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ENOCHEMICAL AND SENSORY CHARACTERIZATION OF SELECTED GEORGIAN GRAPEVINE CULTIVARS: TABIDZISEULI, KAKHURI TETRI AND DAISI

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Abstract

Georgia, recognized as the cradle of wine and viticulture, preserves an exceptional grapevine gene pool of over 525 autochthonous cultivars, forming a vital foundation for modern breeding programs focused on developing disease-resistant and high-quality varieties. This study reports the preliminary results from 2024-2025 of a complex study including enological, enochemical, and organoleptic characteristics was conducted of three Georgian breeding cultivars - Tabidziseuli, Kakhuri Tetri, and Daisi - selected for their productivity, and enological potential which was selected based on the available information on these varieties. This study aimed to evaluate the ripening dynamics, technological maturity, and enological potential of three Georgian grape cultivars - Daisi, Tabidziseuli and Kakhuri Tetri - over a two-year period 2024-2025. Initial juice sugar concentrations ranged from 18.5-22.5 % values. In the second year, harvest dates were determined individually for each variety according to their specific ripening patterns. The ripening period was observed between March and October 2025. The earliest harvest was completed between September 17 and October 14. Juice yield ranged from 41% to 53%. Sensory evaluation was also conducted for the wine produced from the Daisi cultivar, which revealed its profile characterized by moderate alcohol content, above-average acidity, and below-average tannin levels. These characteristics underline the background information identifying this grape as a suitable cultivar for cold and high-altitude mountain regions. These results provide insights into the phenological behavior and technological potential of local cultivars, supporting their optimal use in differentiated enological approaches and future vineyard management strategies.

Keywords: Georgian grapevine, breeding cultivars, enochemical analysis, sensory evaluation

1. INTRODUCTION

Grapevine breeding plays a critical role in modern viticulture, addressing challenges related to climate change, disease resistance, and sustainability.
In many wine regions, traditional cultivars are increasingly vulnerable to fungal pathogens and environmental stress, prompting international programs - notably in Germany, France, and Italy - to develop PIWI (fungus-resistant) varieties such as Regent, Souvignier Gris, and Calardis Blanc.
Institutions like the Julius Kühn Institute (JKI) and the Geilweilerhof Research Center for Grapevine Breeding have led these advances, integrating resistance with high enological quality [1]. Georgia, acknowledged as the cradle of wine, possesses more than 525 autochthonous grapevine cultivars, offering a unique genetic reservoir for breeding [2].
This diversity enables the creation of new varieties combining local adaptability, flavor typicity, and improved resistance. Georgian researchers - including Tabidze, Ramishvili, Kikacheishvili, Shavishvili and Mgeladze - significantly contributed to this field by developing locally adapted breeding cultivars [3].
Among them, *Tabidziseuli, Kakhuri Tetri* and *Daisi* represent key outcomes of Georgian selection. Tabidziseuli is valued for its balanced sugar–acid ratio, Kakhuri Tetri for disease tolerance and enological potential and Daisi for its adaptability to cooler, mountainous terroirs.
However, limited enochemical and sensory data exist for these cultivars under contemporary analytical standards [4].
This study presents the 2024-2025 preliminary characterization of these three Georgian breeding cultivars, focusing on their chemical composition, sensory attributes, and adaptability, thereby contributing to the broader context of sustainable and climate-resilient viticulture. In addition to the existing information on the selected grape cultivars and their presumed resistance to environmental factors, this research also focused on exploring their potential to produce wines with distinctive organoleptic profiles and high quality. Emphasizing these characteristics aims to contribute to the diversification of Georgian wine styles and to highlight the enological potential of underutilized local varieties [5].

2. MATERIALS AND METHODS

Jighaura Collection

The study was conducted at the Jighaura experimental base of the Scientific-Research Center of Agriculture in eastern Georgia, where the grapevine cultivars *Daisi*, *Tabidziseuli* and *Kakhuri Tetri* are cultivated within the national germplasm collection. Each variety was represented by 10-20 vines trained on a bilateral cordon system under uniform vineyard management. The site lies in a temperate climatic zone with hot summers and cold winters; the mean annual temperature is 10.8 °C, with about 22 °C during the warmest months.
The annual sum of active temperatures ranges between 3440 and 3670 °C, mean annual precipitation is 540–590 mm, and relative humidity averages 60–62%.
The soil is loose-textured, gravelly brown, with good drainage, moderate water-holding capacity, and a pH of 7.8–8.1.

