Quality assessment of grapes and wines of the Alminskiy terroir (Crimean Western-Coastal Piedmont viticultural and winemaking region)

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Abstract. Climatic conditions significantly impact the technology of grape cultivation, starting with selecting of varieties, choosing a place to establish a vineyard, and finishing with determining the harvesting time. The study of the effect of abiotic environmental factors on the quality characteristics of grapes and their products of processing is a hot topic. Assessment of the Crimean western-coastal piedmont viticulture and winemaking region was carried out in accordance with the climatic factors. Their impact on the carbohydrate-acid complex of grape varieties 'Aligote', 'Rkatsiteli', 'Cabernet-Sauvignon' and 'Merlot', as well as wines from these varieties, was studied. The sum of active temperatures in the region varied in the range of 3100°C - 3650°C. The hydrothermal coefficient was 0.35-0.76, which characterized the region as arid. Grapes cultivated in this region reach technical ripeness, mass concentration of sugars ranges from 186 to 260 g/L. An inverse correlation between the mass concentration of titratable acids in grapes and precipitation amount during the growing season (r= -0.63) was established. The wines prepared were characterized by distinctive varietal characteristics.

1 Introduction

Climate change is one of the most pressing environmental problems that humanity will face in the coming decades. During last 50 years, the average surface air temperature was increasing at an unprecedented pace [1-7]. In the report of OIV Director General Pau Roca, the viticultural season of 2022 was characterized by abnormal heat and a record-breaking drought over the past 500 years, which accelerated the ripening of grapes in the vineyards all over the world [1].

Forecasts on increasing the average air temperature on the planet by the end of 21st century are presented in accordance to various estimates from 1.0 to 5.3°C under different scenarios of greenhouse gas concentrations [8]. The average rate of warming in the Crimean Peninsula territory for the period of 1976–2021 was 0.49°C/10 years [3, 9, 10]. The maximum summer warming rate was observed in the South (0.74°C/10 years). The air temperature rise extended the duration of growing season across much of Russia [3].

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In the South of European part of Russia, there is a tendency towards a decrease in precipitation and, as a result, an increase in aridity over the period of 2001–2019 [11]. On the Crimean Peninsula territory, tendencies towards an increase in extreme air temperatures and precipitation anomalies were observed [3, 12].

Climatic environmental factors can adversely affect the productivity of vineyards. Grapes (Vítis vinífera L.) are traditionally grown in geographic regions with the average air temperature from 12 to 22°C during the season of growing (from April to October for Northern Hemisphere) [3]. Regional climatic conditions are an important factor influencing the physiological development of grape vine, vegetative growth, phenology, and hence, the quality of wine and its organoleptic properties. The studies to assess the impact of climate, soil and grape varieties on the quality of wine in the Bordeaux region (France) showed that climate is a dominant factor, composing for more than 50% of variations when averaged over all quality parameters [13].

The keyword meteorological parameters for growing grapes are air temperature and precipitation. High air temperature increases the sugar level and reduces the overall acidity of berries, but leads to a decrease in the size and weight of berries, reducing the yield of grapes, and affecting adversely the quality of grapes and wine. Grapes are characterized by incomplete phenolic maturity, imbalance between high accumulation of sugars and a decrease in acidity, increasing the alcohol strength of wine and a risk of its microbial instability [2, 3, 6].

Precipitation has a significant impact on the water balance of soil, as necessary in the winter-spring period for moisture accumulation, as well as at the beginning of growing season for inflorescence development [7]. During the period of flowering and ripening of berries, it is necessary to have dry atmospheric conditions. Excessive precipitation can increase cropping power, but reduce sugar content in berries, cause fungal diseases and stop flower pollination and delay harvest time.

The purpose of this work was to assess the impact of climatic factors of Crimean Western-Coastal Piedmont viticultural and winemaking region on the quality characteristics of grapes and wines.

2 Materials and methods

The objects of research were white (‘Aligote’, ‘Rkatsiteli’) and red (‘Merlot’, ‘Cabernet-Sauvignon’) grape varieties growing in the Alminsky terroir (Western-Coastal Piedmont region of Crimea). The studies were carried out for at least for 3 years in the same farms under the conditions of stable anthropogenic factors.

In total, 20 batches of grapes and related wines were taken for sampling. The studies were carried out from 2016 to 2022.

To identify the effect of factors, characterizing the moisture supply of territory, on the quality indicators of raw materials for wine production, the following parameters were selected: precipitation amount from the beginning of growing season to harvest ($P_{gr.}$), precipitation amount for the last month before harvest (P_{month}), Selyaninov’s Hydrothermal Coefficient (HTC) [3, 14]. To assess the territorial heat supply, the following indicators were used: sum of active temperatures above 10°C (SAT), Huglin Heliothermal Index (HI), Winkler Index (WI), average air temperature from the beginning of growing season to harvest ($t_{gr.}$), average air temperature for the last month before harvest (t_{month}) [3].

