

Analysis of the must and wine of several grape varieties in the Pâncota wine-growing area

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Manuscript received: 8 November 2024; revised: 15 November 2024; accepted: 16 November 2024

Abstract

The western region of Romania stands out as a significant wine-producing area with a rich tradition and deep expertise in viticulture. This region offers highly favourable conditions for cultivating wine grapes. Research conducted in the Miniş-Măderat viticultural area focused on the physicochemical properties of both local and noble grape varieties, including “Fetească Regală”, “Mustoasă de Măderat”, “Merlot” and “Cabernet Sauvignon”. The analyses evaluated the physicochemical parameters of the grapes, grape must, and resulting wines, aligning with the quality standards required for Miniş controlled designation of origin wines. Grape samples were analyzed to establish the optimal harvest time and assess key quality indicators such as sugar accumulation, total acidity, pH, volatile acidity, malic acid content, alcohol volume, and the sensory characteristics of the wines. At harvest, red wine varieties exhibited a greater accumulation of sugars in the berries compared to the white varieties. Grapes from the “Mustoasă de Măderat” variety showed the highest acidity levels at harvest. For all varieties, the sugar content fell below 4 g/L during fermentation, placing the wines in the dry category. The resulting wines retained the distinct characteristics of each analyzed variety, displaying typicity and authenticity.

Keywords: sugars, acidity, physicochemical indicators

Introduction

The western region of Romania has a distinguished tradition in viticulture. High-quality wines meeting the criteria for the Miniş controlled designation of origin are produced within a geographically defined area in the Miniş wine center, where both natural and human factors play a direct role [10]. In the Miniş-Măderat vineyard, predominantly noble grape varieties are cultivated, with a smaller proportion of local grape varieties, resulting in a diverse varietal assortment. Given that the red wines produced in this viticultural area are highly extractive and require longer maturation than other wines, two noble red grape varieties, “Merlot” and “Cabernet Sauvignon” were analysed, alongside the representative local white varieties, “Fetească Regală” and “Mustoasă de Măderat” [9]. The chemistry of grapes and wines is complex, with multiple components playing a crucial role in determining wine quality, flavour, and stability. Among these, sugars, acids, and nitrogen compounds—each with specific contributions to taste, fermentation, and shelf life—are fundamental to wine composition [13]. The sugar content in grapes, measured in degrees Brix, reflects the ripeness of the fruit and typically increases as grapes mature. Higher sugar levels are often associated with warmer growing regions, where elevated temperatures enhance photosynthesis and sugar accumulation in grapes [6]. Total acidity, which can range from 4 to 8 grams per liter in most wines, is essential in balancing sweetness and alcohol, providing a crisp, refreshing quality. However, pH reflects the strength and dissociation of these acids rather than their concentration [3]. Typical wine pH levels fall between 3.0 and 4.0, with lower pH wines being more microbiologically stable and brighter in colour, particularly in red wines [7]. Acidity and pH are therefore critical not only for flavour but also for the stability and longevity of the wine. Tartaric acid is unique to grapes and is the most stable of grape acids, providing the backbone of a wine's acidity. It is resistant to changes during fermentation and aging, making it a central contributor to a wine's final taste. Tartaric acid can form crystals known as “wine diamonds”, which are harmless but can influence consumer perception [17]. Malic acid, on the other hand, has a fresher, more apple-like taste and is metabolically less stable, typically undergoing a transformation during malolactic [2]. Volatile acidity (VA), which encompasses acetic acid and

its associated compounds, is a measure of wine's spoilage level and is essential to both sensory quality and microbial stability. VA levels above 0.8 grams per liter are generally considered a fault in wine, often a result of bacterial spoilage. Careful handling of grapes and sanitation in the winery are essential to maintaining desirable VA levels [14]. Gluconic acid is not typically present in healthy grapes but accumulates in fruit affected by *Botrytis cinerea*, a fungus that can cause "noble rot" in some controlled winemaking practices or lead to spoilage [4]. Its presence is often a marker of rot or disease, and high levels of gluconic acid can alter the wine's quality, making it essential to measure in the production of high-quality wine [5]. Ammonia and other nitrogen compounds are vital nutrients for yeast during fermentation. They enable yeast cells to reproduce and facilitate the conversion of sugars into alcohol efficiently. Ammonia, as part of the yeast-assimilable nitrogen (YAN), is carefully monitored because low nitrogen levels can lead to sluggish or stuck fermentations, while excessive nitrogen can result in undesirable by-products like ethyl carbamate. Ensuring appropriate levels of nitrogen in the must can enhance fermentation health and lead to cleaner flavour profiles in the final wine [12]. The colour, aroma, and taste of wines are essential attributes that reflect a wine's quality, variety, and regional character. Colour varies widely, with wines variety [1]. Aroma is equally distinct and complex, influenced by grape variety, fermentation, and aging [13]. Taste balances sweetness, acidity, tannins, and body. White wines tend to be light and crisp, with flavours ranging from fruity to mineral. Red wines vary from soft and velvety to more robust, with complex flavours of dark fruits, chocolate, and tobacco emerging with age [11].

The objective of this paper is to investigate the physicochemical properties of the grape varieties "Fetească Regală", "Mustoasă de Măderat", "Merlot", and "Cabernet Sauvignon", focusing on key components such as sugars, acids, and nitrogen compounds. These components are analyzed for their influence on wine quality, flavour, stability, and sensory attributes, particularly in the context of factors like acidity, pH, and nitrogen levels, which are critical to the fermentation process, shelf life, and the balance of sweetness and acidity in the wine. The study aims to deepen the understanding of how these elements contribute to the overall composition, aroma, taste, and aging potential of wines produced from these grape varieties.

