UDC 663.252
DOI: 10.15587/1729-4061.2026.360314

IDENTIFICATION OF FACTORS INFLUENCING THE COMPOSITION AND QUALITY OF WINE MATERIAL

Hasil Fataliyev
Doctor of Technical Sciences, Professor*
ORCID: https://orcid.org/0000-0002-5310-4263
Vugar Mikayilov
Professor, Doctor of technical Sciences
Department of Technology of Organic Substances and High Molecular Compounds
Azerbaijan State Oil and Industry University (ASOIU)
Azadlig ave., 34, Baku, Azerbaijan, AZ 1010
ORCID: https://orcid.org/0009-0000-9283-2952
Mehman Ismayilov
Doctor of Philosophy in Engineering, Associate Professor**
ORCID: https://orcid.org/0000-0001-8620-3412
Elnur Heydarov
PhD, Associate Professor**
ORCID: https://orcid.org/0009-0002-7643-7746
Natavan Gadimova
Corresponding author
Candidate of Technical Sciences, Associate Professor
Department of Engineering and Applied Sciences
Department of Food Engineering
Azerbaijan State University of Economics (UNEC)
Istiglaliyyat str., 6, Baku, Azerbaijan, AZ1001
E-mail: natavan.qadimova@mail.ru
ORCID: https://orcid.org/0000-0003-1939-1796
Shabnam Fataliyeva
Assistant*
ORCID: https://orcid.org/0000-0001-9727-7492
*Department of Food Engineering and Expertise
Azerbaijan State Agricultural University (ASAU)
Ataturk str., 450, Ganja, Azerbaijan, AZ 2000
**Department of Food Engineering and Expertise
Azerbaijan Technological University (ATU)
Shach Ismail Chatai ave., 103, Ganja, Azerbaijan, AZ 2011

The object of the study is the production technology of high-quality Cahors wines. Although a number of studies have been conducted on the production of Cahors wines, the factors affecting the composition and quality of the wine material-particularly the regime of thermal treatment of the mash, as well as the type of alcohol and the method of fortification and their influence on the physicochemical composition of Cahors wine material-have not been sufficiently studied.

The total content of phenolic compounds in the control sample produced by the white winemaking method was 980 mg/dm^3, whereas it reached 2740 mg/dm^3 in the red winemaking method, 3230 mg/dm^3 during thermovinification, and 3860 mg/dm^3 in the Kurdamir method. A similar pattern, with some exceptions, was observed for color compounds. Relatively prolonged thermal treatment (4 hours) resulted in a pronounced caramelized note in taste and was evaluated 0.2 points lower than the preceding variant. In terms of quality, the second variant subjected to thermal treatment at 65°C for 3 hours performed better, receiving a score of 8.7 points. According to the results of organoleptic analysis, samples fortified with wheat alcohol were rated 0.9–1.6 points higher than the others.

Determining the effects of technological methods on the composition and quality of Cahors wine material samples, the duration of CO_2 maceration, and the changes in physicochemical composition caused by thermal treatment, as well as the correct selection and use of alcohol for Cahors wines, is of practical importance for production. The results obtained can be applied in wineries and wine-producing enterprises

Keywords: wine material, phenolic compounds, anthocyanins, thermovinification, fortification, tartaric acid

Received 20.02.2026
Received in revised form 27.05.2026
Accepted date 06.05.2026
Published date 30.06.2026

How to Cite: *Fataliyev, H., Mikayilov, V., Ismayilov, M., Heydarov, E., Gadimova, N., Fataliyeva, S. (2026). Identification of factors influencing the composition and quality of wine material. Eastern-European Journal of Enterprise Technologies, 3 (11 (141)), 73–84. https://doi.org/10.15587/1729-4061.2026.360314*

1. Introduction

In the 1980s, 92–95% of the wines produced by the domestic winemaking industry were fortified wines, many of which gained worldwide recognition. One of the most famous among them was Kurdamir Cahors, produced using the local "Kurdamir technology." In the former USSR, 23 types of wines were produced using the Kurdamir technology, including Shamakhi Cahors, Kazakhstan, Nektar, Chumay, Black Doctor, and others, many of which are still produced today. Both French and local Cahors wines are made from red grape varieties; however, their production technologies differ fundamentally. While French Cahors is a natural wine obtained by heating the mash, Azerbaijani Cahors produced by the Kurdamir method is a dessert wine prepared by fortifying the mash with alcohol.

