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Yeast race effect on the quality of base and young sparkling wines

Alexander S. Makarov, Igor P. Lutkov*

All-Russian National Research Institute of Viticulture and Winemaking "Magarach" of RAS, Yalta, Russia

* e-mail: igorlutkov@mail.ru

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Abstract:
Introduction. A disadvantage of the ancestral method (la méthode ancestrale), which is widely used in the production of sparkling wine, is that it is difficult to control fermentation. We aimed to identify the optimal yeast race for obtaining high-quality young sparkling wines with varietal aroma without yeast tones.
Study objects and methods. Our study objects were base and young sparkling wines from Cabernet-Sauvignon prepared on various yeast races. Organic acids, sugars, and ethanol contents were determined by high performance liquid chromatography. Phenolic and coloring substances were measured by colorimetric method. Foaming properties were determined by air barbotage of a wine sample in a measuring cylinder; sparkling properties, by measuring the CO_2 desorption rate; CO_2 content, by volumetric method; viscosity, with a viscometer. Sensory evaluation was carried out according to standard methods.
Results and discussion. The wines produced on the Odesskiy Chernyi-SD13 yeast race received the highest tasting scores of 7.82 and 9.05 points for base wine and young sparkling wines, respectively. They contained larger amounts of phenolic substances (1103 mg/dm^3) and coloring agents (275 mg/dm^3) and had higher color intensity (1.614). The panelists rated them highly on their complex varietal aroma and harmonious, velvety flavor, as well as their foaming and sparkling properties. This yeast race ensured intensive fermentation of sugars and a great amount of bound CO_2 (up to 24.93%).
Conclusion. The Odesskiy Chernyi-SD13 yeast race is optimal for making base and young sparkling wines by the bottle method. This technology can be used to produce high-quality sparkling wines in the crop year by large and small enterprises.

Keywords: Fermentation, descriptors, color, aroma, acids, carbon dioxide, foaming properties, sparkling properties

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INTRODUCTION

Russian sparkling wines enjoy a well-deserved popularity among consumers. Despite the growing demand, Russia has a shortage of raw materials for their production. Grapes suitable for sparkling wines can only be cultivated in certain parts of the country, mainly in the southern regions. Local agricultural lands have different forms of ownership and many landowners have lost interest in grape cultivation due to a long payback period. Yet, most large producers of sparkling wines do not have their own source of raw materials and therefore have to import cheap base wines, often of poor quality. The long production cycle (over 9 months for the bottle method) holds back increased production of domestic sparkling wines. The need to purchase expensive equipment for pressure operations limits the use of the acratophoric method by small farms.

The solution is to produce young sparkling wines (aged 2–3 months) by the bottle method. They can be made during one wine-making season and delivered to the consumer by the New Year. The EU countries make sparkling wine by the ancestral method (la méthode ancestrale), i.e., incomplete fermentation of grape must on spontaneous microflora. Fermentation is suspended by cooling and the stuck must is stored until spring. Then it is bottled and sealed for complete fermentation and saturation with carbon dioxide [1]. This method has two disadvantages: it is difficult to control fermentation when using spontaneous microflora and the finished wine has a tendency to cloudiness.

In Russia, a similar method is used to produce "Tsymlyanskoe Igristoe" red sparkling wine. It is also based on subsequent fermentation of stuck must in bottles, but this process may stop spontaneously and result in varying contents of sugars, ethanol, and carbon dioxide in the finished wines.

Hypothetically, the optimal yeast race should provide young sparkling wines with the desired properties. Most importantly, it should be suitable for primary and secondary fermentation, have no yeast tones and preserve the varietal aroma.

The yeast used in the production of bottled sparkling wines must meet a number of requirements. In particular, it must have autolytic and flocculating power and be resistant to high ethanol concentration and pressure, as well as low fermentation temperature and pH [2, 3]. For this, yeast is preliminarily acclimatized and fertilized with nitrogen compounds [4]. After fermentation, when aging on yeast, the wine is saturated with yeast autolysis products (e.g., amino acids) and phenolic compounds (e.g., catechins, caffeic and gallic acids in rosé wines) [5, 6]. The technology for young sparkling wines excludes yeast aging, thus preserving the original varietal aroma. Also, there is only one fermentation process and therefore yeast does not need to adapt.

We aimed to study the effect of yeast race on the quality of base and young sparkling wines produced by the bottle fermentation method.

STUDY OBJECTS AND METHODS

Our study objects were base and young sparkling wines produced with various yeast races from Cabernet-Sauvignon grapes grown on the South Coast of Crimea in 2019. The grapes were processed in micro-vinification conditions in line with the relevant standards and guidelines. The mass concentration of sugars was 202 g/dm^3 and titratable acids amounted to 10.0 g/dm^3. Must was fermented with glucosophilic, fructosophilic, S-sensitive, and killer factor yeast races. The latter significantly increased the dominance of this species during fermentation [7]. In total, we selected five races from the Magarach Collection of Winemaking Microorganisms (Table 1).

Wine-making. Rosé must was obtained by pressing pulp on a basket press, yielding 50 daL per 1 ton of grapes. Then it was sulfurized (75 mg/dm^3 SO_2), sedimented at 15°C, and decanted. To obtain red must, grapes were crushed on a roller crusher and destemmed, with the pulp sulfurized (75 mg/dm^3 SO_2). The pulp and must were fermented at 15°C. The pulp was fermented (2/3 of sugars) and pressed, with the resulting must fermented in separate tanks. At a residual sugar concentration of 22–24 g/dm^3, one part of each batch of stuck must was bottled for champagnization, with the other part fermented dry. After introducing bentonite (0.2 g/dm^3), the bottles were stoppered, stacked, and stored at 12–14°C. After 60 days, the sediment was reduced to the neck (remuage) and discharged (degorgeage). The resulting rosé and red base wines met the requirements of State Standard 32030-2013 "Table wines and table winestocks. General specifications."

The physicochemical parameters of the base and sparkling wines were determined in accordance with the current standards. Phenolic substances were measured colorimetrically by the Folin-Ciocalteu reaction. Optical characteristics were determined by measuring optical density at 420 and 520 nm. The dynamic viscosity was measured with a viscometer. Foaming properties (maximum foam volume and time of foam break) were determined according to Standard STO 01580301.015-2017 "Table base wines for sparkling wines and drinks saturated with carbon dioxide. Determination of foaming properties." A 200 cm^3 sample of degasified wine was poured in a 1 dm^3 measuring cylinder. Barbotage was carried out using a portable compressor and a sprayer lowered to the bottom of the measuring cylinder. Foaming took place at the same time. The maximum foam volume was determined visually using the cylinder scale, and the time of foam break was measured with a timer. This method, as well as Mosalux, provided an accurate determination of the wine's foaming properties [9].

