COMPARISON OF MECHANIZED AND MANUAL GRAPE HARVESTING ON SELECTED PARAMETERS OF MUST AND OXYGEN CONTENT

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Abstract
This study examines the impact of mechanized and manual grape harvesting on selected physicochemical parameters and dissolved oxygen content in must from two grape varieties—Traminer red and Riesling Italico—harvested in the Nitra region during 2023. Grapes were collected in both morning and late-morning intervals and processed under controlled winemaking conditions. Measurements included total soluble solids (TSS), acid content, temperature during harvest and after destemming, and oxygen concentration in must. Results showed that neither harvesting method nor time significantly influenced dissolved oxygen levels. However, mechanized harvesting in cooler early mornings yielded musts with marginally higher TSS and acidity, lower dissolved oxygen, and must temperatures up to 12 °C lower than those from manual harvests. The highest acetic acid (0.56 g/L) occurred in midday manual Traminer, and the lowest (0.31 g/L) in early-morning mechanized Riesling. No consistent oxygen trends were associated with harvesting time alone. These findings support mechanized harvesting as an efficient alternative to manual picking, offering labor savings without compromising must quality, making it a valuable tool for modern viticulture under increasing economic and workforce pressures.

Key words: *harvest, acetic acid, mechanized harvest, temperature of grapes*

INTRODUCTION

There are many factors that influence the concentration of phenolics in wine. Researchers have extensively studied these parameters, focusing particularly on differences between grape varieties, agronomic techniques used in vineyards, and the winemaking process. They have investigated the correlation between total phenolic content, anthocyanins, and antioxidant potential, and found only a weak correlation between yield and these parameters (Radonjić, et al., 2019). The phenolic content of wine plays a decisive role in its organoleptic properties and, consequently, its quality. Numerous internal and external factors significantly influence the concentration of phenolic compounds. Researchers have examined some of these variables with the aim of controlling and/or modifying phenolic concentration and the related sensory characteristics of wine. Factors affecting phenolic content can be grouped as follows: Vineyard/vine factors – cultivation method *(organic or conventional)*, use of biostimulants, climatic conditions, and varietal diversity; Wine production factors – pre-fermentation maceration, post-fermentation maceration, electric field treatment and thermovinification, fining agents, additives, filtration, yeast strain, and bacterial species *(Gutiérrez-Escoba, et al., 2021)*. Hand harvesting offers certain advantages, including selectivity *(avoiding rotten or unripe bunches)*. However, it is labor-intensive and limited to daylight hours, when higher temperatures can accelerate premature fermentation *(Kurtural & Fidelibus, 2021)*. Grapes harvested manually are typically collected in enameled or plastic buckets, then transferred to boxes, containers, or special trailers. From an economic and productivity standpoint, stacking boxes or containers is generally the most suitable method. Using plastic bags or other closed packaging poses the risk of rapid moisture loss, rendering grapes unsuitable for winemaking. Even in open containers, evaporation can occur if grapes are not processed within a week *(Balík & Stávek, 2017)*. Hand harvesting is the only suitable method for organic grape processing, as mechanized harvesting is prohibited for organic production in many wine regions and countries *(Domin et al., 2017)*. Ailer *(2016)* states: "In mechanized harvesting, we harvest grapes using harvesting equipment. In common communication, the incorrect term "harvester" is used for these devices; the more correct term is "picker". The principle of mechanized harvesting is to destem the grapes in the vineyard as carefully as possible. Using special spring-loaded fingers, the picker removes the grapes from the bunches, and they are transported to the storage bin by a conveyor." Modern grape harvesters also destem grapes — or rather collect the berries themselves. For this method, it is important to assess the readiness of the grapes in terms of variety, maturity, and health status. It is recommended to first manually remove unsuitable bunches, such as those that are rotten, sour, or unripe, before using a mobile harvester *(Balík & Stávek, 2017)*. Mechanized harvesting helps overcome the disadvantages of manual harvesting, particularly in terms of technical and economic factors, such as timely intervention and the ability to harvest grapes with uniform ripeness. This has a positive impact on both grape quality and the resulting wine. The introduction of machines that reduce costs therefore improves the farm's economic performance and supports product quality—an increasingly strategic factor in times of globalization, when, thanks to modern trade and telecommunications, food products can reach even the most distant markets. In recent years, especially in developed countries, there has been a notable increase in the number of workers willing to harvest agricultural products by hand. This phenomenon has social implications, as such work is typically carried out by individuals engaged in less demanding jobs. In industrialized nations, these workers often come from developing countries and may not be fully adapted to local labor standards *(Sgroi, 2023)*. The main factor driving winegrowers toward mechanization is the goal of reducing production costs. Lowering the expense of mechanized systems without compromising product quality is the most effective way to remain competitive in the global market *(Pezzi & Martelli, 2015)*. While mechanized grape harvesting is less selective, it requires far fewer workers, is much faster, and can be performed at night. Under favorable conditions, approximately 5 tons of grapes can be harvested per hour during nighttime, when lower temperatures help preserve quality and reduce the risk of premature fermentation. When speed is essential, mechanized harvesting is the optimal choice. The efficiency of mechanical harvesters gives growers greater control over harvest timing than is possible with manual methods *(Kurtural & Fidelibus, 2021)*. Therefore, the aim of this study was to compare the effects of mechanized and manual grape harvesting, conducted at different times of day, on selected physicochemical parameters of must and its dissolved oxygen content in two grape varieties *(Traminer red and Riesling Italico)*.