Material and Method

To conduct research on the physicochemical properties of certain wine grape varieties in the 2024 growing season, grape samples were collected from a vineyard located in Pâncota, within the Miniș-Măderat wine-growing region. The plots corresponding to each grape variety under study were situated relatively close to each other, benefiting from the same environmental conditions. The experiments aimed at assessing physicochemical parameters for producing typical and authentic wines with the controlled designation of origin (D.O.C.) Miniș were carried out on four varieties: two for white wines ("Fetească Regală" and "Mustoasă de Măderat") and two for red wines ("Merlot" and "Cabernet Sauvignon").

To determine the optimal harvest time, grape samples were taken from each plot within the vineyard. The plots with the selected varieties were divided into three equal sections, and two representative rows were chosen for sample collection. From each row, 10 vines were selected, and from each vine, two grape clusters were picked, ensuring one cluster was on one side of the row and the other on the opposite side to capture varying sun exposure. From each selected cluster, berries were sampled with their pedicels, clipped with scissors from the top, middle, and bottom, with 5-6 berries taken from each section. In total, 500-800 g of berries was collected. The berries were then placed in polyethylene bags, labelled with the variety, plot, and collection date, and promptly transported to the winery's oenology laboratory. The grape berries were crushed using a manual press, and the resulting must was filtered through filter paper. A few drops of the filtered must were taken with a pipette and placed in the FTIR module of the OenoFoss device to determine sucrose concentration and pH. Sucrose concentration was also measured in parallel using a portable Falko handheld refractometer with an accuracy of $\pm 0.1\%$, calibrated in refractometric degrees (percentage of soluble solids—using sucrose as a standard) from 0-30% and standardized at 20°C. This yielded the soluble solids content expressed as a percentage of sucrose. The pH of the grapes was determined using the Eutech Instruments pH 700 XS digital pH meter. Regarding must and wine, the physicochemical parameters studied included glucose/fructose, ethanol, pH, density, total acidity, volatile acidity, and malic acid. Sample collection was performed after homogenizing the must/wine in stainless-steel tanks. Prior to sampling, approximately 1-2 liters of must/wine were allowed to flow out, after which samples were collected from the "tasting tap" in new plastic bottles, with approximately 100-200 ml of must taken from each tank. The collected must/wine was filtered through filter paper, in which a few grams of filter aid had been added beforehand to facilitate the release of CO₂. A few drops of the filtered must/wine were then transferred using a pipette to the FTIR module of the OenoFoss device. The values of the relevant physicochemical parameters (glucose/fructose, ethanol, pH, total acidity, volatile acidity, and malic acid) were automatically read by the instrument and stored in a specially installed program on a laptop connected to the OenoFoss module. To determine free SO₂, 20 ml of the wine

to be analyzed was placed in a Berzelius flask, and then 1 ml of 1:5 H₂SO₄ was added using a pipette, along with 5 drops of a 1% amine salt solution. The prepared Berzelius flask was placed over a light bulb emitting white light and agitated slowly, continuously, and consistently. During this process, a manual or automated pipette was used to titrate a 0.025 N-N/40 iodine solution until the colour of the wine began to change gradually to a violet hue. At this point, the titration was stopped, and the volume of iodine dispensed was read from the pipette. This value was multiplied by 40 to obtain the concentration of free SO₂ in mg/l. Bound SO₂ was released by treating the wine sample with a 4 N NaOH solution.

The technology used in the winery for fermenting the must involves vertical cylindrical tanks made of stainless steel, equipped with sensors to monitor temperature. This allows for the control of every stage of fermentation to ensure the production of quality wines (keeping the temperature below 20 °C for white wines and below 25 °C for red wines, in accordance with D.O.C. Miniş regulations). This technology influences the rate of the fermentation process and the growth rate of the yeast.

To determine the organoleptic properties of the wines produced from the varieties "Fetească Regală", "Mustoasă de Măderat", "Merlot", and "Cabernet Sauvignon" studied in the Miniş-Măderat vineyard area, a tasting session was conducted with ten local viticulturists and oenologists. They analyzed the following characteristics: appearance, colour, aroma, and taste for each wine variety.

Results and Discussion

The analysis of grape parameters for the year 2024 was conducted on the variety "Fetească Regală" from August 18 to September 2. A significant increase in sugars was observed, rising from 19.70 to 21.90 °Brix. There was a decrease in the total acidity value from 5.25 to 4.30 g/l H₂SO₄, and the pH recorded values ranging from 3.12 to 3.31. Tartaric acid decreased from 8.2 g/l to 7.1 g/l, while malic acid declined from 1.8 g/l to 0.3 g/l. For the variety "Mustoasă de Măderat", the analysis of grape parameters in 2024 was performed from August 28 to September 8. An increase in sugars was noted, from 16.50 to 18.70 °Brix, along with a reduction in total acidity from 7.23 to 5.85 g/l H₂SO₄.

