



QUALITY CHARACTERISTICS OF TECHNICAL GRAPE (*VITIS VINIFERA* L.) CULTIVARS GROWN UNDER ENVIRONMENTAL CONDITIONS OF THE MOUNTAINS AND SEA

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SUMMARY

A vineyard with diverse climatic conditions along the seaside affects the growth and development of the vines and grapes (*Vitis vinifera* L.). Therefore, knowledge about these factors is crucial for determining how viticultural practices need to be adapted to improve the grape yield and quality. The submitted study aimed to evaluate the effect of the terroir between the mountains and sea on the berry composition, grape ripening, and produced wines' characteristics. In the vineyard located in Aghbash Village, within the Samur-Devechi lowland at the foothills of the Greater Caucasus Mountains and on the coast of Caspian Sea, several grape cultivars incurred assessment during 2023. The Saperavi, Merlot, Madrasa, Muscat, Chardonnay, Cabernet Sauvignon, and Khindogni grape cultivars bore scrutiny for titratable acidity, pH, and sugar concentration. Correspondingly, wines produced from these grape cultivars also underwent analysis for ethyl alcohol content, residual sugar, titratable acidity, volatile acidity, extract content, and total and free sulfur dioxide concentrations as per standard procedures. The grape cultivars Muscat and Cabernet Sauvignon had lower sugar concentrations (21.2 g/100 cm³), and cultivars Muscat and Cabernet Sauvignon emerged with lower titratable acidity (5.0 g/L) and higher titratable acidity (6.4 g/L), respectively. However, cultivar Madrasa exhibited a higher sugar concentration.

Keywords: Grape (*V. vinifera* L.), Caspian Sea, Greater Caucasus Mountains, terroir, climate, technical grape cultivars, grape ripening, wine, physicochemical properties

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Key findings: A vineyard comprising different grape (*V. vinifera* L.) cultivars with diverse climatic conditions along the seaside affects the growth and development and shows varied values for grape composition and maturity and the produced wines.

INTRODUCTION

The geographical location of a vineyard, such as its altitude above sea level, proximity to water bodies (sea, lake, and river), and soil mineral composition, are the key factors determining the quality of wine produced by the grapes (*Vitis vinifera* L.) (Vaudour, 2003). The sea warms up and cools down slowly, developing cool summers and mild winters in coastal climates. In areas influenced by seas, lakes, and rivers, the nighttime cooling lowers due to decreased radiative heat loss. In viticulture and winemaking, terroir is a crucial term encompassing geographical location, climate, soil, and viticultural practices. By the combination of sun, mountains, and the cooling breeze from the sea, the vineyards gain benefits often located on the eastern-facing slopes of the Greater Caucasus Mountains. Moreover, proximity to the sea has contributed to the diversity of grape cultivars. Constant gentle breezes improve air circulation, preventing fungal diseases, and are therefore, highly desirable (Salimov *et al.*, 2022).

Microclimatic differences related to soil structure and geographical orientation within the same vineyard develop favorable conditions for cultivating different grape cultivars for producing high-quality wines. The coastal location of vineyards allows them to benefit from the sea's moderating influence and the steady sea breezes, positively affecting viticulture. The sea's influence typically extends up to 6–8 km inland (Jackson, 2000). One of the most important features of District Shabran is that most of its vineyards are benefiting from the moderating effects of the Caspian Sea and its breezes.

In addition to grapes' remarkable role in human nutrition, their phenolics also exhibited various biological activities beneficial to human health (Xia *et al.*, 2010). The specific environmental factors of the terroir affect the grape composition and allow the characterization of vineyards by unique profiles

of metabolites (Anesi *et al.*, 2015). Sunlight is crucial for photosynthesis in vines and berries, influencing the grape yield and quality by altering the concentration of soluble solids and other vital components (Spayd *et al.*, 2002).

Past research concluded altitude influences climatic factors and eventually affects the vine physiology and berry biochemistry, thereby altering the grape's chemical composition (Teixeira *et al.*, 2013; De-Oliveira *et al.*, 2019; Mansour *et al.*, 2022). Several terroir factors influence vine vigor, grape yield, cluster morphology, and their chemical composition (Bramley *et al.*, 2011), as well as procyanidin concentration in seeds (Edo-Roca *et al.*, 2014b) and anthocyanin levels in skins (Edo-Roca *et al.*, 2014a). However, in orographic vineyards (hilly and mountainous terrains), it is possible to homogenize the climate parameters for vines and berries. In the Shabran District, diverse foothill and coastal conditions existed for technical grape production. Thus, understanding knowledge about climate variability in the terroir between the mountains and sea influencing grape growth and development and adjusting viticultural practices is essential.