MATERIALS AND METHODS

The research took place in the agronomic year 2023 in the Nitra wine-growing area. The harvest was carried out on September 4, 2023, in the time interval 7:00 - 8:00 *(morning harvest)* and 11:00 - 12:00 *(afternoon harvest)*. After harvesting, the grapes were treated with potassium pyrosulfate at a dose of 8 g/100 kg of grapes. The pressing was carried out gently using a hydropress and a maximum pressure of 0.1 MPa was used for all variants. After pressing and before fermentation, each variant was treated with the same enological preparations. The must was settled statically for 8 hours at a temperature of 8-10 °C and the fermentation took place in the temperature range of 15-18 °C. The analytical evaluation of the samples was carried out using an FT-IR spectrophotometer and the temperature values were measured using a portable thermometer with a needle.

Tab. 1 Added enological preparations after pressing and before fermentation

Name of preparate	Dosage *(g/hl)*
Lafazym CL *(Lafford, France)* [1]	1
Must bentonit *(Lallemand, Austria)* [1]	100
Vinosil Plus *(Lallemand, Austria)* [1]	15
Zymaflore X5 *(Lafford, France)* [2]	25
Thiazote PH *(Lafford, France)* [2]	50
Nutristart organic *(Lafford, France)* [2]	30

1 – added after pressing; 2 – added before fermantation

Tab 2. Designations of experimental variants

Variant designation	Variant characteristics
T A	Traminer red mechanized harvesting in morning 7:00 – 8:00

T B	Traminer red mechanized harvesting in afternoon 11:00 – 12:00
T C	Traminer red hand harvesting in morning 7:00 – 8:00
T D	Traminer red hand harvesting in morning 7:00 – 8:00
R A	Riesling Italico mechanized harvesting in morning 7:00 – 8:00
R B	Riesling Italico mechanized harvesting in afternoon 11:00 – 12:00
R C	Riesling Italico hand harvesting in morning 7:00 – 8:00
R D	Riesling Italico hand harvesting in afternoon 11:00 – 12:00

The oxygen content in must was quantified using an OXI 45 DL analyzer. The analytical principle is based on luminescence in combination with a platinum electrode immersed in the liquid matrix. The OXI 45 DL is specifically designed for the determination of total package oxygen *(TPO)* at various stages of the winemaking process, including grape processing, clarification, fermentation, maturation, and bottling. Monitoring TPO is essential because dissolved oxygen can influence oxidation reactions, affecting the color, aroma, and overall stability of the wine. Elevated oxygen levels during early stages of winemaking can accelerate the degradation of aromatic compounds and promote browning, whereas controlled oxygen exposure can contribute positively to wine maturation. By measuring TPO at different processing stages, winemakers can optimize handling techniques to minimize unwanted oxidation while maintaining the desired sensory profile and shelf life of the final product.

