a correlation was found between TPC and the anthocyanins ratio in all experimental variants, as the trend was kept in the obtained wines (Table 2). The content of these components, as well as the spec-

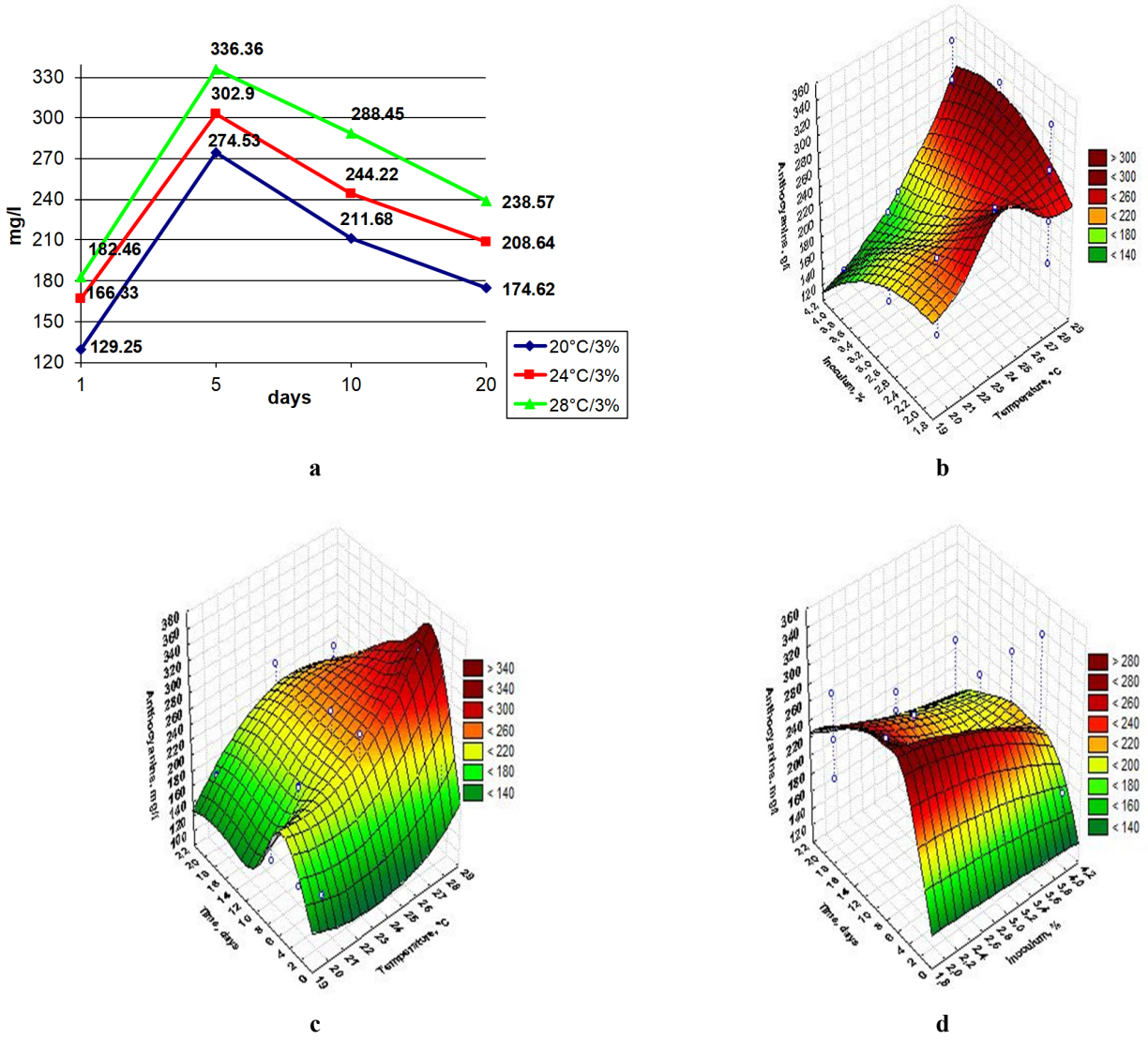


Fig. 3. Change in the concentration of anthocyanins during alcoholic fermentation with the strain *Saccharomyces cerevisiae Badachoni: a*) change in anthocyanins at different fermentation temperatures; *b*) influence of temperature and inoculum yeast culture amount; *c*) influence of temperature; *d*) influence of inoculum yeast culture amount

tral characteristics of the experimental Gamza wines, were close and within the typical range for the variety. As the temperature rose, their amount got higher due to the better extraction conditions. The samples of both strains fermented at 28°C/4% contained more TPC and anthocyanins, as well as FPC and NPC. The increase in FPC during the fermentation might be explained by their extraction from the solids and an increase in the amount of the anthocyanins that belonged to this group of compounds, and the rise in NPC was probably due to the formation of new phenolic acids during the decomposition of the sugars. However, their concentration did not reach such rates that affected negatively the qualities of the wines.