The steady market demand for Cahors wines, their special role in maintaining church traditions (as an essential attribute of church rituals), and their popularity as dessert wines make the production of this type of wine promising. This is also supported by the specific features of their production (obtaining wines through thermal treatment and fortification methods), as well as their sensory quality. The increase in production is further driven by the use of high-quality grape varieties and the application of innovative technologies. Due to its tonic properties and its ability to improve blood circulation and strengthen immunity, Cahors wine is widely used in folk medicine. From this perspective, expanding the production of Cahors wines-traditionally produced since the beginning of the last century and having a well-established consumer base-is highly relevant. In recent years, the varietal composition of domestic vineyards has been enriched with valuable grape varieties such as Merlot and Cabernet Sauvignon, which were previously not used for Cahors production, and the processing industry has been equipped with modern facilities. Therefore, the existing conditions necessitate further research. As can be seen, the sector faces scientific problems that require resolution.

In the production of high-quality Cahors wines, the preparation of wine material with a high extract content is a crucial stage. However, it cannot be stated that sufficient study has been conducted on technological methods such as "heating of the mash" and "fortification of the mash", which are applied in winemaking. Therefore, determining the effects of various technological methods, CO_2 maceration and thermal treatment, as well as the type of alcohol and the method of fortification, on the composition and quality of Cahors wine material samples is highly relevant.

Based on the above, it can be concluded that these studies-focused on determining the composition and quality of wine samples depending on the production method, the type of alcohol, and the fortification procedure, as well as on investigating the effects of various technological approaches (including maceration duration and thermal treatment) on the physicochemical composition of wine materials-are of significant scientific and practical relevance.

2. Literature review and problem statement

In the paper [1], the results of a study related to the evaluation of the quality of wines obtained from certain clones of the Merlot and Cabernet Sauvignon grape varieties are presented. It is shown that the three-year average indicators of the evaluated clones of Merlot and Cabernet Sauvignon demonstrate the feasibility of producing wines from these varieties in the given region. In particular, it is reported that Merlot clones 181, 346, and 348, as well as Cabernet Sauvignon clones 18A and 163, produce wines with a rich composition. However, this study has unresolved issues, as it covers a limited number of clones from only one region and does not provide comprehensive information on wine quality across the entire country and the studied varieties. To address these shortcomings, another study encompassing a broader area-five regions and the same two varieties – can be cited. This approach is reflected in [2], which investigates the anthocyanin profile of Cabernet Sauvignon and Merlot varieties in five regions of Xinjiang. It was found that, for Merlot, higher anthocyanin concentrations were observed in southern Xinjiang under relatively lower average temperatures and higher relative humidity. Compared with Cabernet Sauvignon, Merlot was reported to be more sensitive to environmental factors, with its anthocyanin composition varying across regions.

The paper [3] presents the results of a study on the effects of various processes on the production of clarified red grape juice. It is shown that these processes ensure a 30.9% reduction in total phenolic compounds and a 99% reduction in turbidity. However, in this study, other factors affecting the content of total phenolic compounds, anthocyanins, and turbidity are not comparatively evaluated. The paper [4] reports the results of a study on the evaluation of the physicochemical parameters of wines obtained from the Syrah grape variety grown under different conditions. It is shown that the composition of wines produced from winter-grown Syrah vineyards located from north to south and from east to west differs significantly. Based on the results, it is suggested that this factor can be used to manage the production of individual wine styles.

