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Comparative Assessment Of Vinegar Production Potential From Technical Grape Varieties In The Tashkent Region

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Abstract: This study evaluates the technological potential of four distinct technical grape varieties – Pinot Noir, Bayan Shirey, Saperavi, and Cabernet Sauvignon for vinegar production under the specific pedoclimatic conditions of the Tashkent region, Uzbekistan. By systematically analyzing the initial sugar content, must volume, and subsequent dilution requirements, the research identifies the correlation between raw material composition and final vinegar yield. The results indicate that while red varieties like Pinot Noir exhibit superior sugar accumulation, the white variety Bayan Shirey demonstrates the highest total volumetric yield (1.6 L), driven by superior must extraction rates.

Keywords: Grape, vinegar, technical varieties, Brix, sugar, must, pulp, pomace, dilution factor.

Introduction: The diversification of viticultural processing remains a strategic priority for the agricultural sector of Uzbekistan. While the production of table wines and fresh grapes has historically dominated the industry, there is a growing market demand for locally sourced, biologically active fermented products, specifically natural wine vinegar. The Tashkent region, situated in a zone of distinct continentality, provides a unique agro-climatic framework where the high insolation and extended growing season promote the rapid accumulation of soluble solids (sugars) in technical grape varieties.

However, this high sugar content poses a specific technological challenge for acetous fermentation: excessive ethanol concentrations resulting from complete alcoholic fermentation can inhibit Acetobacter activity. Therefore, determining the optimal balance between initial sugar concentration, must yield, and the necessary dilution coefficients is critical for maximizing production efficiency.

This study aims to scientifically validate the processing parameters for four distinct varieties:

1. Pinot Noir and Cabernet Sauvignon: Classic international red varieties known for high extract content.
2. Saperavi: An ancient Georgian variety widely acclimatized in Central Asia.
3. Bayan Shirey: A high-yielding white variety (autochthonous to Azerbaijan but historically dominant in Uzbek technological vineyards) known for its vigorous growth and abundant juice production.

METHODS

Raw Material Acquisition. The grapes were harvested at technical maturity from vineyards located in the Kibray and Parkent districts of the Tashkent region. The harvest timing was determined by the achievement of a target Brix level sufficient for winemaking, which in the conditions of the Tashkent region often exceeds standard European parameters due to rapid sugar accumulation (gluconeogenesis) triggered by high summer temperatures.

Technological Protocol. The experimental production followed a dual-stage fermentation pathway:

Primary Alcoholic Fermentation: The grapes were crushed and destemmed. For red varieties, fermentation on skins was conducted to extract anthocyanins and tannins, whereas for Bayan Shirey, the juice was separated immediately.

2. Dilution and Correction: To prevent osmotic stress on acetic acid bacteria and to standardize the final acid concentration, the mash was diluted with water. The "Required Sugar Amount" was standardized at 110 g/L, which is the theoretical optimum for producing vinegar with 6%-9% acidity without residual alcohol toxicity.

3. Acetous Fermentation: The alcoholic wash was inoculated with a selected strain of Acetobacter aceti. Fermentation was conducted in submerged culture with active aeration at 28±1°C.

Calculation of Yields. Total vinegar yield was calculated as the sum of the liquid fraction obtained from the free-run must, the pressed pulp, and the secondary extraction from the pomace (water extraction of residual sugars/alcohol from skins).

RESULTS AND DISCUSSION

The experimental data, summarized in Table 1 (see previous section), reveals significant divergences in the technological behavior of the studied varieties.

Biochemical Characteristics of the Must. The analysis of the initial raw material highlights the impact of the Tashkent region's thermal regime. Pinot Noir exhibited the highest sugar concentration at 24°Bx (240 g/L), confirming its tendency to rapidly accumulate carbohydrates in hot climates. Similarly, Saperavi and Cabernet Sauvignon reached 23°Bx. In contrast, Bayan Shirey showed a more moderate sugar accumulation of 18°Bx (180 g/L). While lower sugar content is typically viewed as a disadvantage in winemaking, for vinegar production, it proved advantageous as it required significantly less dilution (0.6 L water/L) compared to the red varieties (1.1-1.2 L water/L).

Dilution Factors and Volumetric Efficiency. A critical finding of this research is the non-linear relationship between sugar content and final product volume.

- The "Sugar Trap": Although Pinot Noir possessed the highest potential alcohol (and thus acetic acid) per liter of juice, the necessity to dilute it by a factor of 2.2 (adding 1.2 L of water per liter of solution) meant that the final volume was heavily dependent on the initial volume of juice available.
- The "Volume Advantage": Bayan Shirey, despite lower sugar, produced the highest initial must volume (800 ml) and pulp mass (975 g). Consequently, even with a lower dilution factor (1.6), it achieved the highest total vinegar yield of 1.60 L. This demonstrates that in vinegar production, the physical yield of juice (rheological factor) can outweigh the chemical concentration of sugar (biochemical factor).

Table 1.

Vinegar yield from technical grape varieties under the agro-climatic conditions of the Tashkent region (Uzbekistan)

Grape varieties / Parameters	Pinot Noir	Bayan Shirey	Saperavi	Cabernet Sauvignon
Brix, °Bx	24	18	23	23
Sugar, g/l	240	180	230	230
Required sugar amount, g/l	110	110	110	110
Must, ml	700	800	650	700
Pulp (Mash), g	925	975	945	985
Pomace, g	230	155	155	150
Dilution factor	2.2	1.6	2.1	2.1
Water added per 1 L of solution, l	1.2	0.6	1.1	1.1
Vinegar from must, l	0.65	0.75	0.61	0.65
Vinegar from pulp, l	0.7	0.74	0.72	0.75
Vinegar from pomace, l	0.16	0.11	0.11	0.1
Total vinegar volume, l	1.51	1.6	1.44	1.5

Fractionation of Yield. The distribution of vinegar recovery from different processing fractions provides insight for waste management:

- Vinegar from Pomace: The highest recovery of secondary vinegar from pomace was observed in Pinot Noir (0.16 L), correlating with its high skin-to-juice ratio and significant pomace mass (230 g). This suggests that Pinot Noir processing residues retain high value and should be subjected to secondary fermentation to maximize economic return.

- Extraction Efficiency: Cabernet Sauvignon showed the lowest pomace mass (150 g) but a high yield from pulp (0.75 L), indicating that this variety releases its liquid fraction efficiently during the primary pressing/fermentation stage, leaving little residual value in the solid waste.

CONCLUSION

The comparative assessment of technical grape varieties for vinegar production in the Tashkent region leads to the following conclusions:

1. Optimal Volumetric Yield: Bayan Shirey is the superior candidate for bulk vinegar production, yielding 1.6 L of finished product per unit of raw material. Its moderate sugar content minimizes the need for excessive water usage, making the process more resource-efficient.

2. High-Concentration Potential: Pinot Noir and Cabernet Sauvignon, while requiring substantial dilution due to high Brix (23-24°Bx), offer the potential for producing premium, high-extract vinegars. The significant yield from Pinot Noir pomace suggests a specific protocol for "double-fermentation" waste recovery is warranted.

3. Technological Recommendation: For producers in the Tashkent region, it is recommended to utilize Bayan Shirey for standard table vinegar due to its processing ease and high output, while reserving Pinot Noir and Saperavi for premium or balsamic-style vinegars where the concentration of phenolic compounds (anthocyanins) is prioritized over total volume.

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