The differences in the content of the studied components in the variants of both strains were insignificant (Table 2). The wines of the strain *Badachoni* were characterized by a slightly higher concentration of TPC, NPC, FPC and anthocyanins. The amount of TPC in these samples varied from 1.00±1.13 to 1.25±0.88 g/l and of anthocyanins from 165.72±5.01 to 239.35±9.30 mg/l. Their ratio in the wines of *24-6* strain was within the range from 0.95±2.15 to 1.22±1.33 g/l and from 154.08±3.40 to 222.00±4.39 mg/l, respectively.

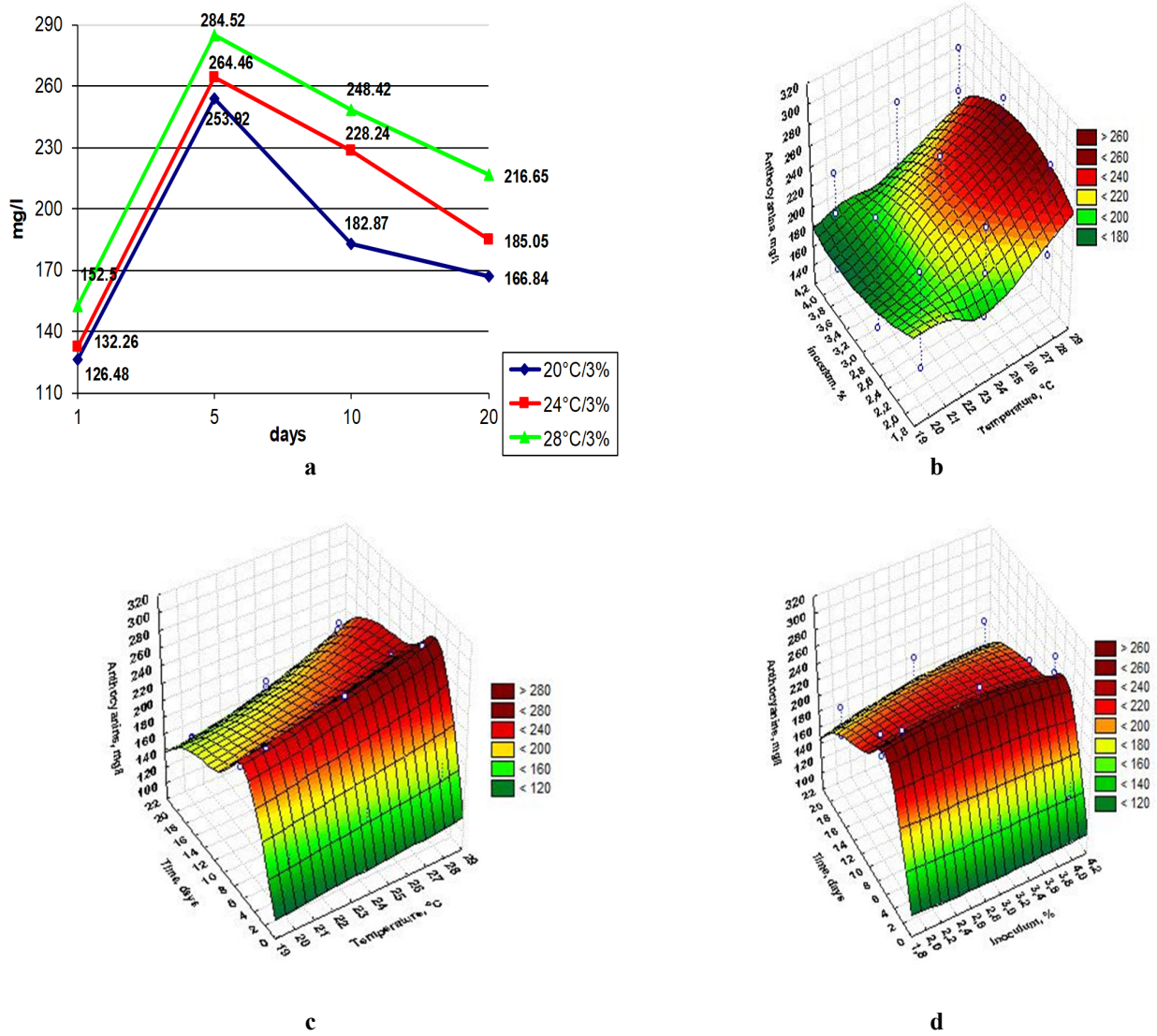


Fig. 4. Change in the concentration of anthocyanins during alcoholic fermentation with the strain *Saccharomyces cerevisiae 24-6: a*) change in anthocyanins at different fermentation temperatures; *b*) influence of temperature and inoculum yeast culture amount; *c*) influence of temperature; *d*) influence of inoculum yeast culture amount