The paper [5] presents the results of a study aimed at determining the optimal method for quantifying resveratrol in three different grape varieties. It is shown that, for the extraction of resveratrol from 1 g of berry skin or leaf tissue, 10 mL of a 50:50 methanol-ethanol mixture should be used under dark conditions at 25°C for 24 hours. However, this study does not address other groups of stilbenes or phenolic compounds. Article [6] reports the results of studies related to the determination of wine origin. It is shown that identifying the chemical compounds present in wine and the differences between them is important for determining wine origin. Phenolic and aroma compounds are identified as the most important factors determining wine quality. However, the individual roles of different groups of phenolic compounds and specific aroma components are not addressed, making the study impractical for applied purposes.

The paper [7] presents the development and application of an express method for determining the phenolic content of winemaking by-products. It is shown that seeds, skins, stems, and pomace exhibit different phenolic profiles and antioxidant activities in terms of quality and quantity. However, only three groups of phenolic compounds were identified and studied, while other groups were not considered. The paper [8] presents the results of studies on various maceration methods and different processing techniques. It is shown that microwave and ultrasound treatments increase the content of polyphenols with high antioxidant activity. Compared with enzymatic methods, catechins increased from 0.87 to 37.40 mg/100 g and trans-resveratrol from 0.09 to 0.23 mg/100 g. However, no comparative analysis of other alternative methods and maceration techniques was performed.

The paper [9] presents the results of studies on the determination of phenolic compounds and antioxidant properties at different mash maceration durations. It is shown that, as the maceration duration increases, the total content of phenolic compounds, anthocyanins, hydroxycinnamic acids, and antioxidant activity also increase. However, this study does not address the qualitative composition of phenolic compounds and anthocyanins, and different phenolic groups are not represented. The paper [10] presents the results of studies aimed at improving the quality of aronia juice. It is shown that, compared with traditional methods, ultrasound and microwave technologies open new possibilities for quality improvement. The extraction of color, sugars, acids, and phenolic compounds improves. However, a limited number of maceration methods were used, and the issue was not resolved at the industrial scale.

The paper [11] presents the results of studies on thermal and enzymatic treatments. It is shown that thermal treatment increases flavanol concentration by 41%. In general, thermal and enzymatic treatments-especially at high enzyme concentrations-increase the quality and content of biologically active components in juice obtained from the Merlot Cantus variety. However, this study does not present results on the negative effects of thermal treatment on biologically active components. The paper [12] reports the results of a study on the combined effect of thermal treatment and pectolytic enzymes. It is shown that the combined effect of different concentrations of pectolytic enzymes and thermal treatment increases the content of biologically active compounds and juice yield in Merlot Cantus grape juice. A total of 78 individual phenolic compounds were more pronounced during treatment with high enzyme concentrations. However, other components contributing to extractability, including polysaccharides, were not investigated.

The paper [13] presents the results of studies on cold maceration. It is shown that prolonged maceration enhances the color intensity and aroma of wine obtained from the Syrah variety, while also increasing astringency, which is reflected in the organoleptic properties of the wine. The paper [14] presents the results of a study examining the effects of various pre-maceration methods. It is shown that maceration methods that include preliminary thermal treatment produce lighter or redder juices. After fermentation, all samples were characterized by weak red and more yellow hues. This indicates that these methods do not produce wines with an intense red color.

Article [15] presents studies on experts' mental perceptions of oxidation. It is shown that the views of 26 French experts, half from Burgundy and half from Jura, on oxidation are generally consistent, although their opinions on oxidation types differ. This study is purely sensory in nature and reflects subjective expert opinions, making practical application difficult. Article [16] presents the results of studies on oxygen addition during alcoholic fermentation and lees aging. It is shown that oxygen addition at early stages of winemaking can significantly affect the composition of volatile compounds and organoleptic properties, influencing wine style diversification. However, these studies do not focus on the physicochemical composition of juice and wine material following oxygen addition.