Vineyards, through their production landscapes, serve as part of the natural rural tourism resources and considerably contribute to the ecological, social, and economic sustainability of the area. District Shabran has become an important destination for tourists, mainly from Baku and the surrounding areas, who seek recreation, escape from daily routines, and exploration of new places. Specifically, visitors desired tasting local products, enjoying mountain-sea-vineyard landscapes, visiting wineries, participating in grape harvests, witnessing local production processes, and tasting regional products.

From the above discussion, the presented study is a first-time evaluation of the terroir environmental conditions' effects. It focused on the ripening and physicochemical

characteristics of wines produced by Saperavi, Merlot, Madrasa, Muscat, Chardonnay, Cabernet Sauvignon, and Khindogni cultivars in Aghbash Village, District Shabran, Azerbaijan.

MATERIALS AND METHODS

Description of the experimental vineyard

The research began in 2023 on different grape (*V. vinifera* L.) cultivars in a vineyard located on the southeastern slopes of the Greater Caucasus Mountains, within the Samur-Devechi lowland. The vineyard is approximately 8 km from the Caspian Sea in Aghbash Village, District Shabran, Azerbaijan. The vineyard's elevation ranges between -27 meters and 200 meters above sea level or masl (41°08' N and 49°08' E). For this study, the selected technical grape cultivars were Saperavi, Merlot, Madrasa, Muscat, Chardonnay, Cabernet Sauvignon, and Khindogni—grafted onto SO4 rootstock. All the cultivar vines were 14 years old, having been planted within the same vineyard and divided into four sectors. The vineyard covers an area of 132.0 hectares and belonged to the Merit Brand LLC, located in the Big Hamya Village, District Siyazan. The selected grape cultivars are currently the most important recognized autochthonous and introduced cultivars for the regional wine industry. The vines succeeded in their planting in a 2.80 m × 1.25 m spacing, with a North-South orientation, and parallel to the coastline. The use of the 'bilateral Guyot training system' consisted of a shoot load of 6–8 buds per cane, resulting in a vineyard yield of 6–8 tons per hectare. The vineyard boast of a trellis system and drip irrigation equipment.

Two rivers, Gilgilchay (originating at an elevation of 1980 meters on Mount Gulumdostu) and Atachay (originating at 1870 meters on Mount Dubrar), flow nearby and are part of the Caspian Sea basin. The soils were predominantly slightly saline gray-brown. The soil analysis results are available in Tables 1 and 2, while irrigation water analysis appears in Table 3. Depending on the vine's yield

management, the leaf area approximately ranged between 1.87 and 3.14 m² per vine.

Climate conditions

The monthly climate data for 2023 occur in Table 4. The data comprising average monthly air temperature (°C), precipitation amount (mm), and sunshine duration (hours) came from the nearby Quba Meteorological Station, National Hydrometeorological Service, Ministry of Ecology and Natural Resources, Azerbaijan (AzStat, 2025).

The area climate classification consist of mild, warm, and dry subtropical. In January 2023, an intense snowfall occurred, forming a thick snow cover, which ensured the higher level of water availability for local vegetation and water resources. Although the recorded temperature peaks were in the early spring, the temperature and precipitation patterns continued as usual during the rest of the spring. The summer was dry, and the vegetative cycle proceeded normally according to its typical rhythm.

Experimental sampling

For the prevention of temperature influence and preservation of characteristics' quality, the grape samples' collection ensued on a clear day, with no recent rainfall and heavy fog, between 05:00 and 11:00 in the morning. The samples preceded their placement in airtight, resealable (Ziploc-type) transparent plastic bags measuring 30 cm × 15 cm. The sample bags attained labeling with corresponding identification names before being transported from the vineyard to the laboratory in a portable refrigerator with ice for analysis. Sampling continued for three days before harvest according to the specified methodology. The study's design had five replications based on 'the study of enochemical and enocarpological characteristics of the grapes' (Salimov, 2019). Each replicate used 15 clusters. Taking 15 berries from the mid-third of each cluster totaled 225 berries per replicate.