To calculate agroclimatic parameters in the analyzed areas, the method of non-linear interpolation of data from stationary weather stations was used. It is based on the authorial mathematical models that take into account topographic features, geographical and hydrological parameters of the analyzed territory and their effect on the spatial distribution of agroclimatic factors [3].

To analyze the surface topography of the studied area, a digital terrain model SRTM-3 with a spatial resolution of 3 arc seconds was used.

During the industrial crop harvesting, grape samples were taken in the amount of not less than 10 kg. Grapes were evaluated according to the following physicochemical parameters: mass concentration of sugars, titratable acids, pH value and a profile of organic acids [15]. The degree of grape ripeness was assessed by glucoacidimetric parameter (GAP), calculated as a ratio of mass concentration of sugars and titratable acids.

Grape processing was carried out in laboratory conditions according to the following scheme by varying the degree of contact between liquid and solid pulp fractions: grape processing (pressing with destemming) → pulp separation (for white grape varieties) → sulfitation (70-75 mg/L of total sulfur dioxide) → introduction of yeast starter (yeast race 47-K of Saccharomyces vini species phenotype "killer", 2% of the volume) → fermentation at a t = 18-20 °C with intermittent mixing → yeast racking after fermentation of 2/3 sugars (for red grape varieties - pulp pressing) → after-fermentation and self-clarification → sedimentation and racking → sulfitation (200 mg/L of total sulfur dioxide).

In the studied wine samples, mass concentration of titratable acids was determined potentiometrically, of sugars and organic acids - using high-performance liquid chromatography [15].

Experimental data were processed by generally accepted methods of mathematical statistics using IBM SPSS Statistics (v 17.0) software package, Microsoft Excel. All studies were carried out in triplicate. Pair correlations between indicators were calculated for a significance level of 0.05.

3 Results and Discussion

In order to conduct these studies, the data on meteorological conditions for the years of research were analyzed. Climatic factors that characterize the criteria for heat and moisture supply during growing season (to the harvesting date) and for the last month before harvest were estimated (Tables 1, 2).

Table 1. Factors to characterize heat supply of the terroir

Year	SAT, °C	HI	WI	t_{month}, °C	$t_{gr.}$, °C
2017	3091	1833	1595	19.51	19.71
2018	3644	2157	1875	18.48	20.21
2019	3222	1933	1679	19.33	19.88
2020	3142	1733	1501	21.10	17.42
2021	3300	1882	1646	15.67	19.71
2022	3335	1910	1650	18.81	19.14
standard deviation	179.6	128.8	112.8	1.6	0.92

One of the most important indicators to characterize the climatic conditions of an area is the sum of active temperatures above 10 °C, at which grapes enter the stage of sap flow beginning (base growth temperature). The obtained data analysis show that the sum of active temperatures in the region varies in the range of 3100-3650 °C. This indicator value is appropriate for cultivating grape varieties from very early ripening to medium late ones. At

the same time, these values are lower than recommended for varieties of late and very late ripening (< 3700 °C) [5].

The value of Huglin Index, responsible for the sum of temperatures above 10 °C from the beginning of growing season to the harvesting date, varied in the range of 1733-1933 °C. In 2018, its value was 11.6-24.5% higher than in other years of research. Corresponding tendency was observed for Winkler index. The results obtained are due to specific characteristics of the year, and hotter spring-summer period compared to other years of observation.

Regardless of the year, the average air temperature from the growing season beginning to the harvest time slightly differed, and ranged from 19.14 to 20.21 °C. A distinctive feature of 2020 was the lowest values of this indicator (by 1.72-2.79 °C).

Table 2. Factors to characterize moisture supply of the terroir

Year	P_{gr}, mm	P_{month}, mm	HTC
2017	184.3	1.2	0.60
2018	278.1	80.2	0.76
2019	169.0	5.3	0.52
2020	105.5	29.8	0.35
2021	212.3	47.8	0.67
2022	192.4	32.2	0.58
standard deviation	56.3	29.1	0.13

The moisture supply data analysis of the region shows a significant deficit of precipitation (P_{gr} < 300 mm) in the studied viticultural and winemaking region. The value of Selyaninov's Hydrothermal Coefficient (did not exceed 1) was 0.35–0.76, which classified the region as an arid and very arid zone [3].

Evaluation of carbohydrate-acid complex of grapes showed (Table 3) that mass concentration of sugars in the studied batches of grapes varied in the range of 186–260 g/L, meeting the requirements for industrial processing of grapes for the production of table and fortified wines.

As a result of global warming, there is a discrepancy in the accumulation of mass concentrations of sugars and anthocyanins in red grape varieties, which leads to delayed harvesting in order to achieve phenolic maturity of grapes [16, 17]. This factor is responsible for higher concentrations of sugars in grapes of red varieties compared to white ones. At the same time, this approach may lead to the fact that grape conditions will grow out of recommended quality requirements for the production of dry wines.

The mass concentration of titratable acids widely varied in a range from 4.4 to 7.9 g/L, which was determined by grape assortment and climatic conditions of the year. The minimum dispersion of indicator is typical for 'Aligote' variety. At that, the variation in mass concentration of titratable acids depending on the year for red grape varieties is 2.6–3.0 g/L.

