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ESTABLISHING THE PATTERNS OF INFLUENCE OF ENVIRONMENTAL CONDITIONS ON THE BIOCHEMICAL INDICATORS OF GRAPE MUST AND THE WINE PRODUCED FROM IT

The object of research is grape must and wines made from white and red grape varieties grown in the conditions of the Absheron and Gabala regions. The article provides a comparative analysis of the biochemical indicators of must and wine samples made from grape varieties grown in the ecological and geographical conditions of the Absheron and Gabala regions of Azerbaijan. Grapes of some white (Muscat white, Viognier, Chardonnay, Semillon, Riesling, Bayan Shirey, Rkatsiteli) and red (Aleatico, Shiraz, Merlot, Madrasa) varieties were used as the research material. In order to determine the direction of use and technological suitability of the harvest of the studied grape varieties, the biochemical indicators of must were studied, various wine samples were prepared and their physicochemical analysis was carried out. It was found that the biochemical composition of the must and the physicochemical indicators of wine samples vary depending on the soil and climatic conditions of the place where the grape variety is grown. It turned out that the juice density of grape varieties grown in the Gabala district is 1.09122–1.11207 g/L, and the juice density of grape varieties grown in the Absheron district is higher and is 0.90010–1.90024 g/L. Grape varieties grown in the Gabala district are characterized by a higher content of tartaric acid. The highest content of tartaric acid was noted in the Semillon variety. In grape varieties grown in the Gabala district, the malic acid content varies in the range of 0.3–3.2 g/L, and in varieties grown in the Absheron district, within 0.2–1.2 g/L. The amount of polyphenols in grapes grown in the Gabala district was higher than the similar indicator for the Absheron district. The obtained results can be used in the winemaking industry, which will allow producers to more accurately select raw materials for the production of a specific type of wine, and can also be useful for winemakers in other regions with similar soil and climatic conditions and the assortment of regionalized varieties.

Keywords: white and red grape varieties, must, wine, biochemical indicators, phenolic compounds.

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1. Introduction

Grapes (*Vitis*) are a valuable agricultural crop of great economic importance. The research of grape varieties grown in Azerbaijan and the factors influencing the technological characteristics, composition, and quality of winemaking raw materials remains relevant. Currently, one of the priority tasks is the research of the mechanical composition of grapes, the amount of carbohydrates they contain, seed size, and the consistency of the berry pulp. Along with the development of new productive varieties, timely harvesting, storage, and processing of the crop, improving the quality of grapes is of great importance for the development of agriculture. High air temperatures observed during the growing season due to global warming lead to a reduction in the ripening period of grapes and the accumulation of excessive amounts of sugar in the berries, which leads to an undesirably high alcohol level in the resulting wine [1]. In order to meet the public demand for low-alcohol wines [2] and ensure their compliance with regulatory restrictions, winemakers should consider adaptive and alternative approaches to reducing the alcohol content while maintaining the

taste and quality of the wine. Research has shown that upon reaching full physiological maturity, grapes accumulate the maximum amount of sugar compounds – glucose and fructose – enzymes, vitamins, trace elements, organic acids, and other substances essential to the human body [3]. Studying the biochemical characteristics of fully ripened grapes [4], which have accumulated the required amount of the above-mentioned substances, is the primary objective of scientific research in the field of viticulture [5].

The organic acids contained in grapes play an important role in the metabolism of the grape plant [6]. Grapes primarily contain tartaric and malic acids, and small amounts of citric, glycolic, and some other organic acids [7]. Tartaric acid and its salts, by creating an acidic environment in grape juice and wine, inhibit the growth of microorganisms that impair their flavor [8]. Grapes contain many vitamins: B1, B2, B6, PP, C, etc. [9]. Phenolic compounds, found in grape juice at 5–15 g/kg, white wine at 0.2–1.0 g/dm³, and red wine at 1.5–5.0 g/dm³, are called tannins in winemaking [10]. They consist of condensed catechins and leucoanthocyanins. Phenolic compounds are divided into non-hydrolyzable (condensable) and hydrolyzable.

Non-hydrolyzable phenols include catechins and leucoanthocyanins, while hydrolyzable phenols include gallols and ellals [11].

Of the phenolic carboxylic acids, wines contain small amounts of salicylic and gallic acid. The concentration of phenolic acids in grape skins and wine is 0.1–30 mg/dm³. Grape juice contains a small amount of catechins. White table wines contain fewer catechins than red table wines. The high catechin content in red table wines is due to their transfer from grape juice to wine [12].

Phenolic compounds affect the flavor, color, aroma, and clarity of wine and wine materials. The influence of phenolic compounds on the aroma of grapes, wines, and wine materials is primarily due to the presence of aromatic aldehydes, alcohols, and volatile phenols. About twenty volatile phenols are part of the substances that form wine aroma. The taste and other quality attributes of wine are influenced not only by the quantity of phenolic compounds but also by their physicochemical composition. Wine color, a key quality indicator, depends on the mono- and polymeric phenolic compounds that pass from grapes to wine. The intensity of wine color largely depends on the quality of anthocyanins, their physicochemical composition, pH, sulfur dioxide (SO₂) content, and other factors [13]. The amount of phenolic compounds in red table wines directly affects both the taste and color of the wine. When these compounds are present in small quantities, the wine is insufficiently rich and incomplete, while when they are present in excessive quantities, it becomes coarse and tasteless [14]. It should be noted that some phenolic compounds, by reducing yeast activity, slow down the fermentation process. Polyphenols reduce the undesirable development of microorganisms in wine. For this reason, red table wine is generally more stable than white wine. Thus, phenolic compounds contained in wines undergo enzymatic oxidation under aerobic conditions under the influence of certain oxidases. This process leads to a change in the composition of wines during their aging. Phenolic compounds also bind with oxygen, preventing the oxidation of other compounds contained in the wine, which improves its organoleptic properties [15]. Changes in the quantity and properties of these compounds directly lead to changes in the optical properties of wine and wine materials. During the maturation and aging stages of wines, all substances contained in them, including phenolic compounds, are involved in these processes. The reduction in phenolic compounds during wine maturation is due to their oxidation by atmospheric oxygen, condensation, and compaction, resulting in their precipitation as water-insoluble agglomerates. It has been established that phenolic compounds participate in oxidation-reduction processes and react with carbohydrates during wine maturation. Phenolic compounds act as antioxidants in red wines [14].