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Potassium content is moderate, while phosphorus and nitrogen are relatively low; organic matter ranges between 1.4% and 1.6%, providing balanced fertility for controlled vine growth. These conditions collectively support the evaluation of cultivar adaptability, productivity, and enological potential under representative Georgian terroir [6].

Sugar Level Monitoring

Sugar accumulation in the grapes was monitored directly in the vineyard throughout the ripening period. Berry samples were collected at regular intervals from representative vines, and sugar concentration (°Brix) was measured using a laboratory refractometer. This allowed tracking of ripening dynamics and determining the optimal harvest time for each cultivar [7].

Determination of Grape Juice Yield

Juice yield was determined according to the OIV standard method "Determination of must yield by centrifugation of grapes" (OIV-MA-AS312-01). Grape berries (100–200 g) were crushed and centrifuged at 3000–5000 rpm for 10–15 min. The juice was weighed, and yield was expressed as a percentage of the total berry weight [8].

Vinification Approaches

Two enological approaches were applied: fermentation without skin contact and fermentation with skin contact. For the classical vinification, clarified juice was separated after a three-day settling period and fermented with neutral cultured yeast at 16–17 °C. For the skin-contact vinification, grapes were fermented at 26–27 °C to enhance phenolic and aromatic extraction. This comparative approach allowed the evaluation of the most suitable fermentation method for expressing the varietal character and enological potential of the studied cultivars [9].

Biochemical and Eno-carpological Analyses

These analyses were performed to determine the compositional characteristics of grape berries and wines. The quantification of anthocyanins and total phenolic compounds in grape juice and finished wine was conducted according to the COST Action FA1003 standardized methodology [10].

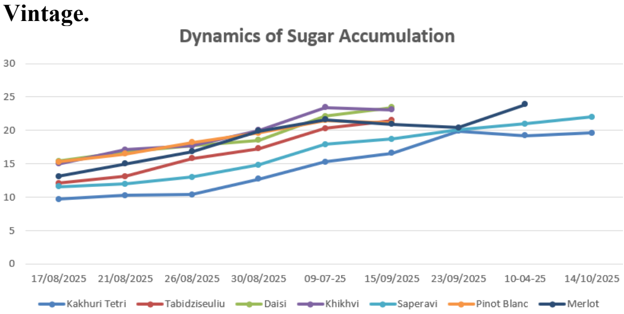
Sensory Evaluation

Sensory evaluation was conducted using the Quantitative Descriptive Analysis (QDA) method in accordance with ISO 13299:2016. A trained panel of ten assessors, including professional Georgian sommeliers and wine experts, evaluated the wines under controlled sensory conditions. Visual, aroma, taste, and mouthfeel attributes were assessed on a 10-point intensity scale using ISO-standard wine glasses at 12–14 °C for white wines and 16–18 °C for red wines. Samples were presented in randomized order to minimize bias. Statistical analysis, including ANOVA, was applied to identify significant differences among cultivars and to establish relationships between sensory attributes and enochemical composition [11].

3. RESULTS

In 2025, monitoring of sugar accumulation in the three Georgian breeding cultivars - *Daisi, Tabidziseuli*, and *Kakhuri Tetri* - together with the control varieties *Khikhvi, Saperavi, Pinot Blanc*, and *Merlot*, revealed distinct ripening dynamics under the specific agro-climatic conditions of the Jighaura site. The overall ripening period extended from 17 August to 14 October, enabling determination of technological maturity for each variety. Among the studied cultivars, *Daisi* reached maturity first (17 September), showing rapid sugar accumulation and balanced acidity, followed closely by the early-ripening control variety *Khikhvi*, which exhibited similar sugar levels. *Pinot Blanc* achieved full maturity shortly thereafter, confirming its adaptation to local conditions. *Tabidziseuli* ripened during the mid-season, while *Merlot* reached harvest readiness on 4 October 2025, slightly earlier than *Kakhuri Tetri* (14 October). *Saperavi* was the last to ripen, consistent with its late-maturing genetic background. These data provide a foundation for evaluating the biochemical composition and enological potential of the Georgian breeding cultivars in relation to both local and international standards.

Figure 1. Dynamics of Sugar Accumulation in Georgian Breeding and Control Grapevine Cultivars During the 2025 Vintage.



Note: Heavy rainfall during September 7-15 and September 23-October 4 affected ripening dynamics, causing a slight dilution effect and temporary decline in sugar levels in some cultivars.