Table 1. Quality parameters in grape must in white and red varieties during 2024 growing seasons

Berry sampling dates	Sugars (°Brix)	Total acidity (g/l H ₂ SO ₄)	pH	Tartaric acid (g/l)	Malic acid (g/l)	Volatile acidity (g/l acetic acid)	Gluconic acid (g/l)	Ammonia (ml/l)
"Fetească Regală"								
18.08.2024	19.7	5.25	3.12	8.2	1.8	0.02	0.1	150.2
23.08.2024	20.1	4.94	3.19	7.9	1.0	0.05	0.4	125.0
28.08.2024	20.6	4.43	3.26	7.5	0.5	0.08	0.7	106.8
02.09.2024	21.9	4.30	3.31	7.1	0.3	0.09	0.6	99.4
"Mustoasă de Măderat"								
28.08.2024	16.5	7.23	2.90	10.8	1.9	0.04	0.5	130.0
02.09.2024	17.0	6.60	2.98	9.7	1.4	0.06	0.4	120.8
05.09.2024	17.7	6.13	3.03	9.0	0.8	0.09	0.5	114.4
08.09.2024	18.7	5.85	3.08	8.7	0.5	0.10	0.6	106.2
"Merlot"								
23.08.2024	21.0	5.96	3.06	9.3	0.2	0.06	0.7	132.4
28.08.2024	21.8	5.62	3.15	8.5	0.4	0.07	0.7	121.7
02.09.2024	22.7	5.04	3.22	7.9	0.5	0.08	0.8	110.5
07.09.2024	23.2	4.60	3.25	7.2	0.6	0.08	0.8	101.5
"Cabernet Sauvignon"								
23.08.2024	18.2	5.98	2.96	9.2	2.4	0.08	0.6	127.6
02.09.2024	19.1	5.64	3.05	8.4	1.0	0.07	0.8	108.6
07.09.2024	21.2	5.00	3.12	7.5	0.5	0.06	0.8	99.8
12.09.2024	22.8	4.70	3.40	7.3	0.3	0.05	0.9	96.2

The pH values ranged between 2.90 and 3.08, with tartaric acid decreasing from 10.8 g/l to 8.7 g/l and malic acid dropping from 1.9 g/l to 0.5 g/l. The analysis of grape parameters for the variety "Merlot" took place between August 23 and September 7, 2024. Sugars increased over the two-week period from 21.00 °Brix to 23.20 °Brix, while total acidity decreased from 5.96 g/l to 4.60 g/l H₂SO₄. The pH values ranged from 3.06 to 3.25, with tartaric acid decreasing from 9.3 g/l to 7.2 g/l and malic acid ranging from 0.2 g/l to 0.6 g/l. For the variety "Cabernet Sauvignon", the analysis was conducted from August 23 to September 12, 2024. An increase in sugars was noted, from 18.20 to 22.80 °Brix, along with a decrease in total acidity from 5.98 g/l to 4.70 g/l H₂SO₄. The pH recorded values between 2.96 and 3.40, with tartaric acid decreasing from 9.2 g/l to 7.3 g/l, and malic acid decreasing from 2.4 g/l to 0.3 g/l. At the time of harvesting, the red wine grape varieties

accumulated the highest sugar concentrations in their berries, with “Merlot” having the highest, followed by “Cabernet Sauvignon”, then “Fetească Regală”, and finally “Mustoasă de Măderat”.

The grapes with the highest acidity at harvest were from the “Mustoasă de Măderat” variety, while the “Fetească Regală” variety exhibited the lowest acidity. The total acidity values are consistent with the specific characteristics of these varieties in this particular viticultural area. The low levels of malic acid indicated that the grapes reached harvest maturity for all varieties. Additionally, the low amounts of gluconic acid suggest that the grape must from all varieties was not affected by *Botrytis*. The ammonia present in the grape must falls within the parameters that ensure effective fermentation during the winemaking process.

Table 2. The quality parameters of the must in fermentation during the 2024 growing season

Sampling dates	Glucose/Fructose (g/l)	Total acidity (g/l H ₂ SO ₄)	pH	Alcohol (%vol)	Malic acid (g/l)	Volatile acidity (g/l acetic acid)
“Fetească Regală”						
05.09.2024	220.0	4.30	3.31	0.31	0.90	0.16
06.09.2024	191.2	4.29	3.21	1.69	0.80	0.17
07.09.2024	136.4	4.33	3.20	4.91	0.90	0.13
08.09.2024	98.3	4.35	3.15	7.15	1.00	0.11
09.09.2024	65.9	4.30	3.25	9.06	1.10	0.11
10.09.2024	30.1	4.28	3.24	11.17	1.50	0.09
11.09.2024	16.2	4.29	3.13	11.98	1.40	0.09
12.09.2024	7.9	4.29	3.15	12.47	2.00	0.08
13.09.2024	4.5	4.28	3.21	12.67	2.20	0.06
14.09.2024	2.2	4.28	3.24	12.81	2.10	0.06
“Mustoasă de Măderat”						
09.09.2024	187.6	5.85	3.08	0.42	1.60	0.37
10.09.2024	148.4	5.80	3.03	2.30	1.50	0.32
11.09.2024	110.2	5.76	2.99	4.54	1.50	0.28
12.09.2024	78.9	5.77	2.99	6.39	1.70	0.22
13.09.2024	60.3	5.76	3.00	7.48	1.90	0.24
14.09.2024	32.5	5.75	2.99	9.12	1.90	0.21
15.09.2024	14.7	5.74	2.99	10.17	2.10	0.18
16.09.2024	6.8	5.76	2.97	10.63	2.20	0.19
17.09.2024	2.9	5.76	2.97	10.86	2.40	0.15
18.09.2024	1.5	5.76	2.98	10.94	2.40	0.17
“Merlot”						
10.09.2024	234.1	4.60	3.25	0.20	1.60	0.26
11.09.2024	201.4	4.58	3.20	1.92	1.40	0.27
12.09.2024	174.5	4.58	3.18	3.50	1.50	0.22
13.09.2024	142.3	4.57	3.16	5.40	1.30	0.21
14.09.2024	120.4	4.58	3.18	6.68	1.20	0.23
15.09.2024	102.3	4.57	3.15	7.75	1.10	0.23
16.09.2024	80.6	4.57	3.16	9.02	1.10	0.21
17.09.2024	38.8	4.55	3.15	11.48	1.10	0.20
18.09.2024	16.4	4.55	3.11	12.80	1.10	0.21
19.09.2024	7.8	4.54	3.11	13.31	1.00	0.19
20.09.2024	3.4	4.53	3.09	13.57	0.90	0.19
21.09.2024	1.5	4.54	3.03	13.68	0.90	0.20
“Cabernet Sauvignon”						
15.09.2024	229.2	4.70	3.40	0.29	2.30	0.27
16.09.2024	190.8	4.68	3.38	2.25	2.10	0.25
17.09.2024	158.2	4.68	3.32	4.17	2.00	0.22
18.09.2024	125.6	4.67	3.33	6.09	1.90	0.21
19.09.2024	84.8	4.66	3.28	8.49	1.70	0.23
20.09.2024	38.4	4.65	3.29	11.22	1.50	0.22
21.09.2024	16.6	4.65	3.28	12.50	1.30	0.20
22.09.2024	6.5	4.64	3.28	13.10	1.30	0.21
23.09.2024	3.4	4.64	3.25	13.28	1.20	0.18
24.09.2024	1.5	4.64	3.25	13.39	1.20	0.18