In both strains the lowest rate was reported for the variant 20°C/2%, and the highest – 28°C/4%.

Due to the higher rate of anthocyanins, the samples of *Badachoni* strain had a more intense colour that had a positive effect on the colour characteristics and tasting evaluations of the variants (Figures 5 and 6). The colour intensity IC' and the indicator dA%, which determined the red colour brightness directly correlated with them. The values of the indicator IC' in the samples of *Badachoni* strain varied from 8.05±0.45 to 9.00±0.42 [abs. units], and in the samples of *24-6* strain – from 7.82±0.55 to 8.80±0.44 [abs. units]. The percentage ratio of the three main colours was within the typical range for young red wines of the Gamza variety. The red colour participation was the greatest in wines obtained at 28°C. Moreover, in the variants of *Badachoni* strain its percentage was higher. The higher percentage of participation of the yellow colour in the samples obtained with *24-6* strain, determined a slight tile hue of the colour, which was confirmed by the values of the nuance.

The organoleptic profile of the wines had been essential for determining their qualities. The experimental

Table 2. Phenolic composition, anthocyanins and spectral characteristics of the experimental Gamza wines

Variants / Indicators	20°C			24°C			28°C		
	2%	3%	4%	2%	3%	4%	2%	3%	4%
	Saccharomyces cerevisiae Badachoni								
Alcohol, vol. %	12.57 ±0.44	12.60 ±0.50	12.65 ±0.62	12.42 ±0.48	12.50 ±0.55	12.67 ±0.53	12.62 ±0.60	12.70 ±0.62	12.70 ±0.54
TPC, g/l	1.00 ±1.13	1.05 ±1.22	1.05 ±2.20	1.10 ±1.41	1.14 ±0.95	1.15 ±2.24	1.20 ±1.33	1.24 ±1.33	1.25 ±0.88
NPC, mg/l caffeic equival.	114.86 ±12.11	124.50 ±16.65	128.16 ±13.75	128.16 ±8.92	129.50 ±15.44	130.15 ±10.68	132.17 ±8.95	132.92 ±11.86	133.44 ±8.02
FPC, mg/l catechin equival.	896.11 ±35.71	912.53 ±43.40	929.63 ±27.54	1088.14 ±41.35	1262.43 ±36.04	1219.51 ±55.14	1306.62 ±43.75	1450.13 ±45.09	1428.00 ±30.02
Anthocyanins, mg/l	165.72 ±5.01	174.62 ±6.33	189.54 ±12.55	195.82 ±9.65	208.64 ±10.66	224.20 ±6.41	226.98 ±8.18	238.57 ±5.36	239.35 ±9.30
Colour intensity IC′ [abs. unit]	8.05 ±0.45	8.07 ±0.53	8.27 ±0.30	8.36 ±0.50	8.36 ±0.63	8.52 ±0.61	8.70 ±0.28	8.86 ±0.33	9.00 ±0.42
Colour tint T	0.515 ±0.19	0.519 ±0.22	0.507 ±0.22	0.500 ±0.16	0.516 ±0.18	0.495 ±0.25	0.493 ±0.23	0.488 ±0.38	0.482 ±0.32