Evaluation of yield data indicated that among the studied cultivars, *Tabidziseuli* exhibited the highest juice yield (53%), followed by *Daisi* (44%) and *Kakhuri Tetri* (41%). These results emphasize the distinct technological potential of the cultivars, particularly the suitability of *Tabidziseuli* for achieving greater juice extraction efficiency.

Table 1. Juice yield of the studied Georgian grape cultivars (2025 vintage)

Cultivar	Juice yield (%)
Tabidziseuli	53
Daisi	44
Kakhuri Tetri	41

Note: Values represent average juice yield per cultivar during the 2025 harvest.

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To produce primary and high-quality wines from the selected grape cultivars, a controlled micro-vinification process was applied. Grape sorting and crushing were carried out manually under small-scale experimental conditions. Each batch was divided into two parts: for white varieties, white and amber wines were produced; for red varieties, rosé and red wines were obtained. Both white and red winemaking followed the same conceptual framework — fermentation with and without skin contact — in order to evaluate the influence of maceration and temperature on phenolic and aromatic extraction.
The 2024 harvest was carried out on 10 September in order to establish the indicative period of technological maturity for the selected grape cultivars for future reference.

Table 2. Grape must parameters at harvest (2024 vintage)

Cultivar	Sugar (Brix %)	Titratable acidity (g/L)	pH	Total phenols (mg/L)
Daisi	22.5	5.4	3.2	10.0
Kakhuri Tetri	18.5	6.8	3.0	7.3
Tabidziseuli	18.8	7.5	3.1	4.2
Khikhvi	22.3	5.4	3.2	13.8
Saperavi	23.2	7.1	3.1	23.1

Note: Values correspond to grape must composition measured at harvest on 10 September 2024.

During the 2025 vintage, the investigated grape cultivars were harvested at their respective optimal stages of technological ripeness to ensure the production of wines with desirable compositional balance and sensory quality. Pronounced varietal differences were observed in the key indicators of technological maturity. The cultivar *Daisi* exhibited the highest soluble solids concentration (23.4%), reflecting a strong sugar accumulation capacity and advanced ripening potential. *Tabidziseuli* reached a slightly lower sugar level (21.8%) but maintained the highest total acidity (6.8 g/L), indicative of a balanced compositional profile suitable for fresh and structured wine styles. In contrast, *Kakhuri Tetri* showed comparatively lower sugar (19.6%) and acidity (4.4 g/L) values, suggesting a delayed ripening pattern and a potential for producing lighter, more delicate wines. The pH values remained consistently low (2.9–3.0) across all cultivars, indicating favorable conditions for microbiological stability and the preservation of freshness in the resulting wines.

Table 3. Technological maturity parameters of the studied grape cultivars at harvest (2025 vintage)

Cultivar	Sugar (Brix %)	Titratable Acidity (g/L)	pH
Daisi	23.4	5.2	3.0
Tabidziseuli	21.8	6.8	2.9
Kakhuri Tetri	19.6	4.2	3.4
Khikhvi	24.4	5.3	3.0
Saperavi	24.2	7.5	3.3
Pinot Blanc	21.0	4.6	2.9
Merlot	23.9	4.7	3.1

Note: Optimal harvest timing was determined based on technological maturity to maximize wine quality potential.

Among the three studied cultivars, *Kakhuri Tetri* exhibited the latest ripening behavior. This was evidenced by its lowest sugar concentration at the fixed 2024 harvest date (18.5 °Brix) and by its later harvest time in 2025 (14 October), when the sugar level reached 19.6%. In contrast, *Daisi* demonstrated the earliest ripening, attaining the highest sugar content (22.5 °Brix in 2024 and 23.4% in 2025) and being harvested first, on 15 September 2025. *Tabidziseuli* displayed an intermediate ripening pattern, with moderate sugar levels at both harvests (18.0 °Brix in 2024 and 21.8% in 2025) and a harvest date coinciding with that of *Daisi* in 2025. These ripening dynamics highlight distinct differences in maturation timing among the cultivars, which are critical for determining optimal harvest schedules and achieving the desired wine styles and quality attributes.
As part of the 2024 vintage study, wines produced from the Georgian breeding cultivars *Daisi, Tabidziseuli*, and *Kakhuri Tetri*, together with the control variety *Khikhvi* and the reference cultivar *Saperavi*, were analyzed for color hue, color intensity, total anthocyanin content, and total phenolic concentration. Vinification was carried out in two modalities: with skin contact (resulting in red and amber wines) and without skin contact (producing white and rosé wines). The results clearly demonstrate the significant effects of both cultivar and maceration regime on pigment extraction and the overall phenolic composition of the wines (Table 4).