The fermentation process of the grape must involves the determination of specific physicochemical indicators, which are then monitored throughout their evolution to ensure compliance with the standard parameters required by current legislation. In managing the fermentation of the grape must, research focused on the volume, temperature control, the sugar content, the clarification process of the must, and the sulphitation process. In 2024, the fermentation process was monitored for approximately 10 to 12 days. For all varieties, the sugar content, primarily glucose and fructose, decreased during the fermentation process to below 4 g/l,

resulting in dry wines ("Fetească Regală" - 2.2 g/l sugars, "Mustoasă de Măderat" - 1.5 g/l sugars, "Merlot" - 1.5 g/l sugars, "Cabernet Sauvignon" - 1.5 g/l sugars). At the end of the fermentation, total acidity stabilized at the following values: "Fetească Regală" - 4.28 g/l H₂SO₄, "Mustoasă de Măderat" - 5.76 g/l H₂SO₄, "Merlot" - 4.54 g/l H₂SO₄, and "Cabernet Sauvignon" - 4.64 g/l H₂SO₄. The "Mustoasă de Măderat" variety exhibited the highest total acidity, characteristic of the variety, while the lowest total acidity was observed in "Fetească Regală". The varieties "Mustoasă de Măderat" and "Merlot" had low pH values of 2.98 and 3.03, respectively, whereas the pH values for "Fetească Regală" and "Cabernet Sauvignon" were similar, at 3.24 and 3.25, respectively. The alcohol content increased during the fermentation process of the grape must, rising from 0.31% to 12.81% vol. alc. for "Fetească Regală". For "Mustoasă de Măderat", the alcohol content increased from 0.42% to 10.94% vol. alc. In the red varieties, the increase in alcohol volume was greater compared to the white varieties, with "Cabernet Sauvignon" rising from 0.29% to 13.39% vol. alc. and "Merlot" increasing from 0.20% to 13.68% vol. alc. The variety with the highest sugar content (234.1 g/l) at the beginning of the fermentation process during 2024 growing season was "Merlot", followed by "Cabernet Sauvignon" (229.2 g/l), "Fetească Regală" (220 g/l), and "Mustoasă de Măderat" (187.6 g/l). The lowest volatile acidity was recorded for "Fetească Regală" at 0.06 g/l acetic acid, while the highest was observed in "Merlot" at 0.20 g/l acetic acid. The varieties 'Cabernet Sauvignon' and 'Mustoasă de Măderat' had similar values of 0.18 g/l and 0.17 g/l acetic acid, respectively.

Košmerl et al. (2013) [9] reported that in the Krstač white grape variety from Montenegro, the sugar content was associated with pH levels between 3.35 and 3.44, total acidity ranging from 6.00 to 6.15 g/L, and tartaric acid levels from 3.76 to 4.57 g/L. In the Vranac red grape variety, the pH ranged from 3.64 to 3.65, with total acidity between 7.38 and 8.13 g/L, and tartaric acid levels spanning 2.84 to 4.78 g/L.