Table 1 Yeast species used in making young sparkling wines

No.	Race title	Yeast species (V. Kudryavtsev taxonomy)	Phenotype	Properties
I-25	Cabernet 5	*Saccharomyces vini* Meyen, 1838 syn. *Saccharomyces cerevisiae* (Kreger-van Rij N.J.W., 1984)	Sensitive (S)	Resistant to cold, SO_2, alcohol, and acid (pH 2.8); glucosophilic; does not form H_2S
I-523	Bastardo 1965	*Saccharomyces oviformis* Osterwalder, 1924 syn. *S. cerevisiae* (Kreger-van Rij N.J.W., 1984)	Sensitive (S)	Resistant to SO_2, alcohol, tannin and polyphenols; fructosophilic
I-525	Sevasto-polskaya 23	*S. oviformis* Osterwalder, 1924 syn. *S. cerevisiae* (Kreger-van Rij N.J.W., 1984)	Sensitive (S)	Resistant to cold, SO_2, and alcohol; glucosophilic; does not form H_2S
I-527	47-K	*S. vini* Meyen, 1838 syn. *S. cerevisiae* (Kreger-van Rij N.J.W., 1984)	Killer (K)	Effective in fermenting non-sterile grape must; high degree of protein hydrolysis; resistant to acid, SO_2, alcohol; forms H_2S in small amounts; glucosophilic; low iron sensitivity index [8]. Recommended for table base wines for sparkling wines.
I-652	Odesskiy Chernyi-SD13	*S. oviformis* Osterwalder, 1924 syn. *S. cerevisiae* (Kreger-van Rij N.J.W., 1984)	Sensitive (S)	Strong ability to form alcohols, esters and lactones; synthesizes β-phenylethanol and aliphatic alcohols; enhances spicy tones in the aroma of base wines. Recommended for red table wines with berry-spicy aroma.

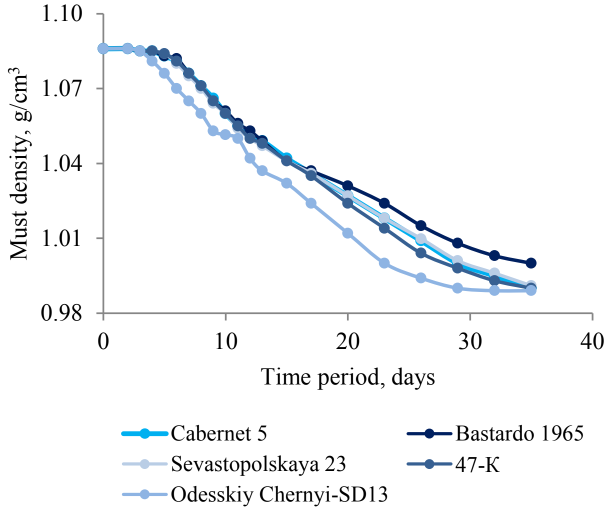

Figure 1 Must fermentation with different yeast races for rosé base wines

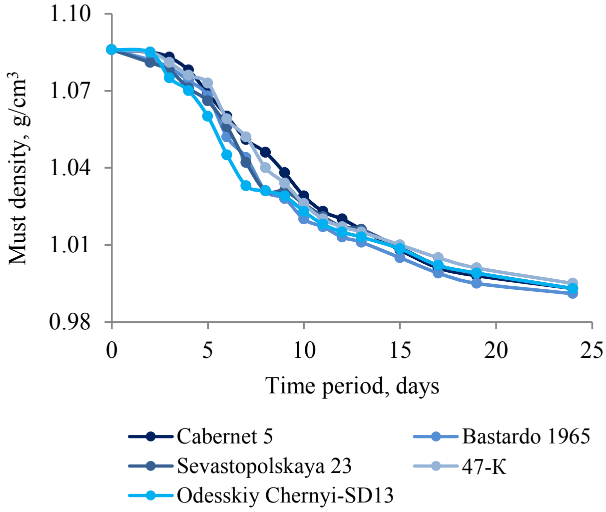

Figure 2 Must fermentation with different yeast races for red base wines

Table 2 Organic acids, sugars, and ethanol contents in experimental base wine samples

Race title	C	T	M	S	L	A	TA	Su	Glu	F	Gly	Ethanol, vol. %
	g/dm^3											
Rosé												
Cabernet 5	0.35	4.04	3.15	1.51	0.09	0.21	9.4	0.26	0.42	3.22	7.80	12.41
Bastardo 1965	0.34	3.93	2.93	1.63	0.35	0.03	9.3	0.24	0.32	0.76	7.81	12.54
Sevastopolskaya 23	0.31	3.87	2.96	1.68	0.11	0.20	9.5	0.19	0.33	1.99	8.05	12.44
47-K	0.31	4.09	3.17	1.58	0.10	0.24	9.6	0.23	0.50	6.88	7.96	12.12
Odesskiy Chernyi-SD13	0.45	3.96	3.18	1.20	0.09	0.14	8.6	0.24	0.38	1.01	5.23	12.95
Red												
Cabernet 5	1.08	2.11	0.41	1.62	1.14	0.27	5.2	0.65	0.25	0.06	8.04	11.41
Bastardo 1965	0.87	2.68	0.36	1.77	1.39	0.20	5.9	0.31	0.30	0.02	8.02	11.28
Sevastopolskaya 23	0.71	2.74	0.39	1.71	1.51	0.20	6.2	0.25	0.31	0.02	7.65	10.63
47-K	0.70	3.16	0.33	1.78	1.97	0.18	7.4	0.26	0.32	2.26	7.81	10.92
Odesskiy Chernyi-SD13	1.06	2.84	2.76	1.75	0.08	0.09	7.9	0.33	0.47	0.41	6.88	12.38

Where: C – citric, T – tartaric, M – malic, S - succinic, L – lactic, A – acetic, TA – sum of titratable acids, Su – sucrose, Glu – glucose, F – fructose, Gly – glycerol

Table 3 Physicochemical parameters of experimental base wines

Race title	pH	Eh	V_{max}, cm^3	t_{br}, s	V, mm^2/s	TPh, mg/dm^3	MPh, mg/dm^3	PPh, mg/dm^3	C, mg/dm^3	I	T
Rosé											
Cabernet 5	3.1	215	900	30	1.697	266	233	32	4	0.594	1.101
Bastardo 1965	3.1	214	800	28	1.684	286	238	48	4	0.607	1.010
Sevastopolskaya 23	3.1	214	920	30	1.684	269	233	36	6	0.630	1.007
47-K	3.1	214	950	31	1.723	275	231	44	4	0.607	1.000
Odesskiy Chernyi-SD13	3.1	214	1000	42	1.674	233	180	53	14	0.656	1.033
Red											
Cabernet 5	3.6	180	1100	> 300	1.640	911	535	376	183	0.855	0.611
Bastardo 1965	3.5	193	1250	> 300	1.633	974	598	376	202	0.864	0.716
Sevastopolskaya 23	3.5	193	1250	> 300	1.581	1027	609	418	207	0.964	0.563
47-K	3.4	199	1250	> 300	1.620	826	503	323	188	0.963	0.573
Odesskiy Chernyi-SD13	3.1	203	1250	> 300	1.692	1101	635	466	287	1.959	0.529

Where: Eh – value of redox potential, V_{max} – max foam volume, t_{br} – time of foam break, V – value of dynamic viscosity, TPh – total content of phenolic substances, MPh – content of monomeric fraction of phenolic substances, PPh – content of polymeric fraction of phenolic substances, C – content of coloring agents, I – value of color intensity (D_{420}+ D_{520}), T – value of color shade (D_{420}/ D_{520})