Table 4. Phenolic and Chromatic Characteristics of Wines from Selected and Control Georgian Grape Cultivars (Vintage 2024)

Cultivar	Wine Type	Color Tone	Color Intensity	Anthocyanins (mg/L)	Total Phenols (g/L)
Daisi	Rosé	0.93	0.96	49.14	0.44
Daisi	Red	1.00	7.77	603.80	0.74
Saperavi	Rosé	0.67	1.77	73.25	0.43
Saperavi	Red	1.00	8.50	856.76	8.60
Tabidziseuli	White	—	—	—	0.14
Tabidziseuli	Amber	—	—	—	0.24
Kakhuri Tetri	White	—	—	—	0.27
Kakhuri Tetri	Amber	—	—	—	0.48
Khikhvi	White	—	—	—	0.34
Khikhvi	Amber	—	—	—	0.83

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Note: Anthocyanin concentrations are expressed as mg malvidin-3-glucoside equivalents per liter; total phenols are expressed as gallic acid equivalents (g/L). Malvidin analysis in Daisi and Saperavi wines indicated non-detectable levels (0 mg/L). Data represent mean values from replicate measurements conducted under identical vinification conditions.

Among the red wines, *Saperavi* exhibited the highest color intensity (8.50) and anthocyanin concentration (856.76 mg/L), confirming its strong pigmentation capacity and serving as a benchmark for high-color potential varieties.

Daisi presented intermediate chromatic attributes, with a color intensity of 7.77 and an anthocyanin concentration of 603.80 mg/L, while also maintaining a balanced phenolic content (0.74 g/L). These characteristics suggest its versatility and suitability for the production of both red and rosé wine styles.

Amber wines produced from *Kakhuri Tetri* and *Tabidziseuli* displayed moderate total phenolic concentrations (0.48 g/L and 0.24 g/L, respectively), reflecting the limited yet effective extraction occurring during skin-contact fermentation.

The amber wine derived from *Khikhvi* exhibited a comparatively pronounced phenolic profile (0.83 g/L), consistent with its long-established role in traditional Qvevri winemaking practices.

Table 5. Main Physicochemical Parameters of Wines from Selected Georgian Grape Cultivars (Vintage 2024)

Cultivar	Wine Type	Alcohol (% v/v)	Reducing Sugars (g/L)	Total Acidity (g/L)	pH	Volatile Acidity (g/L)	Dry Extract (g/L)
Tabidziseuli	White	10.3	1.00	6.30	3.47	0.65	15.5
Tabidziseuli	Amber	10.1	1.11	6.1	3.83	0.74	20.6
Kakhuri Tetri	White	10.5	1.00	5.2	3.16	0.39	12.9
Kakhuri Tetri	Amber	9.8	1.00	4.9	3.54	0.41	17.8
Khikhvi	White	13.5	2.55	5.00	3.36	0.48	16.9
Khikhvi	Amber	13	1.08	3.3	4.1	0.57	51
Daisi	Rosé	12.6	1.00	5.1	3.58	0.67	14.8
Daisi	Red	12.1	1.00	5.6	3.65	0.54	21.2
Saperavi	Rosé	12.7	1.00	6.4	3.41	0.46	17.1
Saperavi	Red	12.1	1.71	7.00	3.66	0.44	23.8

Note: Higher juice sugar levels corresponded to higher wine alcohol, as expected from normal fermentation. A slight reduction in acidity occurred in most samples, typical of tartaric acid loss during winemaking.

Table 6. Results of the 2024 vintage – analysis of malic acid, lactic acid, and nitrogenous compounds in wines

Cultivar	Wine Type	Malic Acid (g/L)	Lactic Acid (g/L)	Nitrogenous Compounds (mg/L)
Tabidziseuli	White	3.06	0.00	31.00
Tabidziseuli	Amber	2.17	0.24	93.00
Kakhuri Tetri	White	2.00	0.15	30.00
Kakhuri Tetri	Amber	2.26	0.02	60.00
Khikhvi	White	2.00	0.14	0.00
Khikhvi	Amber	1.64	0.19	66.00
Daisi	Rosé	1.95	0.29	3.00
Daisi	Red	2.26	0.00	38.00
Saperavi	Rosé	2.89	0.00	0.00
Saperavi	Red	3.03	0.42	0.11

Note: Malic acid concentrations were higher in white wines and slightly lower in amber wines, indicating partial degradation during fermentation. Lactic acid levels remained low, showing that malolactic fermentation was limited, except in Saperavi Red where conversion was more evident. Nitrogenous compound concentrations were notably higher in amber wines, likely due to extraction from grape skins and solids during extended maceration.