Article [17] presents the results of studies on three widespread non-microbial wine defects. It is shown that preventive measures play a key role in eliminating non-microbial defects in wine. However, no experimental studies are provided. Article [18] presents the results of studies on maintaining wine quality from production to consumption. It is shown that balanced effects of closure selection, oxygen, temperature, and light are vital for preserving wine quality. However, as in [7], no experimental results on physicochemical and sensory characteristics are presented.

Article [19] presents the results of studies on the composition and quality of products obtained from unripe grapes. It is shown that, although such products are often considered vineyard by-products, they are rich in various compounds, including organic acids, phenolic compounds, vitamins, and mineral salts, and are important for the pharmaceutical, cosmetic, and food industries. However, this study does not investigate the possibility of using such raw materials for the production of different wines. Article [20] presents the results of studies on the extraction of phenolic compounds from winemaking by-products. It is shown that phenolic compounds extracted and purified from winemaking residues by water extraction are as effective as commercial grape extracts. However, changes in the content of other extractive substances, as well as their separation and use during purification, are not addressed.

Article [21] presents the results of studies on fruits rich in valuable compounds. It is shown that *Opuntia ficus-indica* fruits are rich in compounds with high nutritional value and medicinal properties. However, no studies are provided on the extraction and specific use of these compounds. Article [22] presents the results of studies on obtaining wines of different colors from the autochthonous Madrasa grape variety. It is shown that, according to the developed technological scheme, it is possible to produce delicate white wines, slightly different rosé wines, and extract-rich red wines from the red Madrasa grape variety. However, detailed analyses of phenolic compounds, anthocyanins, and their qualitative composition are not performed.

One way to overcome this limitation is to study the content of phenolic compounds at different maceration durations. This approach is reflected in [23], where Madrasa grape mash was macerated for different durations and at different temperatures, and the phenolic compound content was determined in each case. It was found that higher levels of phenolic compounds were obtained when the mash was macerated for 144 hours at room temperature (20°C) and for 96 hours under cellar conditions (10°C). However, changes in color intensity were not investigated.

Article [24] presents the results of studies on producing wines from red grape varieties without maceration. It is shown that, in some grape varieties where color compounds are located in the skin, gentle separation of the skin without maceration yields uncolored white wines. Prolonged maceration affects wine color intensity. However, individual color components and their qualitative composition are not examined. Article [25] presents the results of studies on juices and wines subjected to various processing methods. It is shown that, compared with traditional (thermal pasteurization) methods, samples treated with ultraviolet radiation practically retained their natural color and flavor, although physicochemical parameters changed more significantly under traditional processing. However, different groups of phenolic compounds were not comparatively studied.

Article [252] presents studies on enriching wine composition by adding extracts obtained from pomace. It is shown that, in functional wine samples prepared with added extracts, the phenolic compound content increased by 100 mg/dm^3, along with increases in vitamin and resveratrol content. However, this study is applicable only to individual grape varieties and cannot be generalized to wines produced from all grape varieties. Article [26] presents studies on the effect of initial raw material processing on the extraction of phenolic compounds. It is shown that initial thermal treatment of raw materials increases the content of phenolic compounds. However, a decrease in ascorbic acid-one of the main components-negatively affected overall quality.

Article [27] presents studies on the effect of cultivation conditions on the composition of juices and wines obtained from cherries. It is shown that the growing zone significantly affects the dry matter content of the resulting juice, while soil and climatic conditions also act as influential factors. However, the qualitative composition of phenolic compounds and anthocyanins is not investigated. Article [28] presents results of studies on factors affecting malt enzyme activity. It is shown that the aminolytic and saccharifying activities of barley and rye malt enzymes depend on temperature. Article [29] presents the results of studies on new malt extracts for the production of non-alcoholic beverages. It is shown that buckwheat extract powder can be used as an ingredient in beverage production and as a standalone product for individuals with gluten intolerance.

The analysis of the conducted literature review shows that individual factors affecting the composition and quality indicators of Cahors wine material have been widely studied in various research works. However, in existing scientific studies, the complex and interactive mechanisms of these factors have not been systematically investigated. Thus, the effects of the methods of obtaining Cahors wine material and the ingredients used on its physicochemical composition and quality indicators have not been sufficiently substantiated. In particular, the regularities of the influence of applied technological methods –including maceration duration, thermal treatment of the mash, and other technological parameters – on the chemical composition of the wine material have not been determined.