dA %	67.37 ±4.05	67.62 ±3.36	68.23 ±5.22	68.90 ±2.84	67.32 ±3.19	69.04 ±2.73	69.43 ±3.56	69.77 ±3.48	70.03 ±4.64
%Yellow colour	31.20 ±0.15	31.50 ±0.22	31.00 ±0.21	30.80 ±0.11	31.40 ±0.09	30.60 ±0.12	30.50 ±0.24	30.40 ±0.12	30.10 ±0.13
% Red colour	60.50 ±0.05	60.70 ±0.03	61.10 ±0.03	61.60 ±0.10	60.90 ±0.10	61.70 ±0.19	62.00 ±0.12	62.30 ±0.05	62.50 ±0.10
% Blue colour	8.30 ±0.18	7.80 ±0.09	7.90 ±0.13	7.60 ±0.11	7.70 ±0.09	7.70 ±0.06	7.50 ±0.05	7.30 ±0.10	7.40 ±0.11
pH	3.25 ±0.00	3.18 ±0.05	3.19 ±0.08	3.17 ±0.02	3.23 ±0.02	3.26 ±0.05	3.22 ±0.07	3.21 ±0.09	3.25 ±0.06
Tasting score	76.66 ±3.08	77.88 ±2.76	73.88 ±2.88	78.00 ±3.33	77.11 ±3.42	77.66 ±3.33	72.44 ±3.26	75.22 ±3.37	72.22 ±3.43
	Saccharomyces cerevisiae 24-6								
Alcohol, vol. %	12.38 ±0.26	12.26 ±0.32	12.58 ±0.38	12.23 ±0.53	12.51 ±0.56	12.48 ±0.41	12.53 ±0.39	12.58 ±0.55	12.57 ±0.52
TPC, g/l	0.95 ±2.15	0.98 ±2.10	1.06 ±1.07	1.09 ±1.18	1.11 ±2.26	1.16 ±1.12	1.17 ±1.08	1.20 ±0.96	1.22 ±1.33
NPC, mg/l caffeic equival.	111.52 ±11.16	116.51 ±18.02	120.50 ±21.08	120.40 ±15.10	127.74 ±10.19	126.30 ±11.02	127.63 ±20.14	130.29 ±22.20	130.35 ±17.19
FPC, mg/l catechin equival.	787.66 ±30.93	851.13 ±31.07	871.83 ±31.11	992.54 ±40.88	1965.36 ±51.12	1163.46 ±60.93	1250.99 ±41.24	1393.21 ±31.22	1394.60 ±51.31
Anthocyanins, mg/l	154.08 ±3.40	166.84 ±4.42	175.04 ±3.30	179.65 ±6.29	185.05 ±4.31	197.72 ±5.32	213.94 ±8.44	216.65 ±6.47	222.00 ±4,39
Colour intensity IC′ [abs. unit]	7.82 ±0.55	7.92 ±0.44	8.07 ±0.51	8.11 ±0.63	8.24 ±0.61	8.36 ±0.70	8.54 ±0.58	8.67 ±0.50	8.80 ±0.44
Colour tint T	0.580 ±0.19	0.585 ±0.11	0.585 ±0.11	0.586 ±0.22	0.580 ±0.29	0.570 ±0.17	0.569 ±0.27	0.558 ±0.17	0.558 ±0.17
dA %	63.47 ±2.93	63.08 ±3.80	64.47 ±4.95	62.04 ±6.06	63.34 ±2.11	64.34 ±5.02	64.55 ±6.00	64.90 ±4.10	65.03 ±3.17
%Yellow colour	33.50 ±0.04	33.60 ±0.07	33.40 ±0.10	33.60 ±0.12	33.40 ±0.12	33.20 ±0.05	33.30 ±0.12	32.80 ±0.14	32.90 0.14
% Red colour	57.80 ±0.10	57.50 ±0.09	57.20 ±0.10	56.90 ±0.18	57.70 ±0.21	58.40 ±0.22	58.50 ±0.19	58.70 ±0.12	58.80 ±0,21
% Blue colour	8.70 ±0.24	8.90 ±0.12	9.40 ±0.11	9.50 ±0.13	8.90 ±0.14	8.40 ±0.17	8.20 ±0.17	8.50 ±0.18	8.30 ±0.23
pH	3.27 ±0.03	3.19 ±0.04	3.22 ±0.00	3.21 ±0.05	3.23 ±0.10	3.17 ±0.08	3.19 ±0.00	3.19 ±0.06	3.15 ±0.06
Tasting score	72.22 ±4.55	75.11 ±4.21	77.44 ±3.49	76.44 ±4.19	75.22 ±4.05	76.44 ±4.49	73.88 ±3.88	72.11 ±3.96	75.00 ±4.03