Phenolic compounds, namely flavonoids and polyphenols, found in grape pulp, seeds, and wine, eliminate free radicals and prevent chain reactions thanks to their antioxidant properties. The antioxidant properties of polyphenols are several times stronger than those of many antioxidants (vitamins C and E, beta-carotene). Medical studies have shown that the antioxidant properties of polyphenols found in grape seeds are 20 times stronger than those of vitamin C and 50 times stronger than those of vitamin E. Polyphenols, by catalyzing certain enzymes as an inhibitor, promote the release of histamine into the blood, which has a therapeutic effect in humans with inflammatory processes and allergic reactions [16]. In addition, polyphenols have a wide range of biological activity and high potential for human health. Grape skin mainly consists of anthocyanins, flavanols, phenolic acids, and stilbenes (resveratrol). Like other fruits and vegetables, grapes are a good source of fiber and water. They also contain well-known antioxidants such as vitamin C and manganese, as well as lesser-known antioxidants such as beta-carotene and resveratrol [17]. As is known, during long-term storage of wine in an oak barrel, hydrolyzable tannins such as ellagitannin are transferred from the oak wood into the wine [18].

A review of the literature shows that the biochemical composition of grape must and wine, depending on their growing location, has been

sufficiently studied. However, such data for Azerbaijan's conditions is clearly insufficient. Therefore, a comprehensive analysis is necessary to further determine the intended use and technological suitability of the grape varieties being studied. The results of a comprehensive analysis of the physicochemical parameters of soils, the biochemical composition of raw materials, and wine material samples will contribute to expanding the range of high-quality wines, taking into account the diverse taste preferences of consumers.

The object of this research is grape must and wines made from white and red grape varieties grown in the Absheron and Gabala regions.

The aim of research is to establish patterns in the influence of various soil and climatic conditions on the biochemical composition of grapes and wine materials made from them. To achieve this aim, the following objectives were set:

- 1) to study the physicochemical properties of the soils of the studied area in the Absheron and Savalan Valleys of the Gabala region (at a depth of 0–30 cm);
- 2) to study the biochemical composition of the raw materials;
- 3) to study the biochemical properties of wine samples made from the studied grape varieties.

2. Materials and Methods

2.1. Materials of research

The research was conducted on grape varieties grown in the ecological and geographical conditions of the Absheron and Gabala regions of Azerbaijan. White and red grape varieties, as well as must and wines from these varieties, were used as the study material. The white varieties selected were Muscat Blanc, Viognier, Chardonnay, Semillon, Riesling, Bayan Shirey, and Rkatsiteli. The red varieties selected were Aleatico, Shiraz, Merlot, and Madrasa.

In the vineyards where the research was conducted, the vines are trained in a double-arm cordon. The vines are 16 years old. Fruiting canes are pruned short, preserving two buds. The number of rows is 33. The planting pattern is 3.0 x 1.5 m. Grape harvesting in the Absheron region is carried out manually, and in the Gabala region, a combination of manual and mechanical harvesting.

2.2. Research methods

Physicochemical and biochemical analyses were conducted using modern laboratory instruments, such as a FOSS Winescan™ SO₂ chromatograph, ICP-OES (Perkin Elmer Optima 8000), Pg instruments, T80 UV-VIS spectrophotometer, a pH meter, a hydrometer, a refractometer, and other equipment [17, 19–21].

Ethyl alcohol in the test wine samples was determined according to GOST 32095, titratable acidity according to GOST 32114, volatile acidity according to GOST 32001, extract content according to GOST 32000, and residual sugar according to GOST 13292-73.

Dry matter, sugar content, titratable acidity, tannins, and coloring agents were determined in grape samples taken during the fully ripened period. Tannin and coloring matter content was determined using the Neybauer-Leventhal method [22].

The process for preparing test wine samples was as follows. Grapes of the studied varieties, supplied from the Absheron and Gabala regions, were first placed in crushers and destemmers upon reaching the required conditions. The crushed grapes were then transferred to temperature-controlled tanks and supplemented with 25 mg/L of SO₂ and 2 g/hl of pectolytic enzyme (Rapidase Extra color, France). Cold maceration was carried out in the tanks for 48 hours at a temperature of 13°C. After maceration, the temperature of the tanks was increased to 26°C to create optimal conditions for yeast activation. Zymaflore FX10 *Saccharomyces cerevisiae* yeast was then added to the pulp at 25 g/hl, and fermentation was carried out with ethyl alcohol. On the third day of fermentation, DAP (diamonium phosphate) (Laffort Dynastart,

Bordeaux, France) was added to the pulp at a rate of 15 g/hl to speed up the process. Fermentation lasted 10 days. The temperature during fermentation was maintained at 26°C. After fermentation was complete, the wine was racked into French oak barrels (Tonnellerie Quintessence Bordeaux) and supplemented with 50 g/hl of bacteria (450 preAC, Bordeaux, France/Oenococcus oeni) to initiate malolactic fermentation. The malolactic fermentation process was monitored by paper chromatography. Malolactic fermentation took place at a temperature of 18°C and was completed within 60 days. After six months of rest in barrels, wine samples were taken and analyzed.

Soil and climatic conditions of the Absheron Peninsula. The climate on the Absheron Peninsula is subtropical. Summers are dry and hot. Winters are relatively mild. In the autumn and winter, the weather is generally cloudy, with frequent rainfall and occasional snowfall. The average annual air temperature is 13.5–14.4°C, the sum of active temperatures is 4192–4461°C, the annual amount of solar radiation is 130–135 kcal/cm², and the annual precipitation is 200–250 mm. The coldest month of the year is January, the hottest months are July and August. The number of cold days is 308, the number of sunny days is 220–230. The Absheron Peninsula is subject to wind influence. Strong winds promote transpiration in plants and also increase evaporation from the soil surface, leading to soil drying. Evaporation is highest in July and August, and lowest in February. The peninsula's soils are predominantly gray sandy and clayey. The most common type of soil is the saline gray-brown soil [23].