Table 4 Sensory evaluation of experimental base wines

Yeast race	General characteristics of aroma and flavor	Score
	Rosé	
Cabernet 5	Aroma – complex, berry. Flavor – soft, pure, complete, varietal, with "spicy bitterness."	7.76
Bastardo 1965	Aroma – neutral, with berry and fruit notes and passing "choking." Flavor – pure, complete, too fresh, plain.	7.67
Sevastopolskaya 23	Aroma – delicate, berry, with light notes of nightshade. Flavor – fresh, well-formed, varietal.	7.75
47-K	Aroma – subtle, berry-fruit, with spicy and cherry notes. Flavor – complete, with residual sugars and inharmonious acidity.	7.70
Odesskiy Chernyi-SD13	Aroma – bright, complex, berry and fruit, with noes of nightshade. Flavor – pure, fresh, harmonious, varietal.	7.83
	Red	
Cabernet 5	Aroma – bright, complex, berry and fruit, with noes of nightshade. Flavor – soft, complete, harmonious, varietal.	7.81
Bastardo 1965	Aroma – mild, varietal, of berry direction. Flavor – harmonious, complete, varietal, velvet.	7.78
Sevastopolskaya 23	Aroma – less expressed, berry, with light notes of nightshade. Flavor – fresh, velvet.	7.77
47-K	Aroma – mild, of berry direction, with notes of nightshade. Flavor – complete, insufficiently velvet.	7.76
Odesskiy Chernyi-SD13	Aroma – bright, complex, berry, with notes of nightshade. Flavor – deep, velvet, with long coffee and spicy finish.	7.82

Table 5 Physicochemical parameters of experimental young sparkling wines

Race title	pH	Eh	V_{max}, cm^3	t_{br}, s	V, mm^2/s	TPh, mg/dm^3	MPh, mg/dm^3	PPh, mg/dm^3	C, mg/dm^3	I
				Rosé						
Cabernet 5	2.92	218	10.3	1.741	214	212	2	3	0.576	0.974
Bastardo 1965	2.92	217	10.0	1.735	195	186	9	4	0.510	0.927
Sevastopolskaya 23	2.92	218	10.4	1.715	247	235	12	5	0.579	0.989
47-K	2.95	218	10.4	1.735	210	210	0	2	0.512	0.961
Odesskiy Chernyi-SD13	2.93	217	9.6	1.735	217	211	6	6	0.499	0.974
				Red						
Cabernet 5	3.55	182	6.5	1.620	757	474	283	164	0.771	0.523
Bastardo 1965	3.33	197	8.4	1.633	916	524	392	170	0.790	0.681
Sevastopolskaya 23	3.33	198	8.0	1.594	847	540	307	171	0.928	0.540
47-K	3.23	202	9.0	1.620	794	498	296	152	0.908	0.574
Odesskiy Chernyi-SD13	3.18	205	8.7	1.601	1103	675	428	275	1.614	0.491

Where: Eh – value of redox potential, V_{max} – max foam volume, t_{br} – time of foam break, V – value of dynamic viscosity, TPh – total content of phenolic substances, MPh – content of monomeric fraction of phenolic substances, PPh – content of polymeric fraction of phenolic substances, C – content of coloring agents, I – value of color intensity (D_{420}+ D_{520}), T – value of color shade (D_{420}/ D_{520})

Organic acids, residual sugars, and ethyl alcohol were determined by HPLC using a Shimadzu LC 20AD chromatograph (Japan) equipped with a spectrophotometric detector. Sample separation was performed on a Supelcogel C610H column (Supelco®, Sigma-Aldrich, USA). We used a sorbent based on sulfurized divinyl-polystyrene (column size 300×7.8, sorbent granules less than 10.0 µm). An aqueous solution of phosphoric acid (1 g/dm^3) was used as an eluent. Concentrations of substances were determined with a detector at 210 nm by the retention time and the signal quantity.

Total carbon dioxide content in sparkling wines was determined according to Standard STO 01580301.016–2017 "Drinks saturated with carbon dioxide. Determination of mass concentration of carbon dioxide by the modified volumetric method." According to this method, CO_2, which evolved from wine under the action of ultrasound, displaced the barrier fluid from the graduated container. The volume of the displaced barrier fluid corresponded to the volume of carbon dioxide contained in the bottle with sparkling wine. The content of related forms of carbon dioxide was calculated according to Merzhanian method [10], based

