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

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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 CO₂ desorption rate; CO₂ 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/dm³) and coloring agents (275 mg/dm³) 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 CO₂ (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.

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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/dm³ and titratable acids amounted to 10.0 g/dm³. 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/dm³ SO₂), 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/dm³ SO₂). 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/dm³, one part of each batch of stuck must was bottled for champagnization, with the other part fermented dry. After introducing bentonite (0.2 g/dm³), 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 cm³ sample of degasified wine was poured in a 1 dm³ 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 |
|------|------------|----------------------------------------|-----------|------------|
| 1-25 | Cabernet 5 | *Saccharomyces vini* Meyen, 1838 syn. *Saccharomyces cerevisiae* (Kreger-van Rij N.J.W., 1984) | Sensitive (S) | Resistant to cold, SO₂, alcohol, and acid (pH 2.8); glucosophilic; does not form H₂S |
| 1-523| Bastardo 1965 | *Saccharomyces oviformis* Osterwalder, 1924 syn. *S. cerevisiae* (Kreger-van Rij N.J.W., 1984) | Sensitive (S) | Resistant to SO₂, alcohol, tannin and polyphenols; fructosophilic |
| 1-525| Sevastopol'skaya 23 | *S. oviformis* Osterwalder, 1924 syn. *S. cerevisiae* (Kreger-van Rij N.J.W., 1984) | Sensitive (S) | Resistant to cold, SO₂, and alcohol; glucosophilic; does not form H₂S |
| 1-527| 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, SO₂, alcohol; forms H₂S in small amounts; glucosophilic; low iron sensitivity index [8]. Recommended for table base wines for sparkling wines. |
| 1-652| 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. |
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/dm³|       |       |       |       |       |       |       |     |     |     |                 |
| Cabernet 5         | 0.35| 4.04  | 3.15  | 1.51  | 1.51  | 0.09  | 9.4   | 0.26  | 0.42| 3.22| 7.80| 12.41           |
| Bastardo 1965      | 0.34| 3.93  | 2.93  | 1.63  | 1.63  | 0.35  | 9.3   | 0.24  | 0.32| 0.76| 7.81| 12.54           |
| Sevastopolskaya 23 | 0.31| 3.87  | 2.96  | 1.68  | 1.68  | 0.30  | 9.5   | 0.19  | 0.33| 1.99| 8.05| 12.44           |
| 47-K               | 0.31| 4.09  | 3.17  | 1.58  | 1.58  | 0.10  | 9.6   | 0.23  | 0.50| 6.88| 7.96| 12.12           |
| Odesskiy Chernyi-SD13| 0.45| 3.96  | 3.18  | 1.20  | 1.20  | 0.09  | 8.6   | 0.24  | 0.38| 1.01| 5.23| 12.95           |

Table 3 Physicochemical parameters of experimental base wines

| Race title         | pH  | Eh   | V_{max} cm³ | t_{br} s | V_c mm³/s | TPh  mg/dm³ | MPh  mg/dm³ | PPh  mg/dm³ | C   mg/dm³ | I     | T     |
|--------------------|-----|------|--------------|---------|------------|--------------|--------------|--------------|-----------|-------|-------|
|                    |     |      |              |         |            |              |              |              |           |       |       |
| 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 |

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

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})

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Table 4 Sensory evaluation of experimental base wines

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

Table 5 Physicochemical parameters of experimental young sparkling wines

| Race title           | pH   | Eh   | $V_{max}$ | $t_{br}$ | V | 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 | 219  | 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...
on the difference between the measured CO₂ content and the CO₂ 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 CO₂ 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 – Vocabularies,” 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.
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/cm³ 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/dm³, fructose – 0.76 g/dm³), 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 cm³), with the lowest values (800 cm³) 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 ($K = -0.80$). Noteworthy, the sample
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 cm³). 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
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-methoxy-pyrazine [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 |
|---------------------|------------------------------------------------------------------------|-------|
| Cabernet 5          | Transparent. Color: light rosé. Bouquet: pure, varietal, berry with fruit tones. Flavor: fresh, mild, berry with nightshade notes, well-saturated with CO₂. | 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 CO₂. | 8.93  |
| Sevastopolskaya 23  | Transparent. Color: light rosé. Bouquet: berry-fruit. Flavor: fresh, harmonious, of berry direction, well-saturated with CO₂. | 8.97  |
| 47-K                | Transparent. Color: light rosé. Bouquet: pure, berry-fruit. Flavor: fresh, mild, plain, well-saturated with CO₂. | 8.90  |
| Odesskiy Chernyi-SD13 | Transparent. Color: light rosé. Bouquet: pure, fresh, with candy tones. Flavor: pure, fresh, light, well-balanced, well-saturated with CO₂. | 9.03  |

Red

| Cabernet 5          | Transparent. Color: dark ruby. Bouquet: fresh, varietal, berry, with nightshade note. Flavor: harmonious, varietal, well-formed, well-saturated with CO₂. | 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 CO₂. | 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 CO₂. | 8.92  |
| 47-K                | Transparent. Color: dark ruby. Bouquet: varietal, fruit-berry, with light “choking.” Flavor: mild, velvet, with light bitterness, averagely saturated with CO₂. | 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 CO₂. | 9.05  |

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

| Race title          | Equilibrium pressure of CO₂, kPa | CO₂ content per bottle (0.75 dm³), g | Weight ratio of bound CO₂, % | Foaming properties |
|---------------------|----------------------------------|-------------------------------------|------------------------------|-------------------|
|                      | Total in bottle                  | Gasiform                            | Disolved                     | Bound             | Maximum volume of foam, cm³ | 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                              | 8.681                               | 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        |
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,S).

The samples of young sparkling wines were tested for their foaming and sparkling properties, as well as CO₂ 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 CO₂ pressure corresponded to the standard rate (at least 300 kPa), ranging from 460 to 810 kPa. The CO₂ content totaled 6.861–10.520 g in a 0.75 dm³ bottle, depending on the concentration of sugars and dissolved CO₂ in the must with incomplete fermentation when preparing a tirage mixture. The weight ratio of bound CO₂ ranged from 12.28 to 24.93%, depending on the total CO₂ 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 CO₂ compared to rosé wines, which affected their sparkling properties. The correlation coefficient between \( V_{1,300} \) and the weight ratio of bound CO₂ was –0.95. This confirmed the assumption that higher contents of bound CO₂ in sparkling wines improve their sparkling properties [20–25]. The lowest CO₂ 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 CO₂ 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 cm³, weight ratio of bound CO₂: 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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