Table 3. The physico-chemical properties of wines, from 2024 growing season

Sampling dates	Glucose/Fructose (g/l)	Alcohol (%vol)	pH	Total acidity (g/l H ₂ SO ₄)	Volatile acidity (g/l acetic acid)	Malic acid (g/l)	Free SO ₂ (mg/l)
"Fetească Regală"							
25.10.2024	1.50	12.85	3.27	4.30	0.15	2.10	27.00
30.10.2024	1.30	12.86	3.25	4.32	0.13	2.00	25.00
05.11.2024	1.30	12.86	3.26	4.29	0.14	2.00	24.00
"Mustoasă de Măderat"							
25.10.2024	1.20	10.96	3.05	5.78	0.21	2.30	26.00
30.10.2024	1.00	10.97	3.02	5.79	0.20	2.20	23.00
05.11.2024	0.80	10.98	3.04	5.80	0.22	2.22	22.00
"Merlot"							
25.10.2024	1.20	13.70	3.35	4.55	0.27	1.5	18.4
30.10.2024	0.90	13.71	3.42	4.60	0.25	1.6	19.0
05.11.2024	0.70	13.72	3.44	4.60	0.28	1.4	19.6
"Cabernet Sauvignon"							
25.10.2024	1.30	13.40	3.30	4.68	0.16	1.8	16.0
30.10.2024	0.90	13.42	3.33	4.66	0.22	2.4	18.2
05.11.2024	0.80	13.43	3.38	4.64	0.30	2.5	19.1

The analysis of the physicochemical properties of wines from 2024 growing season revealed that the alcohol content was notably high in red varieties, measuring 13.72% vol. alc. for 'Merlot' and 13.43% vol. alc. for 'Cabernet Sauvignon', while it was within normal limits for 'Fetească Regală' at 12.86% vol. alc. and lower for 'Mustoasă de Măderat' at 10.98% vol. alc. The residual sugar remaining after fermentation indicates the production of dry wines; specifically, 'Merlot', 'Cabernet Sauvignon', and 'Fetească Regală', all with an alcohol content exceeding 11%, fall within the standards for D.O.C. Miniș wines. However, the wine produced from 'Mustoasă de Măderat' did not meet the D.O.C. criteria in 2024.

When analyzing the pH parameter in 2024, it was observed that white wines had a slightly lower pH compared to red wines, although the pH was balanced across all analyzed varieties. The lowest pH was measured at 3.04 for 'Mustoasă de Măderat', followed by 'Fetească Regală' with a pH of 3.26, 'Cabernet Sauvignon' with a pH of 3.38, and 'Merlot' with a pH of 3.44.

The lowest total acidity was recorded in the wine from the 'Fetească Regală' variety (4.29 g/l H₂SO₄), followed closely by 'Merlot' and 'Cabernet Sauvignon', which had similar values (4.60 g/l H₂SO₄ and 4.64 g/l H₂SO₄, respectively). The highest acidity was noted in the wine from the 'Mustoasă de Măderat' variety (5.80 g/l H₂SO₄). The volatile acidity, according to the D.O.C. Miniș requirements, was found in white wines with a maximum limit of 1.08 g/l acetic acid, while for red wines, the maximum limit was 1.20 g/l. In the white wines, values of 0.14 g/l acetic acid were recorded for 'Fetească Regală' and 0.22 g/l acetic acid for 'Mustoasă de

Măderat'. The red wines exhibited the following volatile acidity values: 0.28 g/l acetic acid for 'Merlot' and 0.30 g/l acetic acid for 'Cabernet Sauvignon'.

In their study on various grape varieties, including the Turkish variety 'Isabella,' Sabir et al. (2020) [19] found that ripe grapes contained 181.2 °Brix of sugars, 5.2 g/L of tartaric acid, and 3.4 g/L of malic acid. Additionally, the researchers observed a lower glucose-to-fructose ratio of 1.19 g/L in 'Isabella' grapes compared to the levels found in 'Cabernet Sauvignon' and 'Merlot' in the current study. The data show that following malolactic fermentation, malic acid is present in small quantities in the 'Fetească Regală' - 2.2 g/l, 'Mustoasă de Măderat' - 2.22 g/l, 'Merlot' - 1.4 g/l, and 'Cabernet Sauvignon' - 2.5 g/l wines. An analysis of the free SO₂ content in the wines shows that are in the standards set for D.O.C. Miniș, specifically 10-20 mg/l for dry red wines and 20-30 mg/l for dry white wines. The free SO₂ values for the 2024 vintage were as follows: 'Fetească Regală' - 24.0 mg/l, 'Mustoasă de Măderat' - 22.0 mg/l, 'Merlot' - 19.6 mg/l, and 'Cabernet Sauvignon' - 19.1 mg/l.

'Fetească Regală' young wine from 2024 was described as clear with a yellow-green colour, a subtle aromatic bouquet featuring notes of wildflowers and summer apples, and a taste that was characterized as savoury, fruity, floral, fresh, and balanced. 'Mustoasă de Măderat' was characterized as a white wine with a bright and clear appearance, displaying a yellow-green hue, and possessing a fresh flavour reminiscent of grapevine and green pears. Its taste was described as fresh and refreshing, attributed to its pronounced acidity, with herbaceous notes.

Table 4. The organoleptic properties of wines from 2024 growing season

Variety	Organoleptic properties			
	Appearance	Colour	Flavour	Taste
"Fetească Regală"	Clear	Yellow - greenish	Discreet, a light floral scent of wildflowers, notes of summer apples	Fresh and balanced, flavourful, fruity and floral
"Mustoasă de Măderat"	Brilliantly clear	Yellow - greenish	Raw, fresh, notes of vine flowers and green pears	Fresh-cool, grassy, Pronounced acidity
"Merlot"	Clear - transparent	Ruby-red with violet reflections	Flavoured, notes of berries, cherries and blueberries	Attractive - bitter, red fruit flavours, soft tannins, full-bodied
"Cabernet Sauvignon"	Translucent	Deep red, redcurrant shade	Distinct flavour, notes of black berries and aronia	Complex, tannic, notes of currants, woody vegetal notes

The 'Merlot' wine was noted for its clarity and transparency, exhibiting a ruby-red colour with violet reflections, a pronounced flavour of forest fruits, cherries, and blueberries, and a very appealing taste that was slightly bitter, with soft tannins, a full body, and flavours of red fruits. 'Cabernet Sauvignon' was appreciated for its translucent appearance, featuring a red-currant colour, aromas of black forest fruits, and a complex, tannic taste with woody vegetal notes and hints of currants.

