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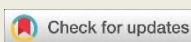
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EVALUATION OF SAFETY PARAMETERS IN RED WINE PRODUCTION PROCESSES

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Key words: *antioxidant protection system, red and white wines, molecular oxygen, technological processing, heat treatment, cold treatment, polyphenols, maceration.*

ABSTRACT

This study aims to evaluate the influence of technological processing methods on the antioxidant protection system and oxygen dynamics in dry white and red wines. The research focuses on secondary winemaking processes, including bentonite fining, cold treatment, and heat treatment. Samples were analyzed before and after processing to determine the concentration of molecular oxygen and the activity of antioxidant defense enzymes. The results indicate that technological interventions significantly affect oxygen concentration and antioxidant activity, with distinct differences observed between white and red wines. Heat treatment of red wines leads to an increase in oxygen concentration and activation of antioxidant mechanisms, while cold treatment enhances susceptibility to oxidative changes. White wines exhibit a more uniform response to fining and cold treatment but differ under thermal processing. The findings demonstrate that the selection and regulation of technological methods are critical for maintaining oxidative stability and preserving the quality characteristics of wines.

QIZIL VINO ISHLAB CHIQRARISH JARAYONLARIDA XAVFSIZLIK PARAMETRLARINI BAHOLASH

Kalit soʻzlar: *antioksidant himoya tizimi, qizil va oq vinolar, molekulyar kislorod, texnologik ishlov berish, issiqlik bilan ishlov berish, sovuq ishlov berish, polifenollar, makeratsiya.*

ANNOTATSIYA

Ushbu tadqiqot quruq oq va qizil vinolarda texnologik ishlov berish usullarining antioksidant himoya tizimi va kislorod dinamikasiga taʼsirini baholashga qaratilgan. Tadqiqot ikkilamchi vinochilik jarayonlari, jumladan bentonit bilan tiniqlashtirish, sovuq ishlov berish va issiqlik bilan ishlov berishni qamrab oladi. Namunalar ishlov berishdan oldin va keyin olinib, molekulyar kislorod konsentratsiyasi hamda antioksidant himoya fermentlari faolligi aniqlanib, solishtirildi. Natijalar texnologik aralashuvlar kislorod miqdori va antioksidant faollikka sezilarli taʼsir koʻrsatishini, shuningdek oq va qizil vinolar oʻrtasida muhim farqlar mavjudligini koʻrsatdi. Qizil vinolarda issiqlik bilan ishlov berish kislorod konsentratsiyasini oshiradi va antioksidant mexanizmlarni faollashtiradi, sovuq ishlov berish esa oksidlanishga moyillikni kuchaytiradi. Oqart vinolar tiniqlashtirish va sovuq ishlovga nisbatan oʻxshash javob beradi, ammo issiqlik taʼsirida farqli xatti-harakat kuzatiladi. Olingan natijalar vino sifatini saqlash va oksidlanish barqarorligini taʼminlashda texnologik usullarni toʻgʻri tanlash va boshqarish muhimligini tasdiqlaydi.

The strategic directions for the development of the national economy of Uzbekistan prioritize the expansion of the product range and the enhancement of the quality of food products, including those of the wine industry. In red wines, polyphenolic compounds inhibit the interaction between sulfur dioxide (SO₂) and oxygen. In general, SO₂ is required for the removal of hydrogen peroxide, while polyphenols function to suppress the “SO₂–oxygen” interaction. The full antioxidant effect in wine is realized only through the combined presence of SO₂ and oxygen. The relevance of this research is determined by the impact of technological operations that bring wine into contact with atmospheric oxygen (e.g., racking, container opening, filtration, and tannin addition) [1, P.3].

Despite extensive study, several aspects of oxygen-related reactions in wine remain insufficiently understood, necessitating further investigation. Cold stabilization of dry red wines has been shown to increase dissolved oxygen concentration, which poses a risk of oxidative degradation of phenolic coloring compounds, thereby altering the color and sensory characteristics of the wine.

Consequently, this technological method is recommended for red wines only in exceptional cases. In contrast, heat treatment also leads to an increase in oxygen concentration but simultaneously activates components of the antioxidant defense system, resulting in dismutation processes and the formation of organic peroxides. Over time, heat treatment enhances antioxidant activity; however, this increase is less pronounced compared to that observed under cold treatment conditions. An additional important parameter in food analysis is the antioxidant content [2, P.3].

The antioxidant spectrum of wines includes phenolic compounds of mono-, oligo-, and polymeric structures, anthocyanins, ascorbic acid, catechins, and tannins, all of which contribute to the formation of aroma and taste during technological processing and play a critical role in determining wine quality. It is well established that white and red wines differ significantly in both qualitative and quantitative composition. Given that antioxidants represent easily oxidizable components and considering the potential presence of radicals and reactive oxygen species [2, P.4], their interactions are of particular scientific interest. Therefore, the study of antioxidant defense enzymes and the comparative analysis of their behavior under different technological processing methods for wines of varying color appear highly relevant. In this study, technological processes associated with secondary winemaking—specifically bentonite fining and heat treatment—were selected for investigation [3, P.2]. Samples were collected before and after treatment. The concentration of molecular oxygen and the activity of enzymes within the antioxidant defense system (AOS) in dry white and red wines were determined and comparatively analyzed.