Table 1. Soil composition analysis of the experimental vineyard.

Depth (cm)	PH	EC (mS/Cm)	Humus (%)	CaCO ₃ (%)	Ppm															CE (meq/100 g)	
					N	P	K	Ca	Mg	Na	Cl	SO ₄	Fe	B	Cu	Zn	Mn	Mo	S		P
0-30	7.8	0.35	1.5	26	34	<0.4	535	9088	944	628	38	137	45	4.1	8.8	1.2	105	<0.1	1.7	4.8	57
30-60	7.9	0.58	1.3	23	33	<0.4	494	10255	993	923	81	271	45	5.2	8.0	0.6	94	<0.1	2.3	6.2	65
60-90	8.0	0.63	1.3	18	24	<0.4	530	9430	1020	1028	60	371	55	4.9	7.8	0.5	111	<0.1	2.7	7.3	61

Table 2. Saturation of the soil used in the experimental vineyard.

Depth (cm)	Saturation (meq/100 g)					Saturation (%)				Total (%)	Oxide content (ppm)			
	Ca	Mg	K	Na	CEC	Ca	Mg	K	Na		K ₂ O	CaO	MgO	Na
0-30	45.4	7.9	1.4	2.7	57	79.2	13.7	2.4	4.8	100	642	12723	1567	628
30-60	51.3	8.3	1.3	4.0	65	79.1	12.8	2.0	6.2	100	592	14357	1649	923
60-90	47.2	8.5	1.4	4.5	61	76.7	13.8	2.2	7.3	100	636	13202	1693	1028

Table 3. Irrigation water analysis of the experimental vineyard.

pH	mS/Cm					mg/L												
	EC	NaNO ₃	N-NH ₄	P-PO ₄	K	Ca	Mg	Na	S-SO ₄	Cl	HCO ₃	Si	Fe	B	Cu	Zn	Mn	Mo
7.2	0.42	1.2	0	0	1.0	4.1	1.3	20	33	3.4	122		0.04	0	0	0	0	0
7.2	0.42	0.1	0	0	0.3	1.0	0.5	0.9	1.0	0.1	2.0	0	0.8	0	0	0	0	0

Juice extraction

In preventing the crushing of seeds during the juice extraction process, researchers used a mortar and strainer to crush the berries. The collection of juice for each sample proceeded in 250 mL container before filtering using sieves and gauze to separate the solid particles. The juice obtained by crushing these berries underwent analysis for sugar concentration, titratable acidity (TA), and pH to monitor ripening.

Wine production

During the stage of technological ripeness, the grape harvest collected was at the density of 1.090–1.100 g/mL, which succeeded in transporting to the processing facility using refrigerated transportation. The treatment of grapes into wine took place in fermentation tanks equipped with a cooling system.

Table 4. Monthly climate data during 2023.

Month	Average Monthly Temperature (°C)	Precipitation (mm)	Sunshine Duration (hours)
January	0.5	25.3	144.4
February	0.8	44.2	128.7
March	8.8	12.6	143.5
April	11.1	25.8	153.4
May	15.8	53.9	158.2
June	20.6	93.0	215.8
July	23.3	39.9	267.1
August	25.4	52.5	281.4
September	17.6	65.7	177.5
October	13.4	47.8	160.5
November	10.6	36.8	120.4
December	5.1	47.1	116.4

During the destemming and berry crushing process, sulfurization progressed using powdered potassium metabisulfite. Yeast (Laffort FX10) and yeast nutrient (Laffort Dynastart) addition initiated maceration and alcoholic fermentation. The use of 'pigeage' technique occurred during maceration. When the density was below 1000, it signaled maceration as complete, with the sugar analysis conducted. Subsequently, bacteria (Laffort 450 Preac) and bacterial nutrient (Laffort PrePreac) mixture began malolactic fermentation, maintaining the temperature at 22 °C (± 1 °C). The monitoring of the malolactic fermentation process comprised regularly checking the malic acid and volatile acidity levels. Once completing malolactic fermentation, the tanks' aeration, the wine racking, and sulfurization take place.