The relationship between various quality parameters in the studied grape varieties was illustrated through the configuration of a PCA diagram. The Principal Component Analysis (PCA) diagram (Figure 1) provides a visual interpretation of the relationships and variances among the quality parameters analyzed across different sampling dates in Feteasca regala variety. The first principal component explains a dominant portion (95.17%) of the variance, indicating that most of the variance in the data can be attributed to factors along this axis. Sugars (S) have a strong influence on the first principal component, suggesting that sugar content is a major differentiating factor in the samples. Gluconic acid (GA) and volatile acidity (VA) indicate a strong correlation with sugars. Their positions imply that samples with higher sugar content also tend to have higher levels of gluconic acid and volatile acidity. Titratable acidity (TA), malic acid (MA), and ammonia (Am) are clustered together on the negative side of F1, suggesting that they are inversely related to sugar content, gluconic acid, and volatile acidity. High values of titratable acidity, malic acid, and ammonia appear in samples with lower sugar content. Tartaric acid (TartA) shows some degree of independence from the other acidity and sugar variables, indicating that it varies independently of the main F1 relationships. Grapes harvested later tend to have higher sugar content. Earlier-harvested samples have lower sugar content but higher acidity, malic acid, and ammonia.

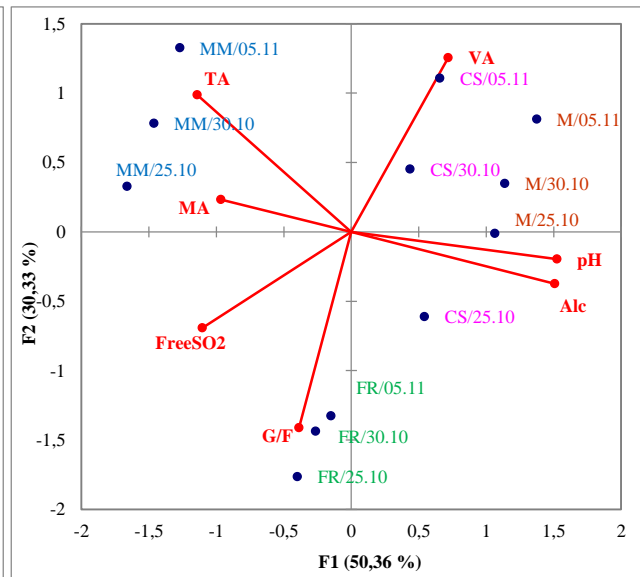
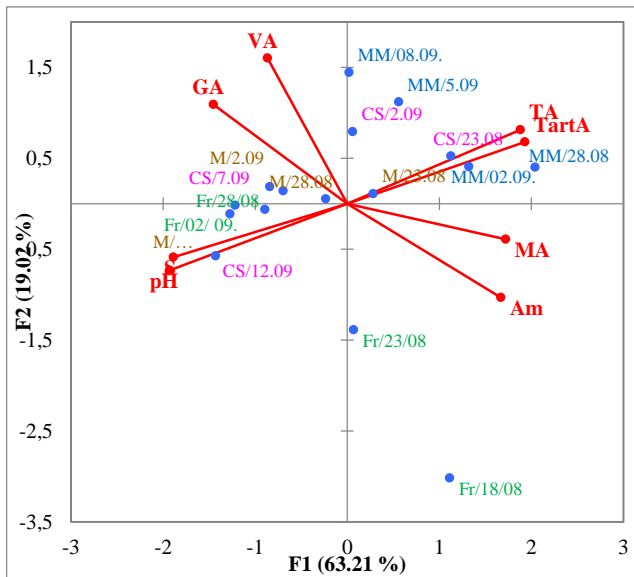


Figure 1. PCA diagram of quality parameters for Fetească Regala (Fr), Mustoasa de Maderat (MM), 'Merlot' (M), 'Cabernet Sauvignon' (CS) across different sampling dates; (S – sugars; TA –titratable acidity; TartA-tartaric acid; MA-malic acid; VA-volatile acidity; GA -gluconic acid; Am – ammonia)

Figure 2. PCA diagram of quality parameters for Fetească Regala (Fr), Mustoasa de Maderat (MM), 'Merlot' (M), 'Cabernet Sauvignon' (CS) across different sampling dates; (G/F – Glucose/Fructose; TA –titratable acidity; MA-malic acid; VA-volatile acidity; GA -gluconic acid; Alc - alcohol)

The second PCA diagram (Figure 2) illustrates the relationship among quality parameters across different grape varieties at specific sampling dates. The two principal components, F1 and F2, account for 50.36% and 30.33% of the variance. Higher alcohol levels are often associated with a higher pH in these grape samples. Sampling for Mustoasa de Maderat on dates such as 30/10 and 05/11 show an association with higher levels of titratable acidity (TA) and malic acid (MA). This suggests that Mustoasa de Maderat exhibits higher acidity on these dates. Samples from 30/10 and 05/11 suggest elevated volatile acidity in 'Cabernet Sauvignon' during this period; this may indicate a distinct characteristic of this variety during late sampling dates. The samples value from 'Merlot' indicates balanced acidity characteristics, with slight shifts in pH and alcohol levels. Values for Feteasca Regala sampling dates on 25/10 and 30/10 may suggest that this variety has relatively higher residual sugars and free SO₂ levels on these dates, aligning with a profile that could support certain freshness attributes. Feteasca Regala (FR) appears associated with higher glucose/fructose ratios and free SO₂, suggesting that this variety may retain sugars and exhibit good preservation traits (linked to free SO₂). Mustoasa de Maderat (MM) tends to be more acidic, as indicated by its association with higher titratable and malic acid levels. 'Cabernet Sauvignon' (CS) shows higher volatile acidity (VA), particularly during later sampling dates, which could impact its flavour profile, while 'Merlot' (M) is relatively balanced but has instances of alignment with both VA and pH, showing a profile that could include nuanced acidity and body.