Statistical evaluation of the data obtained made it possible to establish a linear dependence of mass concentration of titratable acids on the amount of precipitation during the growing season (r= -0.63).

The indicator of technical ripeness (TRI) is defined as the product of the mass concentration of sugars and the square of pH value. The value of this indicator varies in the range of 188-249 for white grape varieties under study, and corresponds to the recommended

values (130-260) for sparkling and still wine production. For red grape varieties, TRI value reaches 350, which is typical for late crop harvesting and warm climate in the region [17].

Table 3. Values of indicators of the chemical composition and ripeness of grapes

Grape variety	Mass concentration of		pH	GAP	TRI
	sugars, g/L	titratable acids, g/L			
Aligote	186-212 204	4.7-6.1 5.4	3.2-3.6 3.4	3.4-4.5 3.8	188-249 226
Rkatsiteli	188-210 195	5.0-7.1 6.0	3.1-3.4 3.2	2.8-3.8 3.3	191-219 204
Cabernet-Sauvignon	220-247 235	5.3-7.9 6.7	3.2-3.7 3.4	2.9-4.4 3.6	228-334 268
Merlot	239-260 250	4.4-7.4 6.1	3.3-3.4 3.4	3.2-5.6 4.2	268-298 283
standard deviation	0.5	0.06	0.03	0.04	3

Dry wines were prepared from the studied grape batches. Volume fraction of ethyl alcohol varied in 'Aligote' wines in the range of 10.6-13.3%; in the wines of 'Rkatsiteli' variety -11.0-14.7%; in 'Cabernet-Sauvignon' wines - 11.8-14.2%; in 'Merlot' wines - 11.8-14.8%. The content of titratable acids in 'Aligote' wines was 5.7-7.5 g/L; in 'Rkatsiteli' wines – 4.7-8.4 g/L; in 'Cabernet-Sauvignon' wines - 6.9-8.0 g/L; in 'Merlot' wines - 5.5-7.8 g/L. All wines were meeting the requirements of regulatory documentation.

The composition of organic acids in grapes was changing during fermentation (Fig. 1). A decrease in the mass concentration of tartaric acid by 14-40% was shown. In the process of alcoholic fermentation, succinic and lactic acids were produced, their content in wines varied in the range of 0.1–1.9 and 0.3–2.2 g/L, respectively. The content of citric acid has slightly increased.

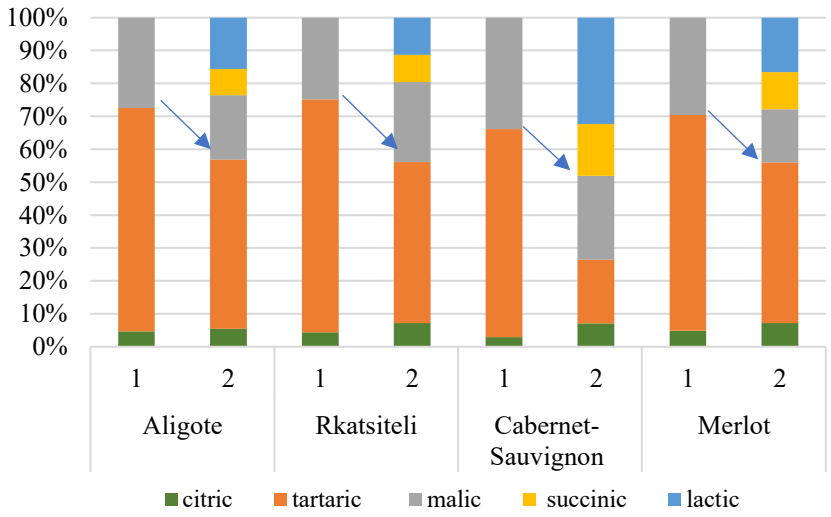

Fig 1. Dynamics of organic acids in the system "must-wine" (1 - must, 2 - wine)

Organoleptic analysis of wines showed that all of them were characterized in accordance with varietal features.

4 Conclusion

Thus, the assessment of climatic factors characterizing the heat and moisture supply of the Alminskiy terroir for the period 2017-2022 was carried out. It was shown that the sum of active temperatures in the region varies in the range of 3100-3650 °C. This indicator value is appropriate for cultivating grape varieties from very early ripening to medium late ones. The hydrothermal coefficient was 0.35-0.76, which characterized the region as arid.

Mass concentration of sugars in the studied grapes varieties ('Aligote', 'Rkatsiteli', 'Cabernet-Sauvignon' and 'Merlot') varied in the range of 186–260 g/L, meeting the requirements for industrial processing of grapes for the production of table and fortified wines.

The mass concentration of titratable acids widely varied in a range from 4.4 to 7.9 g/L, which was determined by grape assortment and climatic conditions of the year. An inverse correlation between the mass concentration of titratable acids in grapes and precipitation amount during the growing season (r= -0.63) was established. The wines prepared were characterized by distinctive varietal characteristics.

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