Analytical evaluation

The harvest time determination included analyzing parameters—acidity level, sugar content, and pH. Sugar content and acidity level measurements were according to the OIV guidelines (Aurand, 2017). Titratable acidity detection comprised titration at pH 7 and 20 °C with the expression in g/L as tartaric acid. The pH estimation used a pH meter, with total soluble sugars (°Bx) determined using a refractometer. In grape juice, determining sugar mass concentration was according to GOST 27198-87, titratable acidity mass concentration according to GOST 25550-82, and the pH level used a pH meter.

In wine samples, the volume percentage of ethyl alcohol succeeded in its determination according to GOST 32095-2013, while residual sugar was according to GOST 13192-73. Moreover, titratable acidity followed the method according to GOST 32114-2013, volatile acidity according to GOST 32001-2012, extract content according to GOST 32000-2012, and total and free sulfur dioxide content according to GOST 32115-2013.

Statistical analysis

Sugar concentration, titratable acidity, pH (for ripeness determination), and the physicochemical properties of the wine entailed evaluation using one-way analysis of variance (factorial ANOVA). The Tukey's b post-hoc test ($p < 0.05$) applied used IBM SPSS software version 27. The calculation of a Pearson correlation matrix also ensued for all the parameters at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The measurement of sugar concentration, titratable acidity, and pH values of grape (*V. vinifera* L.) cultivars and the physicochemical characteristics of the corresponding wine samples succeeded (Tables 5 and 6). The grape cultivar Saperavi gave a sugar concentration of 21.5 g/100 cm³, titratable acidity of 6.2 g/L, and pH of 3.2. According to Salimov *et al.* (2022), the grape cultivar Saperavi recorded with sugar content of 18.2

Table 5. Classification of grape cultivars with the must's juice density, sugar mass concentration, titratable acidity (TA), and pH levels.

Parameter	Saperavi	Merlot	Madrasa	Muscat	Chardonnay	Cabernet Sauvignon	Khindogni
Density (g/mL)	1.091	1.098	1.100	1.090	1.097	1.090	1.094
Sugar concen. (g/100 cm ³)	21.5	23.4	23.9	21.2	23.1	21.2	22.2
Titratable acidity (g/L)	6.2	5.2	6.2	5.0	6.0	6.4	5.8
pH	3.20	3.23	3.18	3.25	3.20	3.17	3.20

Table 6. Physical-chemical properties of the wines obtained from different grape cultivars.

Indicator	Saperavi	Merlot	Madrasa	Muscat	Chardonnay	Cabernet Sauvignon	Khindogni	Norma
Ethyl alcohol volume (%)	12.9	14.0	14.4	12.7	13.8	12.5	13.0	8.5-15.0
Residual sugar (g/L)	3.5	3.5	3.0	2.8	3.1	2.9	3.3	< 4.0
Titratable acids mass concen. (g/L)	5.8	5.0	6.0	4.4	5.4	5.8	5.6	> 3.5
Volatile acids mass concen. (g/L)	0.53	0.60	0.49	0.25	0.41	0.42	0.52	< 1.0
Extract (g/L)	22.2	21.2	21.8	18.0	18.3	18.2	22.0	> 16.0
Total and free sulfur (mg/L)	118/20	120/22	97/23	133/22	92/18	100/22	120/20	< 200

to 22.6 g/100 cm³ and titratable acidity of 5.26 to 7.46 g/L. In the research conducted by Huseynov *et al.* (2019) under Absheron conditions, the pH in cultivar Saperavi occurred at 3.42. According to Habullayev and Alisoy (2021), in cultivar Saperavi, the sugar concentration ranged between 17.0 and 21.1 g/100 cm³, and titratable acidity ranged from 7.8 to 12.6 g/L. In the presented study, the values obtained in the cultivar Saperavi were close to the upper limit of previously reported sugar concentration, moderate in acidity, and slightly lower in pH.

For cultivar Merlot, the sugar concentration was 23.4 g/100 cm³, with titratable acidity (5.2g/L) and pH (3.23). Salimov *et al.* (2022) reported cultivar Merlot had sugar concentrations ranging from 19.2 to 22.6 g/100 cm³ and acidity between 5.2 and 7.2 g/L. According to Alakbarov (2017), the measured pH of the grape cultivar Merlot was 3.0. In this study, sugar content was higher,

acidity was at the lower threshold, and pH was relatively higher than previous findings.