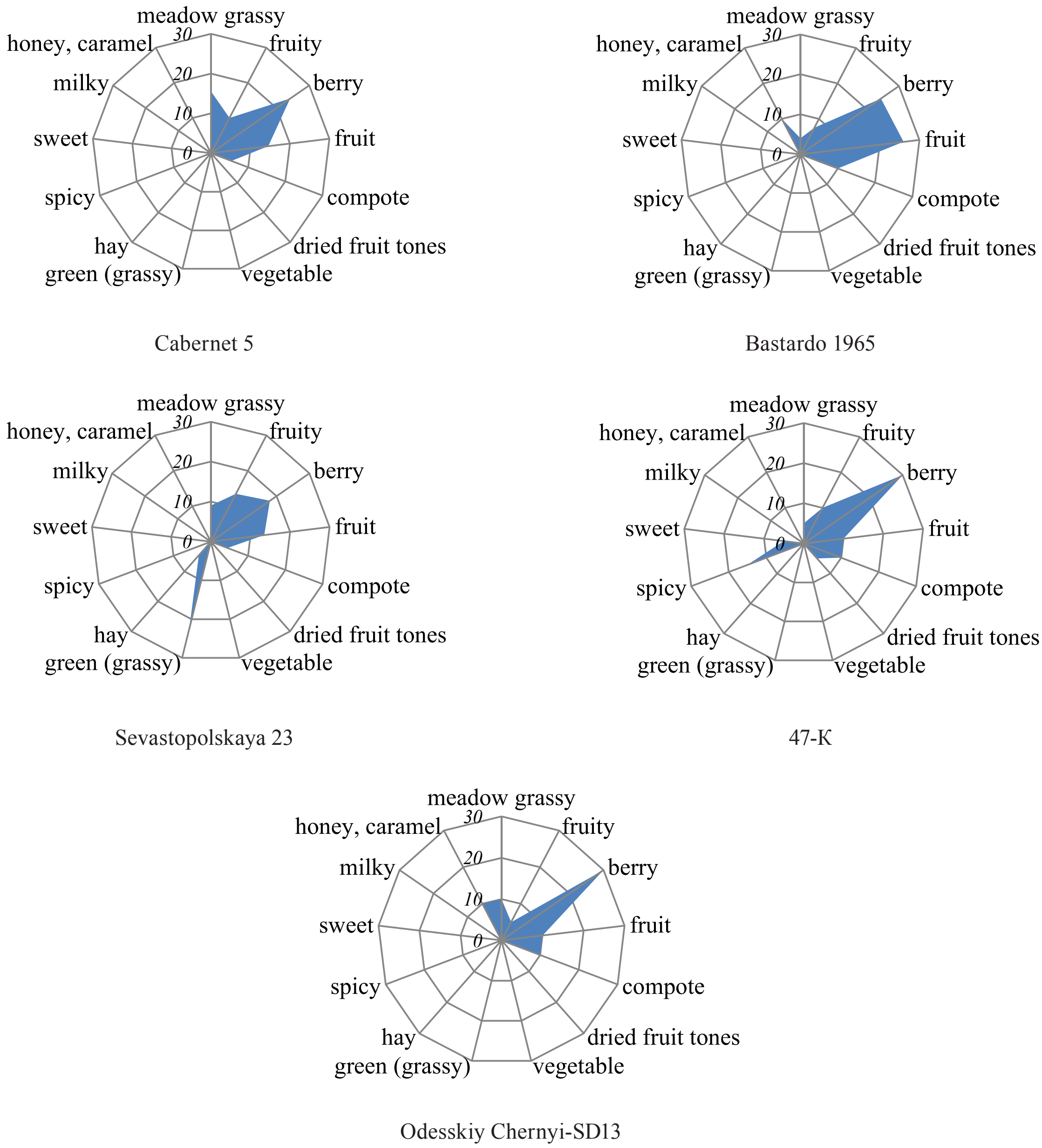

Figure 3 Aromatic profile of rosé base wines on various yeast races

on the difference between the measured CO_2 content and the CO_2 solubility at a certain pressure and ethanol concentration. Sparkling properties were determined according to Standard STO 01586301.022–2019 "Sparkling wines, carbonated wines, and carbonated drinks. Determination of sparkling properties by gravimetric method." In particular, we measured the CO_2 desorption rate from the bottle of wine when depressurizing to the atmospheric level.

Sensory evaluation of base and sparkling wines followed State Standard 32051-2013 "Wine products. Methods of Organoleptic Analysis," ISO 5492:2008 "Sensory analysis – Vocabulary," and ISO 11035:1994 "Sensory analysis – Identification and selection of descriptors for establishing a sensory profile by a multidimensional approach." Sensory evaluation was carried out by trained panelists on a 10-point system, by quantifying the contribution of individual descriptors to the composition of color, flavor, and aroma of wines. The descriptors were selected in accordance with ISO 5492, ISO 11035 and [11, 12, 13].

RESULTS AND DISCUSSION

At the first stage, we assessed the effects of different yeast races on must fermentation (Figs. 1 and 2).

We found that the period of must fermentation using the red method was 10–14 days shorter than that with the white method. This was due to the thermal protective effect of the pomace "cap" and the concentration of yeast cells on the solid parts of pomace, increasing the contact area for yeast and must sugars.

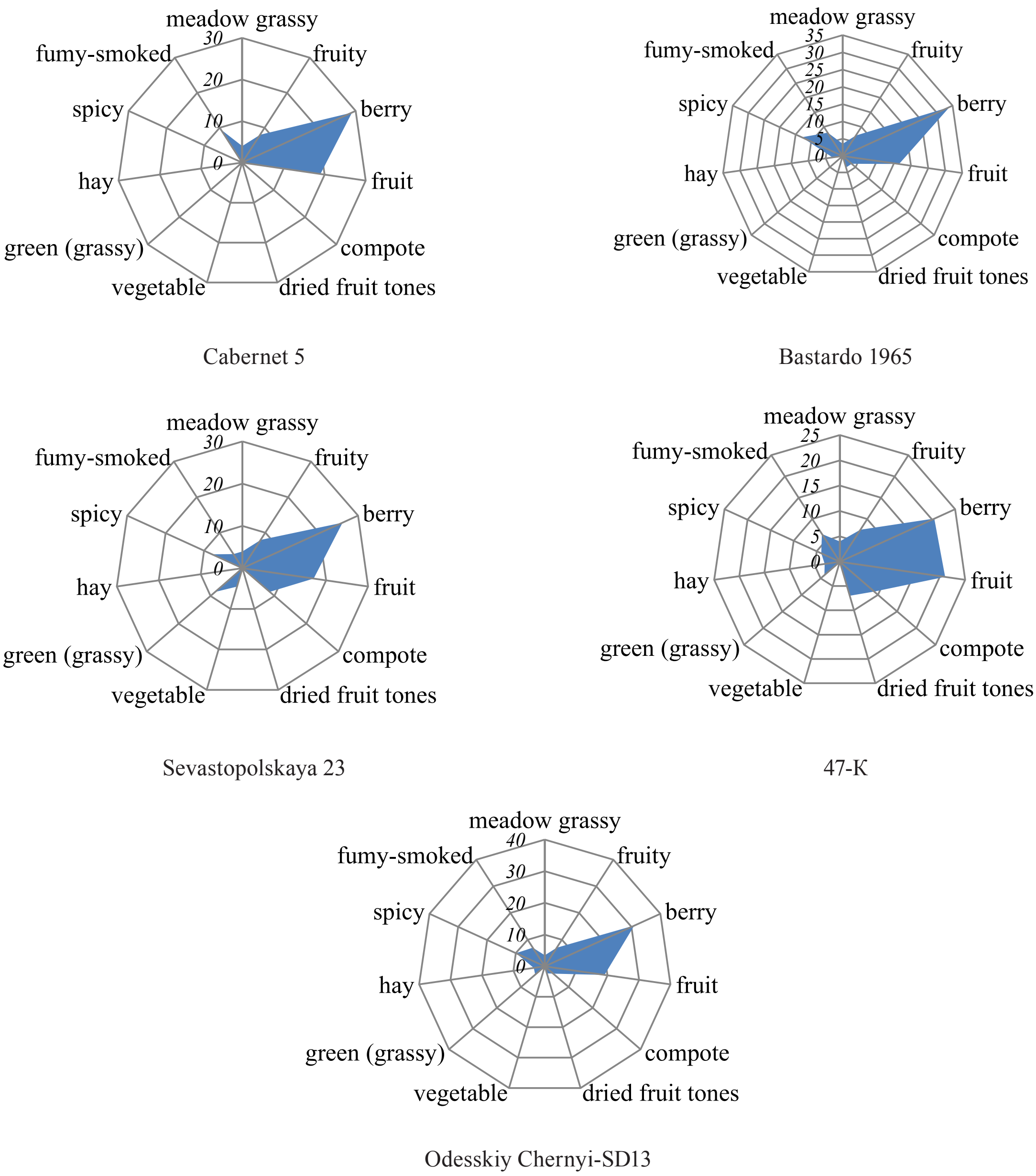

Figure 4 Aromatic profile of red base wines on various yeast races

The fermentation of the rosé must (Fig. 1) was most intensive on the Odesskiy Chernyi-SD13 race and slowest on the Bastardo 1965 race. The red must (Fig. 2) fermented faster on the Bastardo 1965 race and slower on the 47-K race. A slight curvature in the density range of 1.030 g/cm^3 was associated with pulp pressing, which slowed down the fermentation.

Next, we determined the physicochemical parameters of the base wines (Tables 2 and 3).

Among the rosé base wines, the sample fermented on the Bastardo 1965 race had the lowest amount of residual sugars (glucose – 0.32 g/dm^3, fructose – 0.76 g/dm^3), although its fermentation lasted longer than on the other races (41 days). The minimum fructose content in this sample confirmed the fructosophilic properties of this culture. Sugar fermentation proceeded faster (29 days) and more intensively with the Odesskiy Chernyi-SD13 race, with a large volume fraction of ethyl alcohol accumulated at the lowest glycerol content. It indicated that this yeast race fermented a smaller fraction of sugars by the glyceropyruvic path, which was also confirmed by the lower contents of succinic, acetic, and titratable acids. Malolactic fermentation did not take place in the rosé base wine samples. The pH and Eh values were practically the same.