RESULTS AND DISCUSSION

Table 3 shows the basic physicochemical parameters of the musts in the monitored variants. The highest TSS content in the case of the Traminer variety was recorded in the variant T A, namely 23.60 °Bx. The lowest total sugar content was recorded in the variant T C, namely 23.10 °Bx. The highest acid content was recorded in the variant T A.

Tab. 3 Physico-chemical parameters of musts.

Parameters	**Variants**			
	T A	**T B**	**T C**	**T D**
FR	117.18±2.13	116.40±2.24	116.70±1.73	117.42±1.45
GL	107.30±1.11	107.88±1.68	108.95±1.21	107.72±1.53
TSS	23.60±0.30	23.50±0.30	23.10±0.30	23.50±0.20
MA	1.82±0.10	1.83±0.16	1.88±0.12	1.78±0.08
pH	3.35±0.08	3.32±0.10	3.33±0.05	3.37±0.08
TA	6.16±0.19	6.14±0.19	6.13±0.19	6.13±0.19
	R A	**R B**	**R C**	**R D**
FR	95.40±1.61	95.70±2.00	92.40±1.55	93.48±1.53
GL	87.32±1.80	87.43±1.04	84.58±0.60	85.48±1.71
TSS	19.72±0.31	19.78±0.29	19.18±0.15	19.42±0.10
MA	2.48±0.04	2.53±0.10	2.47±0.19	2.52±0.20
pH	3.10±0.09	3.12±0.08	3.03±0.05	3.02±0.10
TA	7.28±0.18	7.12±0.12	7.18±0.13	7.13±0.10

FR – fructose *(g/l)*, **GL** – glucose *(g/l)*, **TSS** – total soluble solids *(°Bx)*, **MA** – malic acid *(g/l)*, **TA** – total acid *(g/l)*, **TSS** – total soluble solids *(°Bx)*. a, b, c, d means that lines with a different letter are statistically different *(LSD test at 95 % significance level)*.

The highest TSS content in the case of the Riesling Italico variety was recorded in the variant R B, namely 19.78 °Bx. The lowest total sugar content was recorded in the variant R C, namely 19.18 °Bx. The highest acid content was recorded in the variant R A, namely 7.18 g/l. The lowest total acid content was recorded in the sample R B, namely 7.12 g/l. From a technological perspective, the higher TSS values in variants T A and R B may be linked to the ripeness of grapes at harvest and potentially to slight microclimatic differences in the vineyard at the time of picking. The observed differences in acidity and TSS between morning and afternoon harvests correspond with earlier observations by Modesti et al. *(2021)*, who emphasized the role of harvest timing in grape composition. The elevated acidity in variant T A suggests that cooler morning temperatures helped preserve organic acids, a common trend in early-day harvesting. In contrast, lower acidity in variant R B could be the result of higher afternoon temperatures, which can accelerate metabolic processes in the berries and reduce acid levels. Mechanized harvesting under cooler conditions *(T A, R A)* appears to help maintain both sugars and acids at desirable levels, which may positively influence fermentation kinetics and the sensory profile of the resulting wine. These results highlight the combined influence of harvest timing and method on must composition, even when overall differences appear modest. Similar findings on the role of cooler harvesting conditions in preserving grape acidity and aroma compounds were reported by Oršulová et al. *(2019)*.