The grape cultivar Madrasa had a sugar concentration of 23.9 g/100 cm³, with titratable acidity of 6.2 g/L and pH of 3.18. Habullayev and Alisoy (2021) declared the sugar levels between 23 and 28 g/100 cm³ and acidity around 7.5 g/L for the grape cultivar Madrasa. Huseynov *et al.* (2022) recorded a pH of 3.3 in the cultivar Madrasa under Shamakhi environmental conditions. Salimov *et al.* (2022) also emphasized soil and climatic conditions play a crucial role in determining the grape quality. The latest results were consistent with these past findings, indicating that grapes cultivated in the mountain-sea terroir exhibited more optimal compositional characteristics, suggesting that alongside technological processes, soil, and climate also play a vital role in shaping wine quality parameters. However, the Brix (°Bx, sugar content) in the grape cultivar Madrasa showed a significant deviation, which can be due to

increased sun exposure and reduced shading, resulting in higher photosynthetic activity.

For the grape cultivar Muscat, the sugar concentration was 21.2 g/100 cm³, with titratable acidity (5.0 g/L) and pH (3.25). According to Salimov *et al.* (2022), the grape cultivar Muscat grown in different regions of Azerbaijan had sugar levels ranging from 21 to 24 g/100 cm³ and acidity between 5.6 and 8.2 g/L. In the presented study, sugar levels were at the lower end, and acidity was also lower than previously reported values. Canbaş *et al.* (2001) recorded the cultivar Muscat with a pH of 3.5 grown in the Tarsus Region of Turkey. The submitted study represents the first scientific evaluation of the grape cultivar Muscat with a pH level in this region.

Greater elevation typically results in stronger sunlight, lower temperature and humidity, larger variation in day-night temperature, and extreme environmental conditions, which influence the chemical composition of grapes (Mansour *et al.*, 2022). For the grape cultivar Chardonnay, the sugar concentration was 23.1 g/100 cm³, with titratable acidity (6.0 g/L) and pH (3.20). In a study conducted by Huseynov and Aghayev (2024) in the Mountainous Shirvan Region of Azerbaijan, the Brix value of the cultivar Chardonnay appeared to be 20.5%, with a pH of 3.65 and acidity of 0.68%. In comparison, in this study, the sugar concentration was considerably higher, while titratable acidity and pH were slightly lower than previously reported values.

For the grape cultivar Cabernet Sauvignon, the sugar concentration was 21.2 g/100 cm³, while titratable acidity and pH values were 6.4 g/L and 3.17, respectively. According to the findings of Habullayev and Alisoy (2021), the sugar content in the cultivar Cabernet Sauvignon ranged from 21.2 to 23.0 g/100 cm³, and titratable acidity ranged from 7.0 to 13.8 g/L. Huseynov *et al.* (2019) in their study under Shamakhi conditions, disclosed a pH value of 3.86 for the grape cultivar Madrasa. In the current study, cultivar Cabernet Sauvignon had a sugar concentration consistent with previous findings, however, titratable acidity and pH values were lower.

Overall, and among all the cultivars, the highest sugar concentration resulted in the grape cultivar Madrasa (23.9 g/100 cm³), while the lowest was evident in cultivars Chardonnay and Cabernet Sauvignon (21.2 g/100 cm³). In terms of titratable acidity, the highest value emerged in the cultivar Cabernet Sauvignon (6.4 g/L), and the lowest was in the cultivar Muscat (5.0 g/L). Regarding the pH value, the topmost value appeared in the cultivar Muscat (3.25), while the lowest values occurred in the cultivar Cabernet Sauvignon (3.17). Past studies enunciated that by making grapes reach their maximum maturity, the berry weight and size of low and medium-vigor grapes were at par (Bramley *et al.*, 2011).

Under the terroir environmental conditions between mountains and the sea, the grape cultivar Madrasa exhibited a higher sugar concentration and similar acidity, while the cultivar Merlot revealed characteristics of the same sugar concentration and lower acidity. However, these results do not align with some past studies, as they claimed that at lower altitudes and higher temperatures lead to a decrease in acidity and an enhancement in sugar concentration due to malic acid catabolism (Regina *et al.*, 2010; Rienth *et al.*, 2016, 2020; De-Oliveira *et al.*, 2019). Therefore, it seemed that temperature had no impact on the chemical composition of the grapes. In the said area, the temperature regulation could have received influences from the wind. The high sugar concentration in the grape cultivar Madrasa and the higher acidity in the cultivar Cabernet Sauvignon may refer to the higher sun rays' effects that promote photosynthetic processes. These results correspond with previous findings (De-Oliveira *et al.*, 2019; Regina *et al.*, 2010).