The best foaming properties were shown by the rosé base wines prepared on the Odesskiy Chernyi-SD13 race (max. foam 1000 cm^3), with the lowest values (800 cm^3) found in the wines on the Bastardo 1965 race. In addition, we found an inverse correlation between the maximum foam volume and the total content of phenolic substances (K = –0.80). Noteworthily, the sample

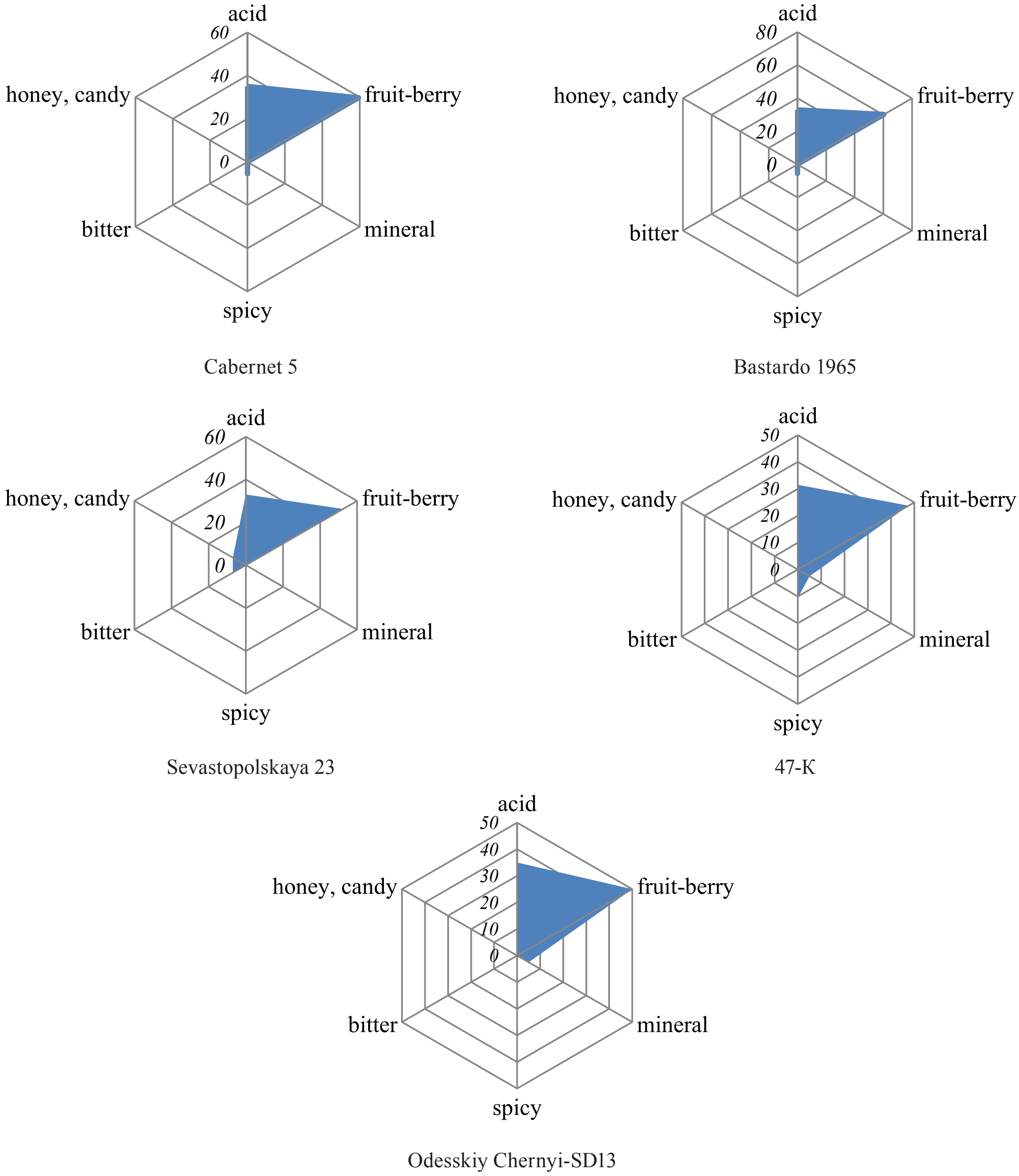

Figure 5 Flavor profile of rosé base wines on various yeast races

prepared on the Odesskiy Chernyi-SD13 race contained the smallest amount of phenolic substances and the highest contents of polyphenols and coloring agents, as well as the highest value of color intensity. The highest dynamic viscosity was shown by the sample prepared on the 47-K race. This was due to the concentration of residual sugars (the correlation coefficient between viscosity and fructose concentration was 0.97).

In the red base wines, the Bastardo 1965 race was the fastest to ferment sugars, while the 47-K race was the slowest. Moreover, the latter race did not ferment about 2 g of fructose. As in the rosé samples, the Odesskiy Chernyi-SD13 race synthesized more alcohol and less glycerin. Malolactic fermentation followed alcoholic fermentation in all the samples, except for the one fermented by the Odesskiy Chernyi-SD13 race. It decreased the Eh value and the concentrations of malic and titratable acids, and increased the pH value and the lactic acid content. In addition, lactic acid bacteria did not utilize residual amounts of fructose in the sample fermented on the 47-K race.

The values of foaming properties were high in all the red base wines (1100–1250 cm^3). The dynamic viscosity was the highest in the sample fermented on the Odesskiy Chernyi-SD13 race, correlating with the concentration of ethyl alcohol (K = 0.98). This sample contained the