The correlation among different grape must quality parameters is essential for optimizing grape maturity, predicting wine quality, and tailoring winemaking practices. This knowledge is valuable for controlling fermentation, managing flavour profiles, and achieving consistency across vintages.

The correlation matrix for the Fetească Regala variety (Table 5) shows several significant relationships between the variables. Sugars and pH have a high positive correlation, indicating that as the sugar (S) level increases, the pH also tends to increase. Titratable acidity and tartaric acid, pH and volatile acidity, malic acid and ammonia show very strong positive relationships. These correlations suggest that these pairs of variables increase together, implying potential interdependence. Titratable acidity and pH, sugars, tartaric acid and gluconic acid all exhibit strong negative correlations, suggesting that as titratable acidity (TA) increases, pH, sugar (S), volatile acidity (VA), and gluconic (GA) levels decrease. Sugars and tartaric acid, sugars and ammonia also show strong negative correlations, suggesting that as sugar levels increase, tartaric acid (TartA) and amino acids (Am) tend to decrease. Most values are bolded, indicating statistical significance at a 0.05 alpha level. This suggests that these correlations are not likely to have occurred by random chance and reflect real relationships within the Fetească Regala variety data.

Table 5. Correlation matrix (Pearson) – Fetească Regala variety

Variables	S	TA	pH	TartA	MA	VA	GA	Am
S	1	-0.890	0.933	-0.970	-0.855	0.881	0.704	-0.869
TA	-0.890	1	-0.989	0.974	0.976	-0.994	-0.944	0.983
pH	0.933	-0.989	1	-0.992	-0.981	0.992	0.912	-0.987
TartA	-0.970	0.974	-0.992	1	0.948	-0.969	-0.855	0.958
MA	-0.855	0.976	-0.981	0.948	1	-0.994	-0.961	0.999
VA	0.881	-0.994	0.992	-0.969	-0.994	1	0.956	-0.997
GA	0.704	-0.944	0.912	-0.855	-0.961	0.956	1	-0.959
Am	-0.869	0.983	-0.987	0.958	0.999	-0.997	-0.959	1

Values in bold are different from 0 with a significance level $\alpha=0.05$; (S – sugars; TA –titratable acidity; TartA-tartaric acid; MA-malic acid; VA-volatile acidity; GA -gluconic acid; Am – ammonia)

Table 6. Correlation matrix (Pearson) – Mustoasa de Maderat variety

Variables	S	TA	pH	TartA	MA	VA	GA	Am
S	1	-0.949	0.964	-0.920	-0.966	0.955	0.728	-0.983
TA	-0.949	1	-0.997	0.997	0.994	-0.989	-0.507	0.988
pH	0.964	-0.997	1	-0.989	-0.991	0.982	0.532	-0.996
TartA	-0.920	0.997	-0.989	1	0.984	-0.980	-0.438	0.974
MA	-0.966	0.994	-0.991	0.984	1	-0.998	-0.588	0.988
VA	0.955	-0.989	0.982	-0.980	-0.998	1	0.593	-0.977
GA	0.728	-0.507	0.532	-0.438	-0.588	0.593	1	-0.592
Am	-0.983	0.988	-0.996	0.974	0.988	-0.977	-0.592	1

Values in bold are different from 0 with a significance level $\alpha=0.05$; (S – sugars; TA –titratable acidity; TartA-tartaric acid; MA-malic acid; VA-volatile acidity; GA -gluconic acid; Am – ammonia)

The Pearson correlation provided for the Mustoasa de Maderat grape variety illustrates that sugars positively correlated with pH and volatile acidity (VA), indicating that higher sugars content in the grape is generally linked with higher pH and volatile acidity. Strongly negatively correlated with titratable acidity (TA), tartaric acid (TartA), malic acid (MA), and ammonia (Am), suggest that as soluble solids increase, these acidity measures tend to decrease. Titratable Acidity (TA) and pH show a very strong negative correlation with each other, typical in grape and wine chemistry, where higher acidity often corresponds to a lower pH. TA is strongly and positively associated with tartaric acid (TartA) and malic acid (MA), which are key acidity components, showing that as titratable acidity increases, these specific acid levels also increase. However, TA is positively correlated with ammonia (Am) but negatively correlated with volatile acidity (VA), implying that higher overall acidity comes with higher specific acids and ammonia but lower volatile acidity. Tartaric acid (TartA) and malic acid (MA) both show strong negative correlations with pH and volatile acidity (VA), meaning as these specific acids increase, the pH tends to decrease and so does volatile acidity. Positively correlated with pH and weakly with gluconic acid (GA), volatile acidity (VA) indicates that higher volatile acidity is linked to higher pH and higher general acidity.