The ethyl alcohol with volume percentage in the wine samples of the different grape cultivars was 12.9% (Saperavi), 14.0% (Merlot), 14.4% (Madrasa), 12.7% (Muscat), 13.8% (Chardonnay), 12.5% (Cabernet Sauvignon), and 13.0% (Khindogni). The promising results were in accordance with the standard range (8.5%–15.0%) and varied depending on the sugar concentration in the grape juice of different grape cultivars (GOST,

2013a). The residual sugar in the wine made from the grape cultivar Saperavi was 3.5 g/L, Merlot (3.5 g/L), Madrasa (3.0 g/L), Muscat (2.8 g/L), Chardonnay (3.1 g/L), and Cabernet Sauvignon (2.9 g/L). The residual sugar was significant for the stability of the wine, indicating that the technological process in production proceeded correctly, and the determined results were below the maximum allowable limit in the standard (<4.0 g/L).

The titratable acids with mass concentration in the wine samples made from the different grape cultivars were in Saperavi (5.8 g/L), Merlot (5.0 g/L), Madrasa (6.0 g/L), Muscat (4.4 g/L), Chardonnay (5.4 g/L), Cabernet Sauvignon (5.8 g/L), and Khindogni (5.6 g/L). These titratable acid values were in accordance with the standard indicator (>3.5 g/L) (GOST, 2013b). Non-volatile aliphatic acids were considerably natural acids, as well as referred as the total acids or titratable acidity of the wine.

In wine samples, the determination of total acidity succeeded in using the titration method, hence, it has become referred to as titratable acidity. Organic acids influence the quality of grape juice and wine. The active acidity (pH = 3.0-4.2) in grape juice and wine, as well as the titratable acidity (based on tartaric acid), should range between 5 and 8 g/L. Organic acids considerably contribute to the fermentation of grape juice and undergo various biochemical reactions during the subsequent stages of wine production, helping to enrich the final product with various nutrients (Conde *et al.*, 2007). They are vital in the fermentation process aside from being crucial in the formation of the wine's color, taste, and aroma during later stages. Organic acids considerably contribute in the metabolic processes in grapes, fermentation, and the wine-making process (Nabiyev, 2010).

The volatile acids with mass concentration in the wine made from the grape cultivar Saperavi was 0.53 g/L, Merlot (0.6 g/L), Madrasa (0.49 g/L), Muscat (0.25 g/L), Chardonnay (0.41 g/L), Cabernet Sauvignon (0.42 g/L), and Khindogni (0.52 g/L). These were in accordance with the standard indicator (<1.0 g/L) (GOST, 2012b). During fermentation of the grape juice, the amount of

volatile acids gradually increases. Acetic acid constitutes 80%–90% of the volatile acids in wine. Compared with the grape juice, acetic acid was 20–50 times more abundant in wine. However, acetic acids sustain influences from various factors, such as temperature during fermentation and the yeast strains used (Conde *et al.*, 2007; Nabiyev, 2010).

The wine extract made from various grape cultivars corresponded with the standard (>17.0 g/L) in studied cultivars, viz., Saperavi (22.2 g/L), Merlot (21.2 g/L), Madrasa (21.8 g/L), Muscat (18.0 g/L), Chardonnay (18.3 g/L), and Cabernet Sauvignon (18.2 g/L) (GOST, 2012a). Ripe grapes have the highest concentration of glucose and fructose, while the colloidal particles, such as cellulose and pectin, were low in quantity (Conde *et al.*, 2007). Wines made from such grape cultivars have higher alcohol yields and a considerable quantity of extractive substances. Therefore, during the wine formation process, special attention must focus on the sugar content and ripeness of the grape genotypes (Nabiyev, 2010).

The total sulfur and free sulfur values in the wine samples made from the grape cultivar Saperavi were 118 mg/L and 20 mg/L, respectively; Merlot (120 and 22 mg/L); Madrasa (97 and 23 mg/L); Muscat (133 and 22 mg/L); Chardonnay (92 and 18 mg/L); and in the cultivar Cabernet Sauvignon (100 and 22 mg/L). These were in accordance with the standard indicator (<200 mg/L) (GOST, 2014). Excessive SO₂ in wine is unacceptable. However, when SO₂ exceeds the normal limit in food products, including wines, it has considerable negative effects on human health (Nabiyev, 2010).