At the same time, a unified methodological approach has not been formed for the comparative analysis of the composition and quality indicators of wine samples obtained depending on the type of alcohol and the fortification regime. In existing studies, the mentioned factors have mainly been studied separately, while their interaction and synergistic effects have not been adequately evaluated.

The fact that these issues remain unresolved is associated with a number of objective and subjective reasons. These include the lack of standardization of research methods and technological regimes, the diversity of raw materials and ingredients used, differences in experimental conditions, as well as the multifactorial and complex nature of technological processes. Thus, based on the conducted literature analysis, it is determined that there are still significant scientific gaps in studying the complex effect of the technology for obtaining Cahors wine material, the ingredients used, and technological parameters on its composition and quality indicators. This, in turn, conditions the existence of an actual scientific problem in the field that requires a solution and necessitates conducting targeted research in the specified direction.

3. The aim and objectives of the study

The aim of the study is to identify the factors affecting the composition and quality of Cahor wine material and thereby improve the quality of the wine.

To achieve this aim, the following objectives were set:

– to determine the influence of various technological methods on the physicochemical composition of Cahors wine material samples;

– to study the effect of heat treatment regimes on the physicochemical and organoleptic characteristics of Cahors wine material.

4. Materials and methods

The object of the study is the technology of producing high-quality Cahors wines. The hypothesis of the study is that the quality and chemical composition of Cahor wine material are closely related to the initial characteristics of the grapes (sugar content, acidity, phenolic compounds), as well as to the parameters of fermentation and thermal processing, and storage conditions; when an optimal combination of these factors is selected, the color, taste, and aromatic characteristics of the wine material can be significantly improved.

Assumptions adopted for the study:

– the composition and quality of Cahors wine material directly depend on the biochemical characteristics of the grape variety used (sugar content, acidity, phenolic substances);

– with the increase in the technological ripeness level of grapes, the amount of sugar and extractive substances in the wine material increases, but acidity decreases, which affects the balance of the product;

– the temperature regime of the fermentation process has a significant effect on the preservation of color substances (anthocyanins) and aromatic compounds in Cahors wine material;

– heating of the mash (in accordance with Cahors technology) increases the extraction of phenolic substances and color components, thereby improving the color intensity and structure of the wine material;

– an increase in alcohol content enhances the stability of extractive substances, but at high levels may disrupt the taste balance;

– the yeast strains used have a significant impact on the aromatic profile of the wine material and the composition of fermentation products;

– storage duration and conditions (temperature, contact with oxygen) affect the chemical stability and organoleptic indicators of Cahors wine material.

Simplifications adopted for the study:

– the grapes used during the study are of the same variety and grown under the same agrotechnical conditions, i.e., homogeneity is accepted;

– the technological processes (crushing, fermentation, heating, etc.) for all samples are carried out under the same standard regime;

– the influence of climate, soil and other ecological factors is assumed to be constant and unchanged;

– the effect of production equipment on the material is assumed to be minimal and at the same level;

– the fermentation and oxidation processes proceed under ideal conditions without side reactions;

– operator influence in technological processes is not taken into account and it is assumed that all operations are carried out accurately;

– errors of measurement methods are not taken into account and it is assumed that the results are obtained with high accuracy.

The main idea of the study is to determine the influence of various technological methods and heat treatment regimes on the physicochemical composition of wine samples, as well as to investigate the effects of alcohol type and fortification procedure on the physicochemical characteristics of Cahors wine material. The application of modern processing techniques and analytical methods significantly facilitated the research process.

Grapes cultivated in the Ganja region (Göygöl, Ganja, Shamkir, and Samukh districts) were used as raw materials for the study. During harvesting, the grapes were cleaned of diseased and damaged parts, leaves, broken shoots, dust, and other impurities. The raw material was then divided into equal portions (40 kg each).