Soil and climatic conditions of the Savalan Valley in the Gabala District. The climate in the Gabala District is subtropical. The average annual precipitation is 1,027 mm, the evaporation rate is 680 mm, the humidity coefficient is 1.5, and the relative humidity is 78%. Mountain-valley winds mainly blow in the district, which is due to orographic conditions. The average wind speed is 0.8 m/sec. Strong winds can blow for 3 consecutive days, while hot, dry winds (or so-called "white winds") last 8 days, and hail lasts 2 days. This agroclimatic region covers the Gabala Plateau and the Gash Plain. The lowest average annual air temperature in this area is 0°C, and the temperature difference between January and July (the annual temperature amplitude) is +31...+45°C. The sum of annual temperatures above 100°C ranges from 260–300°C, with an air humidity coefficient of 0.15–0.25. This climate is considered

a special subtropical (Mediterranean type). In such climatic conditions, other agricultural crops can be grown alongside grapes. Between 1978 and the early 1990s, tens of thousands of fruit-bearing vineyards were planted in the Gabala region (in the Gash Plain, as well as in the vicinity of the villages of Gushlar, Savalan, Kurd, Mamayli, Bayramkokha, Melikli, Bylykh, and others), yielding high annual yields [23].

3. Results and Discussion

3.1. Study of soil physicochemical parameters

The presence of sufficient humus is considered one of the main factors of soil fertility. Determining the humus content of the topsoil, which nourishes the root system of grape plants, is an important step in agrochemical research. A humus content of 1.0% in the soil sample is considered normal.

A soil pH of 5.5–6.5 is desirable for grape plants. In the studied area in the Absheron region, the soil pH was neutral at 7.6. The soil electrical conductivity was 0.46 mS/cm, which is within the normal range (0–4 mS/cm) and does not interfere with fertilizer absorption. Based on the analysis results, it was found that, regardless of the sampling location and depth, the calcium carbonate (CaCO₃) content averaged 7.3% (the standard is 10%), and the studied soils were classified as medium-calcareous (medium-calcareous). The research of the macronutrient content (Table 1) showed that the amount of nitrogen (N) in the soil section is 113 mg/kg, which is significantly higher than the norm (20–30 mg/kg), and the potassium (K) content is high (220 mg/kg), but within the norm (120–220 mg/kg). However, according to the metal saturation table, potassium showed a result of 0.5%, which is much lower than the norm (2–5%). To increase the potassium content in the studied soils, it is advisable to use organic fertilizers. Compared with the nitrogen and potassium content, the amount of phosphorus (P) in the soil section was significantly lower – 0.4 mg/kg (the norm is 50–150 mg/kg). The magnesium (Mg) content was 381 mg/kg, which is significantly higher than the norm (60–120 mg/kg). But according to the metal saturation table, magnesium is below the norm (10–20%) – 3.0%. Magnesium levels in the studied soils should be increased through the use of organic fertilizers. Sodium (Na) content in the soil sample was above the norm (0–60 mg/kg) at 705 mg/kg.

Table 1

Physicochemical parameters of the soil in the studied area in the Absheron region (based on a section at a depth of 0–30 cm)

Parameters	Unit of measurement	Study results	Normal values	Conclusions
pH (1:2.5)	–	7.6	5.5–7.5	Soil environment is slightly alkaline
Soluble salt content (ES)	µs/cm	0.46	0–4000	Soil is slightly saline
Calcium carbonate (CaCO ₃) (lime)	%	7.3	5–15	Soil is medium-carbonate (medium-calcareous)
Humus	%	1.0	3–4	Humus content is average
Nitrogen	%	113	20–40	Nitrogen content is average
Phosphorus (phosphorus oxide – P ₂ O ₅)	mg/kg	0.4	15–50	Phosphorus content (phosphorus oxide) is very low
Potassium (potassium oxide – K ₂ O)	mg/kg	220	120–220	Potassium content (potassium oxide) is high
Sodium (Na)	mg/kg	705	0–60	Sodium content is very low
Calcium (Ca)	mg/kg	19745	800–1200	Calcium content is very high
Iron (Fe)	mg/kg	8.6	11–16	Iron content is average or high
Copper (Cu)	mg/kg	0.4	0.9–1.2	Copper content is satisfactory
Zinc (Zn)	mg/kg	0.4	1.1–3.0	Zinc content is low
Chlorine (Cl)	mg/kg	70	20–150	Chlorine content is within normal limits
Iron (Fe)	mg/kg	8.6	11–16	Iron content is within normal limits
Boron (B)	mg/kg	1.2	0.8–2.0	Boron content is within normal limits
Manganese (Mn)	mg/kg	15	4–8	Manganese content is high
Molybdenum (Mo)	mg/kg	<0.1	0.1–0.3	Molybdenum content is not detected in the soil
SAR	%	1.4	<13	Normal
ESP	%	2.9	<15	Normal
CEC	%	106	–	Normal

However, according to the metal saturation table, sodium content was 2.9%, which is within the norm (1–4%). The highest values were obtained for calcium (CA) content at 19.745 mg/kg, which is significantly higher than the norm (800–1200 mg/kg). According to the metal saturation table, calcium content was 93.6%, which is also high.

Table 1 shows that trace element levels such as chlorine, iron, boron, copper, and zinc are within the norm.

Sulfur oxide (SO₄) content was 214 mg/kg, while the norm is considered to be 20–40 mg/kg. The exchangeable potassium (K₂O) content was 264 mg/kg, compared to the recommended value of 150–300 mg/kg.

Molybdenum (Mo), a heavy metal, was not detected in the studied soils.

The sodium adsorption ratio (SAR) (<13) was 1.4%, the percentage of replaceable sodium (ECP) (<15) was 2.9%, and the soil electrical conductivity (EC) (<4) was 0.46 mS/cm, which is within the normal range and does not interfere with fertilizer absorption.

The soil conditions at a depth of 0–30 cm in the studied area were determined to be slightly alkaline, with a pH of 8.03–8.38. Soil electrical conductivity (EC) ranged from 41.2–178.2 MS/cm, leading the soils to be classified as slightly saline. Calcium carbonate (CaCO₃) content ranged from 0.4–13.75%, classifying the soils as moderately calcareous (moderately calcareous). Humus content was determined to be within the range of 1.16–2.67%, which is considered average.

A macronutrient analysis (Table 2) of the soil at a depth of 0–30 cm revealed that, relative to established standards, the nitrogen (N) content in the soil was average (0.1–0.19%), while potassium (K) content was high (536.7–2360.1 mg/kg). At the same time, very low sodium (Na) (9.71–177 mg/kg) and phosphorus (P₂O₅) (7.44–30.34 mg/kg) contents were noted.

The following micronutrient results were obtained: calcium (Ca) content was very high – 4412–19153 mg/kg, iron (Fe) content was moderate to high – 1.336–25.024 mg/kg, copper (Cu) content was satisfactory – 0.8–14.36 mg/kg, and zinc (Zn) content was low – 0.264–0.664 mg/kg.