Table 7 shows that sugars from 'Merlot' are strongly linked to lower acidity, represented by a higher pH, lower titratable acidity, and lower tartaric acid. This reflects a typical ripening trend where sugars increase as acidity decreases. Titratable acidity (TA) and tartaric acid (TartA) show close alignment, as tartaric acid significantly contributes to the total acidity in the 'Merlot' variety. Volatile acidity (VA) and malic acid (MA) are positively associated with pH and general acidity, indicating they might contribute to a perception of acidity without heavily impacting total acidity.

Very strong negative correlation with titratable acidity (TA) and volatile acidity (VA), show that as sugar content increases, overall and volatile acidity decrease, likely indicating a reduction in acidity as grapes ripen. Strong positive correlation with pH, which suggests that higher sugar levels are generally associated with higher pH, a common trend in grape ripening. The positive correlation of titratable acidity (TA) with tartaric acid (TartA) and volatile acidity (VA), show that total acidity reflects both specific acids. This highlights the significant role of tartaric acid and volatile acidity in contributing to overall acidity in 'Cabernet Sauvignon'. Extremely high

correlation of malic acid (MA) with ammonia (Am) indicates near-parallel behaviour, where higher malic acid levels coincide with higher ammonia, both contributing to the overall acidity profile. Preiner et al. (2013) [16] observed a strong correlation (0.83) between titratable acidity and malic acid content in native grapevine varieties from Dalmatia, Croatia. They also reported significant correlations between tartaric acid and malic acid (0.42) and between tartaric acid and citric acid (-0.44).

Table 7. Correlation matrix (Pearson) - 'Merlot' variety

Variables	S	TA	pH	TartA	MA	VA	GA	Am
S	1	-0.991	0.992	-0.992	0.987	0.974	0.919	-0.998
TA	-0.991	1	-0.967	0.989	-0.964	-0.936	-0.927	0.995
pH	0.992	-0.967	1	-0.982	0.994	0.989	0.889	-0.986
TartA	-0.992	0.989	-0.982	1	-0.990	-0.946	-0.874	0.998
MA	0.987	-0.964	0.994	-0.990	1	0.968	0.845	-0.986
VA	0.974	-0.936	0.989	-0.946	0.968	1	0.905	-0.957
GA	0.919	-0.927	0.889	-0.874	0.845	0.905	1	-0.905
Am	-0.998	0.995	-0.986	0.998	-0.986	-0.957	-0.905	1

Values in bold are different from 0 with a significance level alpha=0.05; (S – sugars; TA –titratable acidity; TartA-tartaric acid; MA-malic acid; VA-volatile acidity; GA –gluconic acid; Am – ammonia)

A focused interpretation of the main associations in the correlation matrix for the 'Cabernet Sauvignon' variety is presented in Table 8.

Table 8. Correlation matrix (Pearson) - 'Cabernet Sauvignon' variety

Variables	S	TA	pH	TartA	MA	VA	GA	Am
S	1	-0.993	0.946	-0.956	-0.873	-0.990	0.859	-0.902
TA	-0.993	1	-0.907	0.984	0.913	0.990	-0.875	0.937
pH	0.946	-0.907	1	-0.844	-0.783	-0.945	0.854	-0.811
TartA	-0.956	0.984	-0.844	1	0.965	0.973	-0.908	0.979
MA	-0.873	0.913	-0.783	0.965	1	0.927	-0.965	0.998
VA	-0.990	0.990	-0.945	0.973	0.927	1	-0.923	0.947
GA	0.859	-0.875	0.854	-0.908	-0.965	-0.923	1	-0.962
Am	-0.902	0.937	-0.811	0.979	0.998	0.947	-0.962	1

Values in bold are different from 0 with a significance level alpha=0.05; (S – sugars; TA –titratable acidity; TartA-tartaric acid; MA-malic acid; VA-volatile acidity; GA –gluconic acid; Am – ammonia)

Conclusions

Compared to red grape varieties, the dynamics of sugar accumulation in white grape varieties were lower. At the time of harvest, the sugar content in white varieties exceeded 187 g/l, while for red varieties it was over 204 g/l, values specified by the standards for grape quality at harvest in the specifications for the production of wines with controlled designation of origin (D.O.C.) Miniş. The sugars in the grape must decreased during the fermentation process to a residual value of 1.5–2.2 g/l, indicating the production of dry wines. The alcohol volume exceeded 11% for the varieties 'Fetească Regală', 'Merlot', and 'Cabernet Sauvignon', meeting the minimum natural alcohol strength required by the D.O.C. Miniş standards. However, the 'Mustoasă de Măderat' variety, with an alcohol content of 10.98% vol. alc., did not meet this criterion in 2024. The 'Mustoasă de Măderat' variety recorded the highest total acidity but remained within the typical characteristics of the variety and the cultivation area. Following the organoleptic evaluation of the resulting white and red wines, it was determined that the wines exhibited the characteristics and specificity of each analyzed variety. The PCA analysis provides valuable insights into the ripening process and quality profiles of different grape varieties. It reveals that sugar content increases while titratable acidity, malic acid, and ammonia decrease as grapes mature, following a typical ripening pattern. Each variety exhibits distinct compositional characteristics: Fetească Regala is marked by higher free SO₂ and residual sugars, Mustoasa de Maderat by high acidity, 'Cabernet Sauvignon' by elevated volatile acidity, and 'Merlot' by a balanced profile

with moderate pH and alcohol levels. These findings can guide optimal harvest timing and winemaking strategies to enhance the quality of each grape variety.

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