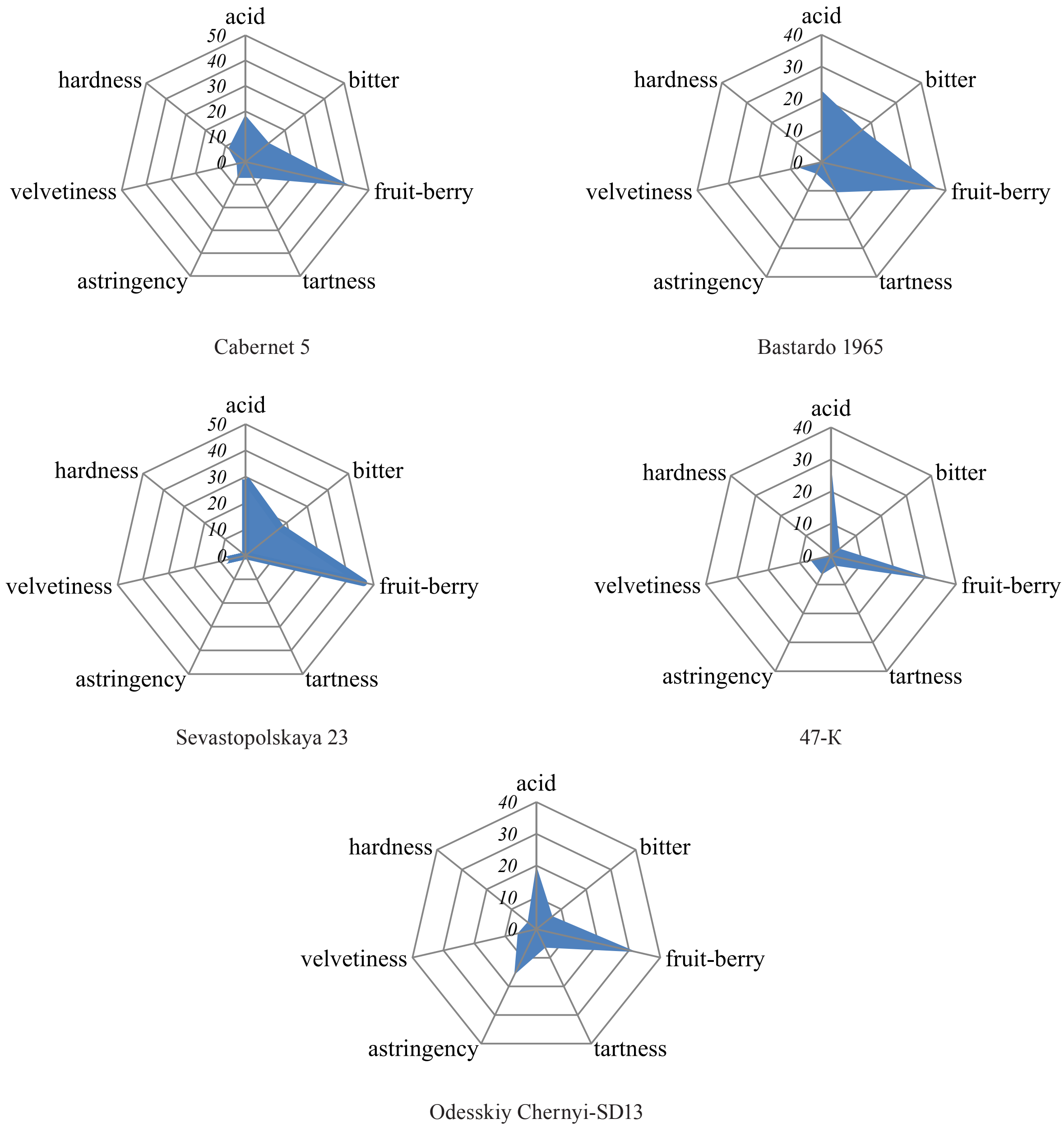

Figure 6 Flavor profile of red base wines on various yeast races

largest amount of phenolic substances (including their polymeric forms) and coloring agents, as well as the highest color intensity. The parameter of color in all the red base wines was less than unity, corresponding to the values for young base wines. This indicated the contribution of anthocyanins and brown condensation products of phenolic substances to the color intensity.

The volume fractions of ethanol in the red base wines were lower than in the rosé samples (on average, by 1 vol. %). This might be due to the partial evaporation of ethyl alcohol from the pomace "cap" during fermentation.

The next stage of our study involved the sensory evaluation of young base wines. Table 4 shows the general characteristics of aroma and flavor, as well as the panelists' scores on a 10-point scale (minimum 7.5 points).

Of the rosé base wines, the sample prepared on the Odesskiy Chernyi-SD13 race was rated highest due to its complex, bright aroma and harmonious flavor. The Bastardo 1965 sample received the lowest score, mainly due to the extraneous note in its aroma associated with long post-fermentation. Among the red wines, the sample prepared on the Odesskiy Chernyi-SD13 race received the higher score due to its rich aroma and velvety flavor.

While tasting, the panelists determined the main descriptors for color and aroma (Fig. 3 and 4), as well as flavor (Figs. 5 and 6). Red (67.5–87.5%) and violet (12.5–32.5%) shades took part in the color composition of rosé base wines. Red (60.5–65.0%), violet (29.5–35.0%), and brown (0–7%) shades took part in the color composition of red base wines.

Berry tones in aroma and flavor are varietal features of Cabernet-Sauvignon rosé and red base wines. The strongest berry tones were observed in the samples prepared on the Odesskiy Chernyi-SD13 and 47-K races. Fruit tones were significant contributors to the aromatic composition of the remaining samples due to complex esters forming during enzymatic processes during fermentation [14, 15]. In addition to berry and fruit tones, the red base wines featured fume-smoky tones and those of dried fruits, which were most pronounced in the 47-K sample. Vegetable notes (green pepper) were identified in the Sevastopolskaya 23 sample, possibly due to the influence of 3-isobutyl-2-methoxypyrazine [16].

The flavor of rosé base wines was based on fruit-and-berry and acid descriptors. The sample prepared on the Sevastopolskaya 23 race expressed honey and candy hints, as well as light bitterness. The Cabernet 5, 47-K, and Bastardo 1965 samples had distinct spicy notes.

The flavor of red base wines was based on the same fruit-and-berry and acid descriptors, with additional velvetiness, astringency, and tartness. Their astringency could be associated with the content of polymeric forms of phenolic substances, usually with an average degree

Table 6 Sensory evaluation of experimental young sparkling wines

Yeast race	General characteristics of aroma and flavor	Score
	Rosé	
Cabernet 5	Transparent. Color: light rosé. Bouquet: pure, varietal, berry with fruit tones. Flavor: fresh, mild, berry with nightshade notes, well-saturated with CO_2.	8.99
Bastardo 1965	Transparent. Color: light rosé. Bouquet: pure, of berry direction, with candy tones. Flavor: fresh, harmonious, berry-candy, with piquant bitterness, well-saturated with CO_2.	8.93
Sevastopolskaya 23	Transparent. Color: light rosé. Bouquet: berry-fruit. Flavor: fresh, harmonious, of berry direction, well-saturated with CO_2.	8.97
47-K	Transparent. Color: light rosé. Bouquet: pure, berry-fruit. Flavor: fresh, mild, plain, well-saturated with CO_2.	8.90
Odesskiy Chernyi-SD13	Transparent. Color: light rosé. Bouquet: pure, fresh, with candy tones. Flavor: pure, fresh, light, well-balanced, well-saturated with CO_2.	9.03
	Red	
Cabernet 5	Transparent. Color: dark ruby. Bouquet: fresh, varietal, berry, with nightshade note. Flavor: harmonious, varietal, well-formed, well-saturated with CO_2.	8.99
Bastardo 1965	Transparent. Color: dark ruby. Bouquet: varietal, of berry direction, with light "choking." Flavor: fresh, full-bodied, tannin, with piquant bitterness, well-saturated with CO_2.	8.91
Sevastopolskaya 23	Transparent. Color: dark ruby. Bouquet: pure, of berry-fruit direction, with morocco leather noes. Flavor: fresh, velvet, with piquant bitterness, averagely saturated with CO_2.	8.92
47-K	Transparent. Color: dark ruby. Bouquet: varietal, fruit-berry, with light "choking." Flavor: mild, velvet, with light bitterness, averagely saturated with CO_2.	8.87
Odesskiy Chernyi-SD13	Transparent. Color: dark ruby. Bouquet: pure, bright, varietal, berry-fruit direction. Flavor: mild, well-balanced, fresh, full-bodied, tannin, well-saturated with CO_2.	9.05