CONCLUSIONS

The analyses of the grape (*V. vinifera* L.) cultivars Saperavi, Merlot, Madrasa, Muscat, Chardonnay, Cabernet Sauvignon, and Khindogni revealed the sugar concentration was more sensitive to the variability in soil-climate conditions. It reaches the highest variability under the influence of the mountainous and coastal terroir compared with

other parameters. In comparison of the physical-chemical parameters of grapes affected by climate change, it appears that the cultivars Madrasa and Cabernet Sauvignon proved more stable and resilient against climate change in the region than the cultivars Merlot and Muscat. These considerable results could assist grape growers in adjusting their strategies toward environmental and vineyard management, helping them make the right cultivar selection to improve the grape production and wine quality.

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REFERENCES

- Alakbarov AM (2017). Evaluation of local wine production and qualitative characteristics of French grapevine varieties. (Abstract of the dissertation submitted for the degree of Doctor of Philosophy in Technology), *Ganja. ASAU*. pp. 5–23.
- Anesi A, Stocchero M, Santo SD, Commisso M, Zenoni S, Ceolodo S, Tornielli GB, Siebert TE, Herderich M, Pezzotti M, Guzzo F (2015). Towards a scientific interpretation of the terroir concept: Plasticity of the grape berry metabolome. *BMC Plant Biol.* 15: 191. <https://doi.org/10.1186/s12870-015-0584-4>.
- Aurand JM (2017). Determination of the $^{13}C/^{12}C$ isotope ratios of glucose, fructose, glycerol, and ethanol in products of vitivicultural origin by high-performance liquid chromatography coupled to isotope ratio mass spectrometry. Resolution OIV, *OENO*. pp. 479. The International Organization of Vine and Wine, Paris. <https://www.oiv.int/public/medias/5363/oiv-oeno-479-2017-en.pdf>.
- AzStat (2025). State Statistical Committee of the Republic of Azerbaijan. Agriculture, Forestry, and Fishing/Plant-Growing. Available online: https://stat.gov.az/source/environment/en/001_2en.xls (accessed on April 12, 2025).
- Bramley RGV, Ouzman J, Boss PK (2011). Variation in vine vigour, grape yield, and vineyard soils and topography as indicators of variation in the chemical composition of grapes, wine and wine sensory attributes. *Aust. J. Grape Wine Res.* 17(2): 217–229. <https://doi.org/10.1111/j.17550238.2011.00136.x>.
- Canbaş A, Erten H, Şanlı B, Selli S (2001). A study on the suitability of muscat grapes grown in the Tarsus Region for sweet wine production. *Food* 27(3): 219–223.
- Conde C, Silva P, Fontes N, Dias ACP, Tavares RM, Sousa MJ, Agasse A, Delrot S, Gerós H (2007). Biochemical changes throughout grape berry development and fruit and wine quality. *Food* 1(1): 1–22.
- De-Oliveira JB, Egipto R, Laureano O, De Castro R, Pereira GE, Ricardo-da-Silva JM (2019). Climate effects on physicochemical composition of Syrah grapes at low- and high-altitude sites from tropical grown regions of Brazil. *Food Res. Int.* 121: 870–879. <https://doi.org/10.1016/j.foodres.2019.01.011>.
- Edo-Roca M, Nadal M, Sánchez-Ortiz A, Lampreave M (2014a). Anthocyanin composition in Carignan and Grenache grapes and wines as affected by plant vigor and bunch uniformity. *OENO One.* 48(3): 201–217. <https://doi.org/10.20870/oeno-one.2014.48.3.1575>.
- Edo-Roca M, Sanchez-Ortiz A, Nadal M, Lampreave M, Valls J (2014b). Vine vigor and cluster uniformity on *Vitis vinifera* L. seed procyanidin composition in a warm mediterranean climate. *Span. J. Agric. Res.* 12(3): 772–786. <https://doi.org/10.5424/sjar/2014123-5188>.
- GOST (2012a). State Standard 32000-2012. Alcoholic products and raw materials for their production. Method for determining the mass concentration of equivalent extract. Moscow: Standards Publishing House, pp. 10.
- GOST (2012b). State Standard 32001-2012. Alcoholic products and raw materials for their production. Method for determining the mass concentration of volatile acids. Moscow: Standards Publishing House, pp. 13.
- GOST (2013a). State Standard 32095-2013. Alcoholic products and raw materials for their production. Method for determining the volumetric fraction of ethyl alcohol. Moscow: Standards Publishing House, pp. 12.
- GOST (2013b). State Standard 32114-2013. Alcoholic products and raw materials for their production. Methods for determining the mass concentration of titratable acids. Moscow: Standards Publishing House, pp. 10.