Table 1*Physical and chemical composition of the studied wines*

Studied material	Specific weight	Fortress %	Titrateable acid, mg/dm ³	Volatile acidity, g/dm ³	SO ₂ mg/dm ³
Dry white wine	0,987	10,8	5,2	0,59	96
Dry red wine	0,990	11,2	5,6	0,59	100

The studied enzymatic systems of antioxidant protection are inherently complex; consequently, the technological methods applied in winemaking exert differential and, in some cases, non-uniform effects on their activity. The highest concentration of molecular oxygen (10.64 mg/cm³) was recorded in dry red wine following heat treatment, whereas the lowest concentration (1.71 mg/cm³) was observed in dry white wine after cold treatment. The most pronounced decrease in molecular oxygen concentration (by 5.57 mg/cm³) occurred in red wine subjected to cold treatment. Conversely, the greatest increase (4.63 mg/cm³) was identified in dry red wine after heat treatment.

Thermal processing of red wines leads to an increase in oxygen concentration while simultaneously activating all components of the antioxidant protection system (AOP), including dismutation processes and the formation of organic peroxides. White wines exhibit a somewhat different response. In these wines, fining and cold treatment exert comparable effects on the AOP system; however, under heat treatment, white and red wines demonstrate divergent behavior.

The principal processes occurring during fermentation include the extraction of polyphenols, alcohol formation (8–15%), extraction of color pigments (anthocyanins), production of carbon dioxide (CO₂), energy release, and the formation of aromatic compounds such as esters, polyhydric alcohols, and fatty acids [4.P.10]. The fundamental difference between red and white wine production lies in the fermentation process: red wines are fermented in contact with grape skins (on the pomace), whereas white wines are produced by fermenting clarified juice alone. When fermentation control is required, temperature reduction to approximately 12°C is employed.

Factors contributing to the cessation of alcoholic fermentation include high sugar concentration, low nitrogen availability, thiamine deficiency, excessive must clarification, the presence of pesticides, and insufficient oxygen. Maceration—the process of maintaining must in contact with grape solids—varies significantly between white and red wines [5.P.12].

For white wines, maceration is typically performed prior to fermentation, whereas for red wines it occurs during and after fermentation. The duration of maceration in white wine production generally does not exceed 24 hours, while in red wine production it may extend to 1–2 weeks or longer. The primary accumulation of anthocyanins occurs within the first 7 days of maceration. Pre-fermentation cold maceration (-5°C to $+5^{\circ}\text{C}$) for approximately 48 hours enhances both the chemical composition and sensory characteristics of red wines. Unlike conventional maceration, which may occur after fermentation, carbonic maceration can be applied prior to fermentation in a carbon dioxide-rich environment. Following fermentation and maceration, red wine is separated from sediments and solid grape components (skins, stems, and seeds) [6.P.11]. Free-run wine is considered to be of the highest quality, while the remaining material is pressed one or more times, producing wine with higher pigmentation and tannin content.

The differences between red and white wine production processes are primarily determined by the methods used to process grape components (juice, seeds, skins, and stems), as well as by clarification techniques applied before, during, and after fermentation. Grape skins impart color and tannins to red wine, necessitating fermentation prior to pressing. Fermentation can be halted using various methods, including sulfitation (sulfur dioxide addition), thermal treatment (heat or cold), and temperature control to facilitate CO_2 accumulation. In the production of fortified, dessert, and liqueur wines, alcohol and other components are added either during fermentation or during blending at the secondary winemaking stage. Fortified oxidized wines include styles such as port, Madeira, and sherry. Heat treatment contributes to an increase in the activity of the antioxidant defense (AOD) system, comparable to the effects observed during fining. However, the increase in molecular oxygen concentration during heat treatment is approximately half that observed during fining. Cold treatment, by contrast, enhances the susceptibility of wine components to oxidation, whereas technological interventions such as fining and heat treatment act to mitigate oxidative processes.

CONCLUSION

The present study has demonstrated that the behavior of antioxidant protection systems in wines is determined by the complex interaction between technological processing methods and the physicochemical composition of the wine matrix. The findings confirm that enzymatic systems of antioxidant protection exhibit a non-uniform response to standard winemaking practices, reflecting their structural and functional complexity. In particular, significant variations in molecular oxygen concentration were observed depending on both the type of wine and the applied technological treatment. Heat treatment of dry red wines resulted in the highest recorded concentration of molecular oxygen, while cold treatment of dry white wines produced the lowest values.