Table 7 Carbon dioxide contents and foaming properties of young sparkling wines

Race title	Equilibrium pressure of CO_2, kPa	CO_2 content per bottle (0.75 dm^3), g				Weight ratio of bound CO_2, %	Foaming properties	
		Total in bottle	Gasi-form	Dis-solved	Bound		Maximum volume of foam, cm^3	Time of foam break, s
				Rosé				
Cabernet 5	610	8.233	0.195	7.026	1.012	12.28	660	112
Bastardo 1965	650	9.330	0.213	7.310	1.808	19.38	585	43
Sevastopolskaya 23	460	6.861	0.143	5.624	1.094	15.94	780	180
47-K	540	7.547	0.188	6.364	0.995	13.19	640	57
Odesskiy Chernyi-SD13	650	10.062	0.170	7.383	2.509	24.93	900	320
				Red				
Cabernet 5	810	10.520	0.284	8.800	1.435	13.64	820	> 300
Bastardo 1965	750	9.696	0.225	8.274	1.197	12.35	1200	> 300
Sevastopolskaya 23	810	10.611	0.336	8.892	1.383	13.04	1100	> 300
47-K	600	8.416	0.152	7.121	1.142	13.57	1000	> 300
Odesskiy Chernyi-SD13	790	10.245	0.337	8.517	1.392	13.59	1150	> 300

Table 8 Sparkling properties of young rosé wines on different yeast races

Yeast race	$V_{1–300}$, mg/min	Angle of deflection of CO_2 desorption curve, °
Cabernet 5	4.097	0.2347
Bastardo 1965	3.559	0.2039
Sevastopolskaya 23	3.662	0.2098
47-K	4.027	0.2307
Odesskiy Chernyi-SD13	3.358	0.1924

Where: $V_{1–300}$ is the average CO_2 desorption rate on the timespan of 1–300 min

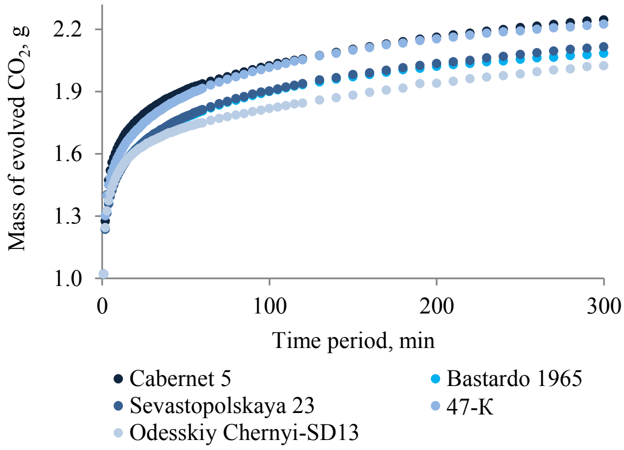

Figure 7 CO_2 desorption from young rosé sparkling wines prepared on different yeast races

of polymerization of ten or more small anthocyanin pigment derivatives (tetramers) [17]. The sample developed on the Odesskiy Chernyi-SD13 race had a richer and more complex flavor.

The physicochemical parameters of experimental young sparkling wines are presented in Table 5.

The samples of young rosé sparkling wines showed similar physicochemical characteristics. Their fermentation process was complete. Their pH was lower than in similar base wines, primarily due to a higher mass concentration of titratable acids.

In young red wines produced on the Cabernet 5 race, alcoholic fermentation was followed by malolactic fermentation, as evidenced by a decreased mass concentration of titratable acids and an increased pH. We found a correlation between the value of redox potential (Eh) and the concentration of titratable acids in young red sparkling and base wines. The correlation coefficient was 0.939 and 0.957 for base and sparkling wines, respectively. This indicated that malolactic fermentation led to a decrease in Eh.

The wine produced on the Odesskiy Chernyi-SD13 race contained the largest amount of phenolic and coloring substances and had higher color intensity compared to the other wines. This might be due to the ability of this race to improve the extraction of phenolic substances during pulp fermentation, with yeast pectolytic enzymes producing a stronger effect on the grape skin [18, 19].

Table 6 shows the results of the sensory evaluation of young sparkling wines, as well as the panelists' scores on a 10-point scale (minimum 8.8 points)

The rosé wines had a distinct varietal berry aroma with various notes. Higher scores were given to the samples prepared on the Odesskiy Chernyi-SD13, Cabernet 5, and Sevastopolskaya 23 yeast races, primarily due to their balanced flavor. The red wines also had a strong berry aroma with various notes. The panelists gave higher scores to the samples prepared on the Odesskiy Chernyi-SD13, Cabernet 5, and Sevastopolskaya 23 yeast races, primarily due to their pure aroma. The samples prepared on the 47-K and Bastardo 1965 races had slight off-tones (H_2S).

The samples of young sparkling wines were tested for their foaming and sparkling properties, as well as CO_2 content and desorption (Tables 7, 8 and Fig. 7).

The best foaming properties were exhibited by the young rosé sparkling wines prepared on the Odesskiy Chernyi-SD13 and Sevastopolskaya 23 races, as well as the young red sparkling wines on the Bastardo 1965 and Odesskiy Chernyi-SD13 races. The red wines showed a direct correlation between the maximum foam volume and the polyphenol content (K = 0.78). The excess CO_2 pressure corresponded to the standard rate (at least 300 kPa), ranging from 460 to 810 kPa. The CO_2 content totaled 6.861–10.520 g in a 0.75 dm^3 bottle, depending on the concentration of sugars and dissolved CO_2 in the must with incomplete fermentation when preparing a tirage mixture. The weight ratio of bound CO_2 ranged from 12.28 to 24.93%, depending on the total CO_2 content in the sample and the peculiarities of fermentation on this yeast race in the bottle. The red wine samples had similar contents of bound CO_2, compared to rosé wines, which affected their sparkling properties. The correlation coefficient between $V_{1–300}$ and the weight ratio of bound CO_2 was –0.95. This confirmed the assumption that higher contents of bound CO_2 in sparkling wines improve their sparkling properties [20–25]. The lowest CO_2 desorption rate and angle of curve deflection (hence the best sparkling properties) were determined in the sample produced on the Odesskiy Chernyi-SD13 race (Table 8, Fig. 7). Slightly higher CO_2 desorption rates were also found in the samples on the Bastardo 1965 and Sevastopolskaya 23 races.

CONCLUSION

Yeast races produce a significant effect on the quality of base and young sparkling wines. Odesskiy Chernyi-SD13 is the best race for rosé and red base wines and young sparkling wines produced from Cabernet-Sauvignon grown in the South Coast of Crimea. This yeast race contributes to a pure varietal aroma and a harmonious flavor (panelists score: 9.03–9.05 points), as well as the best properties (maximum foam volume:

900–1150 cm^3, weight ratio of bound CO_2: 13.59–24.93%). The bottle method of making wines from must with incomplete fermentation ensures original products of high quality. This technology can increase the production of domestic sparkling wines in the crop year. It is especially suitable for small farms since it does not require any complex equipment. Research in this direction is planned to be continued with the aim of introducing this type of product in the regulatory standard documentation.