3.2. Study of the biochemical composition of raw materials

Research has shown that the biochemical composition of grape varieties grown in different environmental conditions varies depending on the characteristics of the variety and the soil and climatic conditions (Table 3).

The dry matter content of grapes is one of the most important indicators. Thus, in grape varieties grown in the Gabala region, the dry matter content (Brix) varied within the range of 22.1–26.8, while in grape varieties grown in the Absheron region it ranged from 19.6–23.8. Table 3 shows that grape varieties grown in the Absheron region are characterized by low sugar content – from 19.6 Brix (Sémillon) to 23.8 Brix (Merlot). In grapes grown in the Gabala region, this indicator was significantly higher and varied within the range of 22.1 Brix (Madrassa) – 26.8 (Shiraz). It is known that to produce high-quality red wine, the

amount of soluble solids in grapes should be from 20.5% to 23.5%. The obtained results are consistent with studies conducted in Turkey [16].

The research examined the density of grape juice. It was found that grape varieties grown in the Gabala region have a juice density of 1.09122–1.11207 g/L, while those grown in the Absheron region have a higher juice density of 0.90010–1.90024 g/L.

One of the main quality indicators of grapes is total acidity. As can be seen from Table 3, grape varieties grown in the Gabala region have relatively high total acidity values – from 3.1 g/L for the Merlot variety to 7.8 g/L for the Sémillon variety. Grapes grown in the Absheron region have lower total acidity values – from 2.9 (Merlot) to 5.9 (Sémillon). This difference is explained by the relatively cool weather and frequent precipitation associated with the mountainous climate of the Gabala region.

It is believed that to produce high-quality red wine, total acidity should be between 6.50 and 7.50 mg/L [17].

Grape juice contains a high amount of tartaric acid. The research revealed that the juice of the same grape varieties, but grown in different soil and climate conditions, contains varying amounts of tartaric acid. Varieties grown in the Gabala region are characterized by higher tartaric acid content: from 5.0 g/L (Shiraz) to 8.6 g/L (Sémillon). Varieties grown in the Absheron region have relatively low tartaric acid levels in their berries: from 3.4 g/L (Merlot) to 6.2 g/L (Sémillon). The highest tartaric acid content was observed in the Sémillon grape variety (in both the Absheron and Gabala districts).

Table 3 shows that there is no significant difference in malic acid content between the studied varieties. Grape varieties grown in the Gabala district have malic acid content ranging from 0.3 to 3.2 g/L, while varieties grown in the Absheron district have malic acid content ranging from 0.2 to 1.2 g/L. The highest amount of malic acid (3.2 g/L) is found in the juice of the Viognier grape variety.

The active acidity (pH) of grape juice ranges from 3.11 to 3.98; there is no significant difference in this parameter depending on the growing location.

Total extractability is one of the characteristics that characterizes the quality of grape juice. Among the studied varieties, this parameter fluctuates widely: from 246.8 to 2943.0 g/L for Gabala varieties and from 286.2 to 3342.0 g/L for Absheron varieties. Among the varieties grown in the Gabala region, Aleatiko (2943.0 g/L) and Shiraz (2763.0 g/L) have the highest extractability, while Riesling has the lowest (246.8 g/L). Among the varieties grown in the Absheron region, the Aleatiko variety had the highest extractivity (2242.0 g/L), while the lowest values were found in the Sémillon (204.6 g/L) and Bayan Shirey (201.1 g/L) varieties. Thus, the highest extractivity values were observed in the Aleatiko (2943.0 g/L – Gabala, 2242.0 g/L – Absheron) and Shiraz (2763.0 g/L – Gabala, 2068.0 g/L – Absheron) varieties.

Table 2

Physicochemical soil parameters of the studied area of the Savalan Valley in the Gabala District (based on a soil cut at a depth of 0–30 cm)

Parameters	Research methods	Unit of measurement	Study results	Normal Values	Conclusions
pH (1:2.5)	GOST 26423–85	–	8.03–8.38	6.5–7.5	Soil environment is slightly alkaline
Soluble salt content (SSC)	GOST 26423–85	μs/cm	41.2–178.2	0–4000	Slightly saline
Calcium carbonate (CaCO ₃) (lime)	Scheibler method	%	0.4–13.75	5–15	Soil is moderately calcareous (moderately calcareous)
Humus	Walkley-Black method	%	1.16–2.67	3–4	Humus content is average
Nitrogen	GOST 26107-84	%	0.1–0.19	0.09–0.17	Nitrogen content is average
Phosphorus (phosphorus oxide – P ₂ O ₅)	Olsen method	mg/kg	7.44–30.34	60–90	Phosphorus (phosphorus oxide) content is very low
Potassium (potassium oxide – K ₂ O)	GOST 26210-91	mg/kg	536.7–2360.1	250–500	Potassium (potassium oxide) content is high
Sodium (Na)	GOST 26210-91	mg/kg	9.71–177	80–120	Sodium content is very low
Calcium (Ca)	GOST 26210-91	mg/kg	4412–19153	1431–2860	Calcium content is very high
Iron (Fe)	GOST 26210-91	mg/kg	1.336–25.024	2.51–4.5	Iron content is moderate to high
Copper (Cu)	GOST 26210-92	mg/kg	0.8–14.36	>0.2	Copper content is satisfactory
Zinc (Zn)	GOST 26210-93	mg/kg	0.264–0.664	0.71–2.4	Zinc content is low

Table 3

Biochemical parameters of grape must from varieties grown in different environmental conditions