At the same time, cold treatment in red wines led to the most substantial decrease in oxygen concentration, whereas heat treatment caused the most pronounced increase. These results indicate that thermal processing activates the antioxidant protection system, including dismutation reactions and the formation of organic peroxides, while also increasing oxygen availability. In contrast, cold treatment enhances the susceptibility of wine components to oxidative transformations, particularly in red wines, where phenolic compounds are more abundant and reactive. The comparative analysis of white and red wines further revealed that their responses to technological interventions differ significantly. While fining and cold treatment exert a relatively similar influence on the antioxidant protection system in white wines, heat treatment leads to divergent effects between white and red wines. These differences are due to variations in qualitative and quantitative composition, primarily in the content of polyphenols and anthocyanins, which play a key role in the formation of antioxidant potential and sensory characteristics. The study also confirms that technological stages such as fermentation and maceration are critical determinants of wine composition and stability.

The extraction of polyphenols, formation of aromatic compounds, and accumulation of anthocyanins during maceration significantly influence both the antioxidant capacity and the overall quality of the final product. The duration and conditions of maceration, as well as temperature control during fermentation, directly affect these processes and, consequently, the oxidative stability of wines. Taken together, the results substantiate that the choice and regulation of technological methods in winemaking must account for their impact on oxygen dynamics and antioxidant systems.

The balance between oxygen exposure and antioxidant activity emerges as a key factor in preserving wine quality and preventing undesirable oxidative changes.

Based on the findings of the study, it follows that the application of cold treatment in red wine production should be limited to exceptional cases, given its tendency to increase the susceptibility of phenolic compounds to oxidation and to negatively affect color and taste characteristics. In contrast, heat treatment may be considered a more appropriate technological intervention for red wines, as it not only increases oxygen concentration but also activates the antioxidant protection system, thereby contributing to greater oxidative stability over time.

Furthermore, technological operations that involve contact with atmospheric oxygen, such as filtration, transfer, and container opening, should be carefully regulated, as they significantly influence oxygen concentration and the behavior of antioxidant systems. The use of fining agents, particularly bentonite, should be applied with consideration of its comparable effect to heat treatment on the antioxidant protection system, while avoiding excessive oxygen enrichment.

Finally, the selection of maceration conditions, including duration and temperature, should be optimized in accordance with the type of wine, as these parameters directly determine the extraction of phenolic compounds and the subsequent antioxidant capacity and stability of the product.

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EDITORIAL REVIEW

The submitted article addresses the impact of technological processing methods on the antioxidant protection system and oxygen dynamics in white and red wines. The topic is timely and relevant, given the growing emphasis on quality control and stability in wine production, as well as the increasing scientific interest in oxidative processes and their regulation in food systems. The author focuses on the interaction between molecular oxygen, phenolic compounds, and enzymatic antioxidant mechanisms, which constitutes an important aspect of modern oenological research.

From the standpoint of scientific novelty, the study contributes to the comparative analysis of white and red wines in terms of their response to technological interventions such as heat treatment, cold treatment, and fining. The work provides additional empirical data on oxygen concentration dynamics and the behavior of antioxidant defense enzymes under different processing conditions. Although the general principles of oxidative stability in wines are well established, the presented results refine existing knowledge by highlighting the differential responses of wines depending on their compositional characteristics, particularly the content of polyphenols and anthocyanins.

The relevance of the study is substantiated by its direct connection to technological practices in winemaking. The findings have practical implications for optimizing processing methods to preserve sensory qualities and prevent undesirable oxidative changes.

The discussion of fermentation, maceration, and secondary processing stages further strengthens the applied significance of the research, linking biochemical mechanisms with production processes. The methodology employed in the study is generally appropriate for the stated objectives. The comparative approach, involving the analysis of samples before and after treatment, allows for the identification of cause–effect relationships between technological interventions and changes in oxygen concentration and antioxidant activity. However, the methodological section would benefit from greater detail regarding experimental conditions, analytical techniques, and statistical treatment of the data, which is essential for assessing the reproducibility and robustness of the results. The results presented appear logically consistent and are supported by quantitative data. The observed trends in oxygen concentration and antioxidant system behavior align with known chemical and biochemical principles.

Nevertheless, the reliability of the conclusions would be enhanced by a more comprehensive description of experimental controls and replication. Among the strengths of the article are its clear focus, logical structure, and integration of technological and biochemical perspectives. The comparative analysis of white and red wines is particularly valuable. At the same time, certain weaknesses should be noted, including occasional inconsistencies in terminology (e.g., designation of antioxidant systems), minor linguistic inaccuracies, and insufficient elaboration of methodological details. In conclusion, the article represents a meaningful contribution to the field of wine science and technology. Subject to minor revisions aimed at improving methodological transparency and terminological consistency, the manuscript can be recommended for publication in a scientific journal.

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