CONTRIBUTION

A.S. Makarov supervised the research, edited the manuscript, and formulated the conclusions. I.P. Lutkov formulated the hypothesis, set the aim and objectives, conducted the research, and wrote the manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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REFERENCES

1. Jeandet P, Vasserot Y, Liger-Belair G, Marcha R. Sparkling wine production. In: Joshi VK, editor. Handbook of enology: principles, practices and recent innovations. API; 2011.
2. Di Gianvito P, Arfelli G, Suzzi G, Tofalo R. New trends in sparkling wine production: Yeast Rational Selection. In: Alcoholic beverages. Volume 7: The science of beverages. Woodhead Publishing; 2019. pp. 347–386. https://doi.org/10.1016/B978-0-12-815269-0.00011-8.
3. Borrull A, López-Martínez G, Miró-Abella E, Salvadó Z, Poblet M, Cordero-Otero R, et al. New insights into the physiological state of *Saccharomyces cerevisiae* during ethanol acclimation for producing sparkling wines. Food Microbiology. 2016;54:20–29. https://doi.org/10.1016/j.fm.2015.11.001.
4. Martí-Raga M, Marullo P, Beltran G, Mas A. Nitrogen modulation of yeast fitness and viability during sparkling wine production. Food Microbiology. 2016;54:106–114. https://doi.org/10.1016/j.fm.2015.10.009.
5. Bozdogan A, Canbas A. Influence of yeast strain, immobilization and ageing time on the changes of free amino acids and amino acids in peptides in bottle fermented sparkling wines obtained from *Vitis vinifera* cv. Emir. International Journal of Food Science and Technology. 2011;46(6):1113–1121. https://doi.org/10.1111/j.1365-2621.2011.02550.x.
6. Sartor S, Toaldo IM, Panceri CP, Caliari V, Luna AS, de Gois JS, et al. Changes in organic acids, polyphenolic and elemental composition of rosé sparkling wines treated with mannoproteins during over-lees aging. Food Research International. 2019;124:34–42. https://doi.org/10.1016/j.foodres.2018.11.012.
7. Velázquez R, Zamora E, Álvarez ML, Ramírez M. Using *Torulaspora delbrueckii* killer yeasts in the elaboration of base wine and traditional sparkling wine. International Journal of Food Microbiology. 2019;289:134–144. https://doi.org/10.1016/j.ijfoodmicro.2018.09.010.
8. El'darov MA, Avdanina DA, Shalamitskii MY, Ivanova EV, Tanashchuk TN, Kishkovskaya SA, et al. Polymorphism of the iron homeostasis genes and iron sensitivity in *Saccharomyces cerevisiae* flor and wine strains. Microbiology. 2019;88(2):200–205. https://doi.org/10.1134/S0026261719020036.
9. Cilindre C, Liger-Belair G, Villaume S, Jeandet P, Marchal R. Foaming properties of various Champagne wines depending on several parameters: Grape variety, aging, protein and CO_2 content. Analytica Chimica Acta. 2010;660 (1–2):164–170. https://doi.org/10.1016/j.aca.2009.10.021.
10. Merzhanian AA. Fiziko-khimiya igristykh vin [Physical chemistry of sparkling wines]. Moscow: Pishchevaya promyshlennost′; 1979. 271 p. (In Russ.).
11. Arroyo BL, Roberts RP. How specific wine tasting descriptors are? Procedia – Social and Behavioral Sciences. 2015;198:287–299. https://doi.org/10.1016/j.sbspro.2015.07.447.
12. Niimi J, Boss PK, Bastian SEP. Sensory profiling and quality assessment of research Cabernet Sauvignon and Chardonnay wines; quality discrimination depends on greater differences in multiple modalities. Food Research International. 2018;106:304–316. https://doi.org/10.1016/j.foodres.2017.12.060.
13. Sánchez-Palomo E, Trujillo M, García Ruiz A, González Viñas MA. Aroma profile of malbec red wines from La Mancha region: Chemical and sensory characterization. Food Research International. 2017;100:201–208. https://doi.org/10.1016/j.foodres.2017.06.036.
14. Lytra G, Franc C, Cameleyre M, Barbe J-C. Study of substituted ester formation in red wine by the development of a new method for quantitative determination and enantiomeric separation of their corresponding acids. Journal of Agricultural and Food Chemistry. 2017;65(24):5018–5025. https://doi.org/10.1021/acs.jafc.7b00979.

15. Kemp B, Herve A, Robillard B, Marchal R. Effect of production phase on bottle-fermented sparkling wine quality. Journal of Agricultural and Food Chemistry. 2015;63(1):19–38. https://doi.org/10.1021/jf504268u.

16. Liang C, Ristic R, Jiranek V. Jeffery DW. Chemical and sensory evaluation of magnetic polymers as a remedial treatment for elevated concentrations of 3-Isobutyl-2-methoxypyrazine in Cabernet sauvignon grape must and wine. Journal of Agricultural and Food Chemistry. 2018;66(27):7121–7130. https://doi.org/10.1021/acs.jafc.8b01397.

17. Sáenz-Navajas M-P, Arias I, Ferrero-del-Teso S, Fernández-Zurbano P, Escudero A, Ferreira V. Chemo-sensory approach for the identification of chemical compounds driving green character in red wines. Food Research International. 2018;109:138–148. https://doi.org/10.1016/j.foodres.2018.04.037.

18. Ageyeva NM, Avanesyants RV. Influence of ferment preparations of new generation the wine biopolymer. Fruit growing and viticulture of South Russia. 2017;46(4):129–140. (In Russ.).

19. Fedosova AN, Kaledina MV, Shevchenko NP, Voloshenko LV, Baydina IA, Trubchaninova NS. Research of the pectolytic ability of saccharomyces cerevisiae yeast. Storage and Processing of Farm Products. 2019;(3):78–89. (In Russ.).

20. Malakhov AA, Naberegnykh IA. Regulation the quality of sparkling wines with structurally destroyed autolysis of yeast. News of institutes of higher education. Food technology. 2010;316(4):57–59. (In Russ.).

21. Kotenko STs, Islammagomedova EA, Khalilova EA, Abakarova AA. Biotechnological properties of new strain of yeast *Saccharomyces cerevisiae Y-3980*. Bulletin of Higher Educational Institutions. North Caucasus Region. Natural Sciences. 2016;192(4):45–50. (In Russ.).

22. Makarov AS, Lutkov IP, Peskova IV, Probeygolova PA, Shalimova TR. Influence of strain of yeast chemical composition and quality of red sparkling wines. Fruit growing and viticulture of South Russia. 2018;50(2):111–122. (In Russ.). https://doi.org/10.30679/2219-5335-2018-2-50-111-122.

23. Gnetko LV, Zolotarev IO, Arutyunova GYu, Khachaturov VN. The effect of yeast race on the composition of a high-molecular fraction and physical and chemical properties of sparkling wines. New Technologies. 2019;(1):29–37. (In Russ.). https://doi.org/10.24411/2072-0920-2019-10103.

24. Mishin MV, Talanyan OR. Assessment of the qualities of sparkling sparkling wines. Scientific works of the Kuban State Technological University. 2015;(8):61–63. (In Russ.).

25. Ageeva NM, Guguchkina TI, Kashkara KE, Kashkara GG, Burda VE. Method of production a young red sparkling wine. Patent RU 2662961C1. 2018.

ORCID IDs

Alexander S. Makarov https://orcid.org/0000-0001-8497-5056

Igor P. Lutkov https://orcid.org/0000-0001-9515-4341