Variety Name	Dry matter, Brix	Density, g/L	Total acidity, g/L	Tartaric acid, g/L	Malic acid, g/L	pH	Extractivity, g/L	Glycolic acid, g/L	Glucose/ Fructose, g/L	Polyphenols, mg/kg	Anthocyanins, mg/kg
Grape varieties grown in the Gabala region											
White Muscat	23.8	1.09918	5.5	7.7	0.5	3.39	266.5	0.08	239.9	1266.4	2.4
Riesling	22.1	1.09122	5.1	7.2	0.5	3.60	246.8	0.20	219.2	3256.0	–
Chardonnay	23.2	1.09789	4.8	6.9	1.5	3.66	261.3	0.10	239.2	993.0	386.4
Sémillon	24.0	1.09878	7.8	8.6	1.8	3.98	278.4	0.42	241.4	1337.6	52.8
Aleatico	26.2	1.11044	5.3	7.2	1.0	3.58	2943.0	0.20	292.9	3066.2	1861.8
Shiraz	26.8	1.11172	4.6	5.0	1.6	3.64	2763.0	0.42	270.6	3304.7	1618.2
Merlot	26.3	1.11207	3.1	6.4	0.3	3.72	297.1	0.11	265.7	2894.6	986.7
Viognier	22.9	1.09634	6.2	6.2	3.2	3.53	256.0	0.20	230.0	1256.7	1.7
Madrasa	22.4	1.09917	5.1	5.3	0.5	3.54	247.5	0.19	238.4	3247.1	1718.0
Bayan Shirey	23.2	1.11201	4.8	6.1	0.8	3.61	251.4	0.27	262.5	1326.4	844.7
Rkatsiteli	22.2	1.09874	4.3	5.0	1.2	3.41	273.5	0.13	283.0	1017.3	52.1
Grape varieties grown in the Absheron region											
White Muscat	22.6	1.09982	4.6	3.6	0.2	3.21	216.2	0.05	205.6	1168.2	1.8
Riesling	21.8	1.90024	4.4	5.3	0.3	3.32	206.2	0.18	209.2	3151.0	1.7
Chardonnay	22.6	0.91245	3.8	4.7	1.1	3.14	216.4	0.7	219.8	883.0	209.4
Sémillon	19.6	0.90003	5.9	6.2	1.2	3.68	204.6	0.32	198.0	1237.7	45.6
Aleatico	23.4	0.95478	3.8	4.7	0.6	3.28	2242.0	0.12	212.2	2969.2	1763.0
Shiraz	23.0	0.91245	3.2	4.2	0.8	3.24	2068.0	0.38	197.6	2704.6	1518.5
Merlot	23.8	0.91852	2.9	3.4	0.2	3.12	207.6	0.9	200.4	2764.6	973.0
Viognier	21.8	0.91141	4.3	4.4	2.9	3.11	208.3	0.14	207.4	1180.1	1.1
Madrasa	21.1	0.90441	4.7	4.9	0.7	3.20	217.2	0.12	216.4	3115.3	1650.3
Bayan Shirey	22.5	0.90312	4.0	5.3	0.3	3.20	201.1	0.17	194.2	1218.4	699.8
Rkatsiteli	21.6	0.90010	3.9	4.7	0.4	3.14	212.0	0.6	215.6	985.0	42.7

The amount of gluconic acid was also determined in the juice of the studied grape varieties. Analyzing the obtained results, it is possible to conclude that for grape varieties grown in both conditions, this indicator, varying between 0.05–0.42 g/L, changes only slightly. Carbohydrates (glucose and fructose) are among the main chemical components of grape juice. The research examined the glucose/fructose content of the grape juice of the studied varieties. It was found that the glucose/fructose content of grape varieties grown in the Gabala and Absheron regions ranged from 219.0 to 292.9 g/L and 194.2 to 219.6 g/L, respectively.

These results correlate with data from previously published studies conducted in Turkey, confirming the identified patterns [24].

The research results demonstrate comparability with data published by Turkish authors [25, 26].

Phenolic compounds are organic substances that are naturally formed and can exert an antioxidant effect due to their ability to readily oxidize. Phenolic compounds are a group of substances that occupy the third place in grape juice after sugars and organic acids. Numerous studies have shown that grape varieties rich in phenolic compounds are more suitable for long-term storage.

The research examined the total polyphenol content of the grape varieties studied. It was found that polyphenol levels in grapes grown in the Gabala region ranged from 993.0 mg/kg (Chardonnay) to 3304.7 mg/kg (Shiraz). For varieties grown in the Absheron region, total polyphenol content in grapes ranged from 985.0 mg/kg (Rkatsiteli) to 3151.0 mg/kg (Riesling).

The content of total phenolic compounds, tannins, and anthocyanins in the grape juice was determined using various agronomic practices applied to Cabernet Sauvignon vines. It was found that the highest content of total phenolic compounds was 3762.73 mg/GAE kg, and the lowest was 2843.03 mg/GAE kg. The total content of tannins varied in the range of 3.53–4.93 g/kg, and the content of anthocyanins

varied in the range of 1330.10–2073.88 mg/kg from the lowest to the highest value [27].

Phenolic compounds are one of the most important criteria for wine quality. They impart a unique, distinctive flavor to wine [28]. The effects of phenolic compounds are primarily manifested in the aroma and color of wine. Phenolic compounds present in wine originate from the grapes [29]. The composition of phenolic compounds in wines typically varies depending on their geographical origin. This indicates that the phenolic content of grapes and wine is highly dependent on terroir [30–32].

Anthocyanins are the main group of phenolic compounds. They are found in grape skins and are defined as natural pigments that impart red, blue, and purple colors to grapes. Anthocyanins begin to accumulate in the skins of grapes during ripening and reach their maximum levels at full maturity. Research has shown that anthocyanin content in grape varieties grown in the Gabala region ranges from 1.7 to 1861.8 mg/kg, while in varieties grown in the Absheron region; it ranges from 1.1 to 1763.0 mg/kg. Anthocyanins were not detected in the Riesling grape variety in the Gabala region alone. In both regions, the Aleatico variety has the highest anthocyanin content.

According to some researchers, the amount of soluble anthocyanins in the juice of industrial grape varieties varies between 500 and 2000 mg/L depending on the variety and the degree of ripeness of the berries [21].

Climatic conditions and soil structure in the area where a particular variety is grown significantly influence the content of anthocyanins and phenolic compounds in grape berries. It has been found that with increasing altitude, the amount of anthocyanins in grapes increases, but this difference is not reflected in the profile [33]. Research conducted in China showed that the red Merlot grape variety had a sugar content of 20.1 g/L, total acidity of 7.1 g/L, pH of 3.5, total phenolics of 52.900 mg/kg, tannins of 23.500 mg/kg, and anthocyanins of 27.500 mg/kg. The white Riesling grape variety had a sugar content

of 19.9 g/L, total acidity of 6.1 g/L, pH of 3.6 g/L, total phenolics of 11.600 mg/kg, and tannins of 14.000 mg/kg. No anthocyanins were detected [34]. Under Romanian conditions, the sugar content of Merlot, Riesling, and Chardonnay grape varieties ranges from 17.4–19.3%, total acidity from 4.8–5.4 g/L, pH from 3.2–3.4, and the 100-berry yield from 121.2–131.9 g [35].

3.3. Study of biochemical parameters of wine samples made from the studied grape varieties

During the research, the biochemical parameters of test samples of wines made from Muscat Blanc, Chardonnay, Semillon, Riesling, Merlot, Aleatico, and Shiraz grapes grown in the Absheron and Gabala regions were also determined. It was found that wines made from the same grape variety but grown in different regions differ in composition (Table 4).