- GOST (2014). State Standard 32115-2013. Production alcohol and corresponding raw materials. Method for determination of free and total sulfur dioxide. Moscow: Standartinform, pp. 10.
- Habullayev ShA, Alisoy RE (2021). The production of sour table wines and methods of ensuring their quality. *Kooperasiya* 2(61): 124-133.
- Huseynov MA, Aghayev UJ (2024). Qualitative parameters of grapevine (*Vitis vinifera* L.) cultivars grown in the Mountainous Shirvan Region of Azerbaijan. *SABRAO J. Breed. Genet.* 56(5): 1994-2003. <http://doi.org/10.54910/sabrao2024.56.5.22>.
- Huseynov MA, Ibrahimli RR, Eyyubova LR, Mammadov NE, Jafarova HA, Baxshaliyeva AI (2022). Study of the physical-chemical and organoleptic properties of wines made from local grape varieties. *Global Challenges and Perspectives in Economic Development*. pp. 173-176. (In Azerbaijani).
- Huseynov MA, Salimov VS, Nasibov HN (2019). The effect of grape variety on technological and quality parameters of grape juice. *Az. J. Agric. Sci.* 1: 122-128. (In Azerbaijani).
- Jackson RS (2000). *Wine Science: Principles, Practice, Perception*. Academic Press. pp. 648.
- Mansour G, Ghanem C, Mercenaro L, Nassi N, Hassoun G, Caro AD (2022). Effects of altitude on the chemical composition of grapes and vine: A review. *OENO One.* 5(1): 227-239. <https://doi.org/10.20870/oeno-one.2022.56.1.4895>.
- Nabiyev A (2010). *Chemistry of Wine*. Textbook, Science. pp. 470.
- Regina MDA, Do Carmo EL, Fonseca AR, Purgatto E, Shiga TM, Lajolo FM, Ribeiro AP, Da-Mota RV (2010). Altitude influence on the quality of Chardonnay and Pinot Noir grapes in the state of Minas Gerais. *Fitotecnia. Rev. Bras. Frutic.* 32(1). <https://doi.org/10.1590/S0100-29452010005000023>.
- Rienth M, Lamy R, Schoenenberger P, Noll D, Lorenzini F, Viret O, Zufferey V (2020). A vine physiology-based terroir study in the AOC Lavaux region in Switzerland. *OENO One.* 54(4): 863-880. <https://doi.org/10.20870/oeno-one.2020.54.4.3756>.
- Rienth M, Torregrosa L, Sarah G, Ardison M, Brillouet J, Romieu C (2016). Temperature desynchronizes sugar and organic acid metabolism in ripening grapevine fruits and remodels their transcriptome. *BMC Plant Biol.* 16: 164. <https://doi.org/10.1186/s12870-016-0850-0>.
- Salimov VS, Huseynov MA, Shukurov AS (2022). Grapes: Agro-Technical, Agro-Chemical, and Integrated Pest Control Measures. *SAPFİR-15*, pp. 784.
- Spayd SE, Tarara JM, Mee DL, Ferguson JC (2002). Separation of sunlight and temperature effects on the composition of *Vitis vinifera* cv. Merlot berries. *Am. J. Enol. Vitic.* 53: 171-182. <https://doi.org/10.5344/ajev.2002.53.3.171>.
- Teixeira A, Eiras-Dias J, Castellarin SD, Gerós H (2013). Berry phenolics of grapevine under challenging environments. *Int. J. Mol. Sci.* 14(9): 18711-18739. <https://doi.org/10.3390/ijms140918711>.
- Vaudour E (2003). *Les Terroirs Viticoles. Définitions, Caractérisation et Protection*. Dunod. (In French).
- Xia E, Deng G, Guo Y, Li H (2010). Biological activities of polyphenols from grapes. *Int. J. Mol. Sci.* 11(2): 622-646. <https://doi.org/10.3390/ijms11020622>.