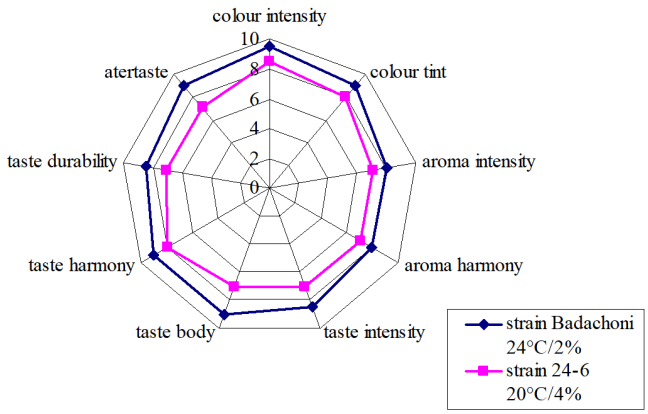
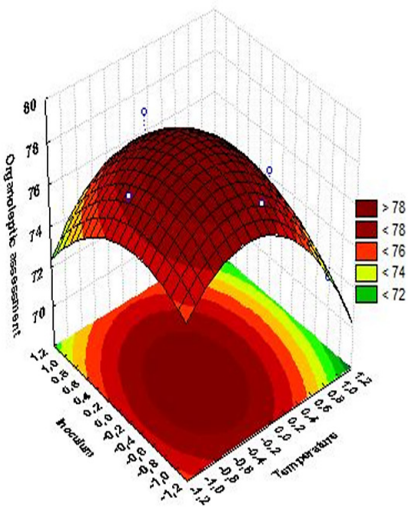


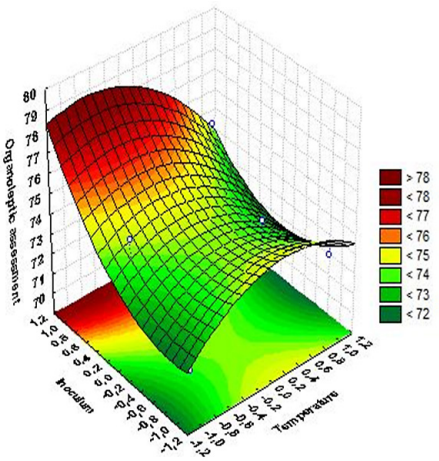
Fig. 5. Organoleptic profile of the experimental Gamza wines

Gamza wines obtained with *Badachoni* strain had better tasting and colour characteristics than the variants of *24-6* strain (Figure 5). The results of the chemical and organoleptic analysis showed that better tasting characteristics and evaluations not always corresponded to the higher content of the analyzed wine components. The reason had been their combined impact on the colour, aromatic and taste perceptions of wines. The samples fermented with *Badachoni* strain at temperature of 24°C had the best organoleptic features (Table 2). The variant obtained under the conditions of a temperature 24°C/2% had the highest tasting evaluation (78.00±3.33 points). It was distinguished by its rich, vibrant colour, intense fruity (raspberry) aroma and harmony between the taste components. Among the variants of strain *24-6* with the best organoleptic characteristics was the one obtained at a temperature of 20°C and 4% inoculum. It was valued at 77.44±3.49 points due to its vibrant colour, pure varietal aroma, good harmony in taste with sufficient freshness and density.

Figure 6 showed the surfaces describing the influence of the studied technological factors during the alcoholic fermentation on the organoleptic characteristics, respectively the tasting evaluations of the obtained wines from Gamza variety. The mathematical modeling and presentation of the organoleptic parameters of the wines in the form of surfaces demonstrated that the results of the tasting evaluations of the samples obtained with *Badachoni* strain were more homogeneous and the zones of maximum were better defined than those of *24-6* strain.



Strain *Saccharomyces cerevisiae Badachoni*



Strain *Saccharomyces cerevisiae 24-6*

Fig. 6. Response surfaces to describe the tasting evaluations of the experimental Gamza wines

Conclusion

On the basis of the obtained results, in the conditions of the conducted experiment, the following conclusions could be made:

- the change in the concentration of TPC and the anthocyanins during the alcoholic fermentation was similar and reached its peak during the rapid fermentation (day 5th), then it began to slowly decrease.
- with increasing the temperature and the amount of inoculum yeast culture, the concentration of the

studied phenolic components went up, reaching the peak values under the conditions of 28°C/4%.

- the content of TPC, FPC, NPC, anthocyanins and the spectral characteristics of the obtained experimental Gamza wines, fermented with both strains of yeast, was close and within the typical range for the variety.
- the colour intensity IC′ and the indicator dA%, which determined the red colour brightness were in direct correlation with the amount of the anthocyanins. The participation of the red colour was the greatest in wines obtained at 28°C.
- the higher content of anthocyanins and the more intense colour in the samples of *Badachoni* strain had a positive effect on the colour characteristics and the tasting evaluations of the variants.
- the mathematical modeling and presentation of the organoleptic parameters of the wines in the form of surfaces demonstrated that the results of the tasting evaluations of the samples obtained with *Badachoni* strain were more homogeneous and the zones of maximum were better defined than those of *24-6* strain.

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