One of the main components in wine, influencing its characteristic taste and aroma, is ethyl alcohol [36]. Ethyl alcohol is one of the indicators determining the taste qualities and type of wine. It was found that, since grape varieties were grown in different soil and climatic conditions, the wines made from them differ from each other in the percentage of alcohol. Thus, in wines made from grape varieties grown in the Gabala region, the alcohol content fluctuated between 12.8–15.2%. It was found that in wines made from Chardonnay and Riesling varieties, the volume percentage of ethyl alcohol is relatively low (12.8%), and in wines from the Aleatico variety, the ethyl alcohol content is the highest (15.2%). In wines made from varieties grown in the Absheron region,

the ethyl alcohol content varied in the range from 11.2% (Chardonnay) to 13.9% (Madrasa). Sugar influences the fullness of wine's flavor and its long-term shelf life. In wines made from grape varieties grown in the Gabala region, residual sugar levels ranged from 0.66 to 2.10 g/L. The highest levels were found in Muscat Blanc (2.10 g/L), Viognier (2.0 g/L), and Bayan Shirey (2.09 g/L). In wines made from grape varieties grown in the Absheron region, residual sugar levels ranged from 0.22 to 1.70 g/L, with no significant differences between samples.

During the research, the extractivity of the test wine samples was determined. Extractivity is one of the important factors affecting the fullness of a wine and represents the sum of non-volatile substances contained in the wine. It was found that the test wine samples varied significantly in extractivity. Thus, in wines made from grape varieties grown in the Gabala region, the extract values were set within the range of 20.5–34.5 g/L. The lowest value was noted in wine from the Viognier variety (20.5 g/L), the highest – in wines from the Shiraz (32.2 g/L) and Aleatico (34.5 g/L) varieties. For the remaining wines, the extract values were: 28.6 g/L (White Muscat and Merlot), 21.2 g/L (Chardonnay), 22.5 g/L (Semillon), 24.4 g/L (Riesling), 31.2 g/L (Madrasa), 26.3 g/L (Bayan Shirey), 22.9 g/L (Rkatsiteli). The extract levels of wines made from grape varieties grown in the Absheron region ranged from 19.1 to 33.6 g/L. The lowest extract level was recorded for Viognier (19.1 g/L), while the highest was for Aleatico (31.5 g/L). The remaining wines had extract levels of: 27.2 g/L (White Muscat), 20.2 g/L (Chardonnay), 21.5 g/L (Semillon), 23.2 g/L (Riesling), 31.5 g/L (Shiraz), 27.2 g/L (Merlot), 30.7 g/L (Madrasa), 25.0 g/L (Bayan Shirey), and 21.2 g/L (Rkatsiteli).

Table 4

Biochemical parameters of experimental wine samples prepared from grape varieties grown under different environmental conditions

Variety Name	Density, g/L	Alcohol content, %	Residual sugar, g/L	Extract, g/L	pH	Total acidity, g/L	Volatile acidity, g/L	Malic acid, g/L	Lactic acid, g/L	Tartaric acid, g/L	Citric acid, g/L	Glycerol, g/L	Methanol, mg/L	Potassium ions	Total polyphenols, mg/L	Anthocyanins, mg/L	Tannins, mg/L
Wines made from grape varieties grown in the Gabala region																	
White Muscat	0.9937	14.7	2.10	28.6	3.49	5.70	0.273	1.10	0.10	3.25	0.24	11.0	0.11	0.98	316	47	0.88
Chardonnay	0.9917	12.8	0.77	21.2	3.51	6.07	0.230	1.42	0.29	4.24	0.10	7.58	0.10	1.04	578	65	1.07
Semillon	0.9903	14.8	1.46	22.5	3.63	6.13	0.240	1.81	0.42	3.86	0.12	8.01	0.09	1.09	663	112	1.48
Riesling	0.9928	12.8	1.20	24.4	3.26	6.00	0.287	1.50	0.20	3.36	0.25	1.71	0.14	1.05	515	63	0.42
Merlot	0.9923	14.7	1.70	28.6	3.49	5.70	0.273	1.18	0.10	3.24	0.24	11.0	0.09	0.78	2928	765	2.74
Aleatico	1.0106	15.2	0.66	34.5	3.45	7.37	0.214	0.92	0.41	5.00	0.94	9.42	0.08	1.07	3108	724	3.72
Shiraz	0.9945	14.2	1.85	32.2	3.49	7.55	0.332	1.76	0.04	3.64	0.16	12.1	0.18	1.33	3091	619	3.56
Viognier	0.9919	14.3	2.00	20.5	3.32	6.50	0.161	2.12	0.10	3.36	0.33	7.40	0.17	1.22	338	68	0.56
Madrasa	0.9901	14.5	1.91	31.2	3.31	5.79	0.232	1.61	0.32	3.32	0.14	9.41	0.25	0.79	3017	721	2.73
Bayan Shirey	0.9916	13.0	2.09	26.3	3.25	5.56	0.301	1.18	0.24	3.27	0.19	7.39	0.08	1.29	325	78	0.41
Rkatsiteli	0.9921	14.6	1.73	22.9	3.49	6.01	0.243	1.76	0.28	4.12	0.14	7.41	0.13	1.02	531	97	0.91
Wines made from grape varieties grown in the Absheron region																	
White Muscat	0.9912	13.3	0.86	27.2	3.32	4.50	0.120	1.06	0.06	2.95	0.20	10.2	0.10	0.23	226	30	0.36
Chardonnay	0.9905	11.2	0.22	20.2	3.40	5.08	0.131	1.34	0.21	3.96	0.09	6.4	0.07	0.26	478	45	0.37
Semillon	0.9812	13.5	0.82	21.5	3.46	5.18	0.236	1.62	0.32	3.54	0.09	7.8	0.02	0.14	593	92	0.96
Riesling	0.9912	11.2	1.00	23.4	3.03	5.08	0.236	1.28	0.10	3.16	0.20	0.9	0.11	0.09	415	53	0.32
Merlot	0.9886	13.8	0.57	33.6	3.18	5.70	0.267	0.72	0.02	4.76	0.76	8.0	0.08	1.00	2826	668	2.71
Aleatico	0.9916	13.1	0.52	31.5	3.12	6.32	0.253	1.56	0.02	3.04	0.06	10.8	0.08	0.78	3006	522	2.94
Shiraz	0.9887	13.2	1.06	27.2	3.18	4.52	0.218	1.04	0.08	2.98	0.23	9.8	0.16	1.02	2992	664	2.53
Viognier	0.9919	13.4	1.70	19.1	3.06	5.00	0.143	1.69	0.05	2.84	0.10	6.4	0.10	0.10	228	44	0.29
Madrasa	0.9864	13.9	1.66	30.7	3.20	4.42	0.207	1.20	0.21	2.15	0.11	7.5	0.09	0.13	2904	694	1.94
Bayan Shirey	0.9904	12.5	1.81	25.0	3.12	4.42	0.256	1.00	0.19	2.73	0.11	5.6	0.05	0.09	209	67	0.12
Rkatsiteli	0.9957	13.7	0.73	21.2	3.04	5.09	0.270	0.81	0.18	3.01	0.11	5.0	0.09	1017	441	57	0.17