Tab. 4 Comparison of temperature during harvest and pomace after destemming

Variant	HT *(°C)*	PT *(°C)*
T A	13.1±0.1	13.0±0.1
T B	18.4±0.2	17.4±0.6
T C	14.3±0.3	17.2±0.4
T D	19.1±0.1	25.1±0.1
R A	12.8±0.4	14.5±0.2
R B	20.3±0.2	17.7±0.4
R C	13.1±0.1	18.3±0.3
R D	19.8±0.2	24.2±0.2

HT – harvest temperature; **PT** – temperature of pomace

A clear influence of harvest time on grape temperature was observed in the measured data. Morning-harvested grapes *(variants T A, T C, R A, and R C)* showed lower HT values, generally between 12.8 and 14.3 °C, compared to afternoon-harvested grapes *(variants T B, T D, R B, and R D)*, which reached HT values from 18.4 to 20.3 °C. The PT values largely mirrored the initial HT readings, but with notable differences between harvest methods. In mechanized morning harvests *(T A, R A)*, PT remained close to HT, indicating minimal temperature increase during processing, most likely due to faster transfer from vineyard to press. By contrast, afternoon manual harvests *(T D, R D)* showed substantial increases after destemming, with PT reaching 24.2–25.1 °C, suggesting longer handling times and greater exposure to ambient heat. From an enological perspective, maintaining lower grape and pomace temperatures is advantageous, as it slows enzymatic and oxidative reactions, preserves varietal aromas, and reduces the risk of premature fermentation. The results suggest that both harvest timing and method influence final pomace temperature, with morning mechanized harvesting offering the greatest potential for temperature control. This benefit is particularly relevant in warm-climate regions, where rapid processing of cooler fruit can have a measurable positive impact on must quality. These results are consistent with the conclusions of Pezzi & Martelli *(2015)* and Mencarelli et al. *(2020)*, who highlighted the economic and qualitative advantages of mechanical harvesting under favorable conditions.

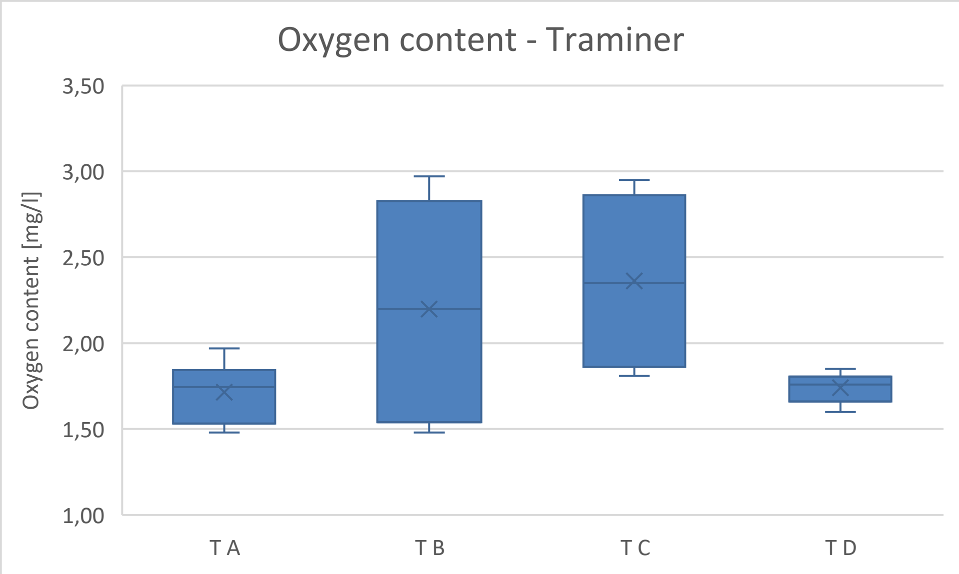

Fig. 1 Relationship between oxygen content and the method and timing of grape harvest – Traminer
T A – Traminer mechanized morning; **T B** – Traminer mechanized afternoon; **T C** – Traminer hand morning; **T D** – Traminer hand afternoon