The organoleptic evaluation of *Daisi* wines was conducted in accordance with ISO standards for sensory analysis. A panel of more than 15 international wine experts and sommeliers participated in the assessment, providing a detailed sensory characterization of wines produced from the *Daisi* grape. The evaluation encompassed key sensory parameters such as appearance, aroma, flavor profile, balance, and overall harmony. The assessment of other wine samples is currently in progress; therefore, their organoleptic results are not yet available.

Diagram 1. Aromatic profile of 2024 vintage Daisi wines

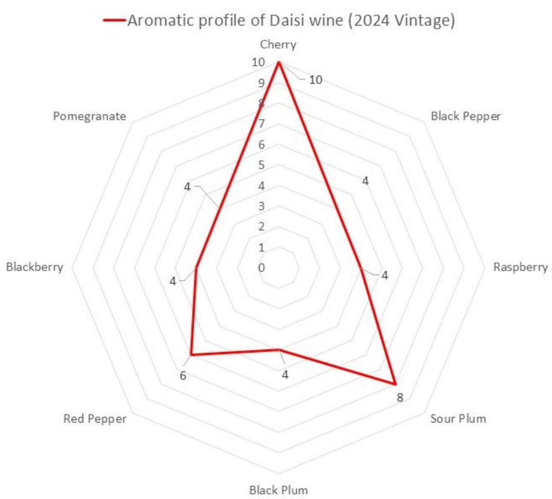

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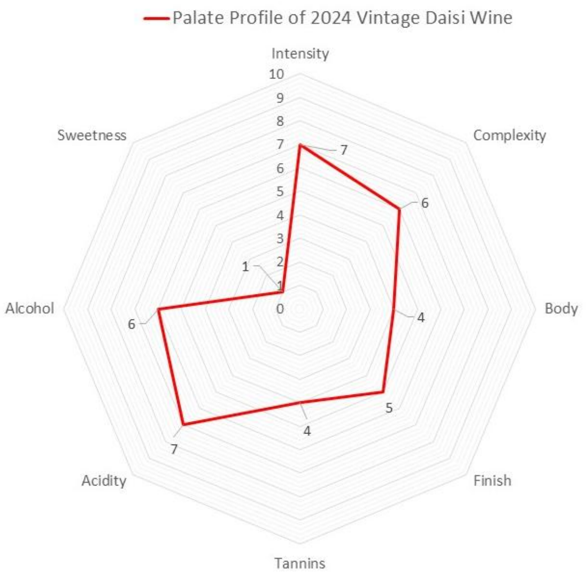
Diagram 2. Palate Profile of 2024 Vintage Daisi Wine



Organoleptic evaluation revealed the distinctive varietal profile of *Daisi* wine, characterized by aromas of cherry, black plum, pomegranate, black and red pepper, raspberry, and blackberry. The sensory panel showed consistent assessments, describing the dry wine as moderately high in acidity, imparting freshness, and with soft, silky tannins. Depending on sugar accumulation, *Daisi* wines may achieve medium to high alcohol content; higher-alcohol wines typically require longer maturation to reach optimal balance, whereas medium-alcohol wines are ready for earlier consumption.

4. CONCLUSIONS

This study evaluated the ripening dynamics, technological maturity, and enological characteristics of the Georgian breeding cultivars *Tabidziseuli*, *Kakhuri Tetri*, and *Daisi*. The varieties exhibited distinct sugar–acid balances and compositional profiles under the climatic conditions of eastern Georgia. *Daisi* demonstrated advanced technological maturity and produced well-balanced rosé and red wines. *Tabidziseuli* showed moderate ripening behavior with stable acidity, whereas *Kakhuri Tetri* yielded lighter wines characterized by pronounced aromatic expression.

Wine composition analyses confirmed high technological quality across all cultivars, and phenolic and sensory evaluations further highlighted clear varietal typicity, structural balance, and harmony between composition and sensory perception.

Overall, these findings underscore the strong enological potential of the studied cultivars to contribute to grapevine biodiversity, promote sustainable viticulture, and diversify Georgia's portfolio of distinctive and regionally expressive wine styles.

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