Active acidity (pH) determines the concentration of hydrogen and hydroxyl ions in wine. Typically, wine's active acidity ranges from 2 to 5 pH. Our research revealed that the pH of our wine samples varied between 3.03 and 3.63, with no significant differences between the samples.

These findings are consistent with research conducted in Turkey [24].

Acidity, an important quality criterion, influences the taste, stability, and color of wine. Analysis revealed that the total acidity content of wines made from grape varieties grown in the Gabala region ranged from 5.70 to 7.55 g/L. The highest levels were observed in Aleatico (7.37 g/L) and Shiraz (7.55 g/L), with similar values for the other wines.

In wines made from grape varieties grown in the Absheron region, the total acidity content was determined to be between 4.42 and 6.32 g/L, with the highest value for Shiraz (6.32 g/L). Overall, it was found that wines made from grape varieties grown in the Gabala region have superior total acidity levels to those made from varieties grown in the Absheron region. Thus, the total acidity in wines from grape varieties in the Gabala region ranged from 5.56 g/L (Bayan Shirey) to 7.55 g/L (Shiraz). In wines from varieties in the Absheron region, the total acidity ranged from 4.42 g/L (Madrassa, Bayan Shirey) to 6.32 g/L (Shiraz).

Volatile acids are formed during alcoholic fermentation. A significant portion of this acid is acetic acid. The amount of volatile acids formed depends on the wine's composition (acid-to-sugar ratio, amount of nitrogenous compounds), yeast strain, and fermentation conditions [37].

The patterns established in the research correspond to data obtained in studies conducted in Turkey [24, 38].

Acetic acid accounts for 90% of the volatile acids contained in wine. Therefore, the amount of volatile acids in wines is determined by acetic acid. It is found that the volatile acid content of wines made from the same grape varieties but grown under different conditions ranged from 0.120 to 0.332 g/L.

Organic acids play a key role in wine formation and maturation. The amounts of malic, lactic, citric, tartaric, and glycerolic acids were determined in the test wine samples. The results showed that malic, lactic, and citric acids were present in approximately equal amounts in wines made from grapes grown in the Gabala and Absheron regions: 0.69 to 2.12 g/L, 0.02 to 0.42 g/L, and 0.06 to 0.94 g/L. Some differences were noted in tartaric acid content. In wines made from grapes grown in the Gabala region, tartaric acid content was recorded in the range of 3.25 to 5.0 g/L. The highest level was observed in Aleatico wine (5.0 g/L), with only minor differences among the other wines. In wines from Absheron region grapes, tartaric acid levels ranged from 2.15 to 4.76 g/L, with slight differences between samples. Significant differences were noted in glycerolic acid levels among the wine samples. For example, in wines from Gabala region grapes, glycerolic acid levels ranged from 1.71 to 12.1 g/L, while in wines from Absheron region grapes, they ranged from 0.9 to 10.8 g/L.

Methanol levels were also analyzed in the prepared wine samples. Methanol levels were found to range from 0.08 to 0.25 g/L. As is well known, the acids found in wine are primarily in free form, and sometimes in the form of acidic and normal salts associated with potassium, calcium, and magnesium. The amount of potassium ions in wine was determined during this research. It was found that in experimental wine samples prepared from grape varieties grown in the Gabala and Absheron regions, the potassium ion content, varying within the range of 0.78–1.26, was approximately at the same level. These results are consistent with research conducted in Turkey [27].

Based on the organoleptic evaluation, the wine was found to have a dark red color, a tart flavor due to its high tannin content, a medium body, and a rich aroma of red fruits with notes of oak and spice [27].

It is revealed that the total phenol content in Cabernet Sauvignon grapes ranged from 1423.71 mg/GAE/kg to 1963.60 mg/GAE/kg.

The results of this research are consistent with the findings of Turkish scientists [39] and Chinese scientists [14].

The results of this research are consistent with the findings of Ukrainian and Indian scientists [40, 41].

The analysis showed that the total polyphenol content in wine samples obtained from grape varieties grown in the Gabala region varied over a fairly wide range (316–3108 mg/L). The highest level of phenolic compounds was observed in Madrasa wine (3017 mg/L), while the lowest was found in Muscat White wine (316 mg/L). Wines produced from grape varieties grown in the Absheron region also showed significant differences in total polyphenol content (from 209 to 3006 mg/L). The highest polyphenol content was recorded in Shiraz wine (3006 mg/L), while the lowest was found in Bayan Shirey wine (209 mg/L). Thus, it was established that, despite the different soil and climatic conditions of the grape varieties grown there, the total polyphenol content in the wines produced from them was approximately the same.

Anthocyanins are the main group of phenolic compounds. During fermentation, anthocyanins are transferred from grapes to wine. In the initial sample of Cahors "Shemakha", prepared from the Madrasa grape variety, the total amount of phenolic compounds was 520 mg/dm³, the amount of anthocyanins was 83 mg/dm³, and after treatment with polyvinylpyrrolidone (PVP), these values decreased by 14.4% and 20.5%, respectively [42]. These results are confirmed by research data conducted in Turkey [24].

It was found that in wines prepared from grape varieties grown in the Gabala region, the amount of anthocyanins varies within the range of 47–765 mg/L. The lowest value was found in wine made from the Muscat white variety (47 mg/L), and the highest values were found in wines from the Merlot (765 mg/L), Aleatico (724 mg/L), and Shiraz (619 mg/L) varieties. No noticeable differences in anthocyanin content were observed in other wines. It was found that anthocyanin content in wines made from grape varieties grown in the Absheron region also varied widely (30–694 mg/L). The highest levels were observed in wines made from Madrasa (694 mg/L), Aleatico (668 mg/L), Shiraz (522 mg/L), and Merlot (664 mg/L), while the lowest was found in Muscat Blanc (30 mg/L).