The oxygen content in Riesling Italico must is presented in Figure 2. The highest average oxygen concentration was recorded in sample R B, representing mechanized harvesting in the afternoon, while the lowest value was found in sample R A, corresponding to mechanized harvesting in the morning. Despite these differences, no consistent trend was observed that would indicate a significant influence of harvest time on oxygen content under mechanized harvesting conditions. Interestingly, the data suggest a contrasting pattern between harvesting methods. In mechanized harvesting, afternoon picking tended to yield must with higher oxygen content, whereas in manual harvesting, the highest oxygen content was recorded in the morning harvest. This variation could be influenced by factors such as differences in grape temperature at processing, the extent of berry damage during handling, and the time elapsed between harvest and pressing. However, these effects do not appear strong enough to establish a statistically significant relationship, indicating that oxygen levels in must are likely influenced by a complex interplay of harvest method, timing, and post-harvest handling conditions. This trend was observed in both varieties studied.

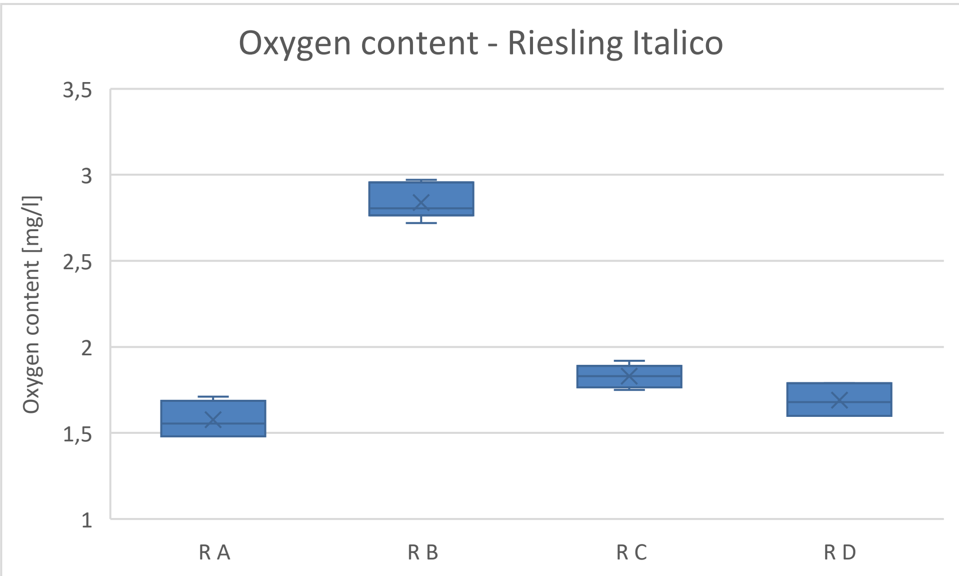

Fig. 2 Relationship between oxygen content and the method and timing of grape harvest. Riesling Italico

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R A – Riesling mechanized morning, **R B** – Riesling mechanized afternoon; **R C** – Riesling hand morning; **R D** – Riesling hand afternoon

CONCLUSIONS

The results of this study indicate that neither the harvesting method *(mechanized or manual)* nor the harvest time *(morning or afternoon)* had a statistically significant effect on the dissolved oxygen content in the must for the tested grape varieties. Nonetheless, certain trends were observed: mechanized harvesting in the morning was associated with slightly higher TSS and total acidity in Traminer, while afternoon mechanized harvesting produced higher TSS in Riesling Italico but slightly lower acidity. Temperature monitoring revealed that grapes harvested in the morning, particularly by mechanized methods, maintained lower fruit and pomace temperatures, which is advantageous for preserving aromatic compounds and minimizing oxidative processes. These findings suggest that, under controlled winemaking conditions, mechanized harvesting can match the quality parameters of manual harvesting while offering considerable labor savings and greater operational efficiency. The ability to harvest larger volumes rapidly, especially during cooler morning hours, makes mechanized harvesting a valuable tool for maintaining grape quality in the face of increasing economic pressures and workforce limitations. In warm-climate regions, optimizing harvest timing and minimizing delays in processing may further enhance must quality and improve overall wine stability.

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