The research also determined the quantitative tannin content in the test wine samples. It was found that in wines made from grape varieties grown in the Gabala region, tannin content ranged from 0.42 (Riesling) to 3.72 (Aleatico) mg/L. In wines from the varieties of the Absheron region, the amount of tannins fluctuated in the range of 0.32 (Riesling) – 2.94 (Shiraz) mg/L.

The research results demonstrate that the growing conditions in both regions allow the grapes of the studied varieties to be used to produce high-quality wines. The results obtained during the research may be of significant scientific and practical interest, as their implementation in production will allow producers to more accurately select grapes for the production of specific types of wine. The results may also be useful for winemakers in other regions with similar soil and climate conditions and a range of regionalized varieties. In the future, it will be interesting to conduct similar experiments on local grape varieties to assess the potential for their large-scale introduction in other wine-growing regions of the country.

3.4. Limitations and future directions for research

The research was conducted within a limited geographic region and on a limited number of grape varieties, limiting the generalizability of the results to other climatic zones. Furthermore, the observations covered only a short period of time, and the analysis involved a limited set of environmental factors and standard biochemical methods, which may reduce the completeness and accuracy of the data obtained. In the future, it will be advisable to expand the geographic and varietal coverage, conduct long-term observations, and consider additional soil,

agronomic, and environmental parameters. The use of more modern analytical technologies, such as chromatograph mass spectrometry, will enable a more in-depth research of the composition of grape must and wine. Another promising area is the development of models for predicting wine quality based on environmental conditions, which will help adapt winemaking technologies to a changing climate.

4. Conclusions

1. The research results showed that the soil and climatic conditions of the Absheron and Gabala regions allow for the production of high-quality grapes from the studied varieties. The presence of sufficient humus in the upper soil horizon ensures the nutrition of the grape plant's root system and is an important step in agrochemical research. A humus content of 1.0% in the soil profile is considered the standard. A soil pH of 5.5–6.5 is considered optimal for the normal growth and development of grape plants. However, in the studied area of the Absheron district, the soil pH was neutral, with a pH of 7.6. The soil's electrical conductivity was 0.46 mS/cm, which is within acceptable limits (0–4 mS/cm) and does not limit the absorption of mineral nutrients. Analysis revealed that, regardless of sampling location and depth, the average calcium carbonate (CaCO₃) content was 7.3%, with a standard value of 10%. Accordingly, the studied soils are classified as medium-carbonate (medium-calcareous). Analysis of macronutrient content revealed that, unlike phosphorus, the amounts of nitrogen, potassium, magnesium, sodium, and calcium in the soil significantly exceeded standard values. According to the cation saturation table, the proportion of calcium and magnesium was higher than that of potassium. The content of micronutrients, including chlorine, iron, boron, copper, and zinc, was within standard limits. The soil environment at a depth of 0–30 cm in the studied area was characterized as slightly alkaline, with a pH in the range of 8.03–8.38. Soil electrical conductivity (EC) was 41.2–178.2 mS/cm, based on which the studied soils were classified as slightly saline. A study of the macronutrient content in soils of the studied area of the Savalan Valley, Gabala District, in the 0–30 cm layer showed that, compared to the established standard values, the nitrogen content is characterized as average (0.1–0.19%), while the potassium supply is high and amounts to 536.7–2360.1 mg/kg. At the same time, very low sodium content was noted – 9.71–177 mg/kg and phosphorus (P₂O₅) – 7.44–30.34 mg/kg. The following results were obtained for microelements: calcium content is very high, iron content is average and high, copper content is satisfactory – 0.8–14.36 mg/kg and zinc content is low – 0.264–0.664 mg/kg.

2. The results of the research of biochemical parameters of grape varieties showed that the dry matter content was higher in grape varieties grown in the Gabala region (22.1–26.8), while in grape varieties grown in the Absheron region it varied within the range of 19.6–23.8. Grape varieties grown in the Absheron region are characterized by low sugar content, while this indicator is significantly higher in grapes grown in the Gabala region. According to the density of grape juice, the juice density of grape varieties grown in the Gabala region was 1.09122–1.11207 g/L, while that of grape varieties grown in the Absheron region was higher and amounted to 0.90010–1.90024 g/L. It is known that for the production of high-quality wine, the total acidity must correspond to the condition of the product. Analysis revealed that grape varieties grown in the Gabala region have relatively high total acidity levels, ranging from 3.1 g/L for Merlot to 7.8 g/L for Semillon. Grapes grown in the Absheron region have lower total acidity levels, ranging from 2.9 (Merlot) to 5.9 (Semillon). Active acidity levels in grape juice ranged from 3.11 to 3.98, with no significant differences observed between cultivation sites. Total extract content is a key indicator of grape juice quality. This level varied widely across the studied varieties, ranging from 246.8 to 2943.0 g/L for Gabala varieties and from 286.2 to 3342.0 g/L for Absheron varieties. The polyphenol research

revealed that the polyphenol content in grapes grown in the Gabala region ranged from 993.0 mg/kg for Chardonnay and 3304.7 mg/kg for Shiraz. For varieties grown in the Absheron region, the total polyphenol content in grape juice ranged from 985.0 mg/kg for Rkatsiteli and 3151.0 mg/kg for Riesling.

3. Analysis of wines made from grape varieties grown in both regions showed that their biochemical parameters fully meet the technological requirements for specific wine types. The research of the grape composition, influenced by environmental conditions, allows to draw a preliminary conclusion about the feasibility of producing dry table wines and champagne base wines from the studied grape varieties in the Gabala region. In the conditions of the Absheron Peninsula, considered a classic table viticulture zone, it is possible to produce dry, fortified, and dessert wines from the harvest of the technical grape varieties studied.

Conflict of interest

The authors declare no conflicts of interest with respect to this research, whether financial, personal, authorial, or otherwise, that could influence this research and the results presented in this article.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in the creation of this work.

Authors' contributions

Vusala Shukurova: Data curation, Formal analysis, Writing – original draft; **Movlud Huseynov:** Methodology, Data curation, Formal analysis; **Vugar Salimov:** Conceptualization, Methodology, Writing – review and editing; **Afet Gasimova:** Formal analysis, Writing – original draft, Writing – review and editing, Visualization.

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