In the study, raw materials harvested from vineyards cultivated in the Ganja region (Göygöl, Ganja, Shamkir, and Samukh districts) were used. During harvesting, grapes are cleaned from diseased and damaged parts, leaves, stem fragments, dust, etc. Then they are divided into equal-weight portions (40 kg each).

The first sample is crushed and fermented together with the stems (using the Kakheti method). In subsequent samples, the stems are separated and crushing is carried out, and processing is performed according to the following variants: the crushed mass is immediately pressed and the juice is separated (white method), and fermentation takes place in the juice. Other portions are macerated in CO_2 atmosphere for 12, 16, and 36 hours; fermented in the crushed mass (red method); the crushed mass is heat-treated at different durations and temperatures (thermovinification); and alcohol enrichment of the crushed mass is carried out (Kurdamir method). Then the crushed samples are pressed separately and collected. A portion of the samples obtained for each variant is taken for analysis, and the remaining main portions are subjected to further processing.

In the first variant, the grapes were crushed and fermented together with stems (Kakheti method). In subsequent variants, the stems were removed before crushing, and the mash was processed according to the following schemes: immediate pressing of the mash with fermentation carried out in the juice (white method); maceration of the mash in a CO_2 atmosphere for 12, 16, and 36 hours; fermentation on the mash (red method); heat treatment of the mash at different temperatures and durations; fortification of the mash (Kurdamir method). After processing, the mash samples were pressed separately. A portion of the obtained samples was used for analytical measurements, while the remaining volumes were subjected to further technological operations.

Heat treatment of the mash was carried out at temperatures of 55°C, 65°C, and 75°C for durations of 2, 3, and 4 hours. Additionally, the possibility of using grape alcohol and rectified wheat alcohol in fortified wine production was comparatively evaluated. For this purpose, fortified wines were produced using rectified wheat alcohol with a strength of 95% (v/v) and grape alcohol with strengths of 65% and 87% (v/v), and the resulting samples were analyzed.

The physicochemical and organoleptic parameters of raw materials, semi-finished products, and final wines were determined using standard oenochemical analysis methods [30, 31]. Statistical analyses were performed using the SPSS 18 software package [32].

The mass concentration of phenolic compounds in wine was determined using the Folin-Ciocalteu method. The Folin-Ciocalteu reagent oxidizes phenolic groups in the wine and is reduced to form a blue-colored complex, the intensity of which is proportional to the concentration of phenolic compounds.

Volatile components and bouquet-forming substances in wine materials were determined using gas-liquid chromatography with a flame ionization detector. The method is based on gas chromatography principles. Metal content was determined by atomic absorption spectroscopy.

5. Results of studies on the identification of factors affecting the composition and quality of Cahor wine material

5. 1. Determination of the influence of different technological methods on the physicochemical indicators of Cahors wine material samples

Taking into account the role of Cahors wines, the influence of fermentation carried out in a carbon dioxide environment on the amount of phenolic compounds and anthocyanins was studied (Fig. 1, 2).

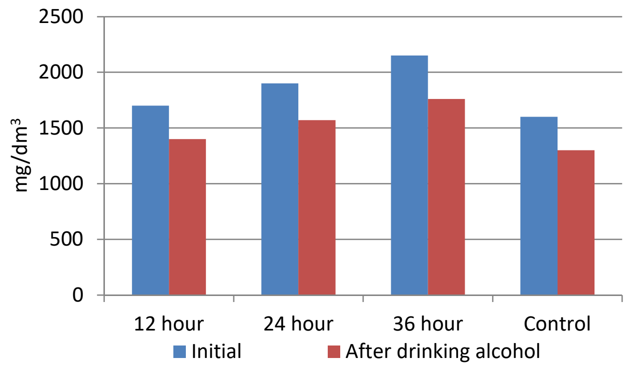

Fig. 1. Effect of carbon dioxide maceration time on the amount of phenolic compounds

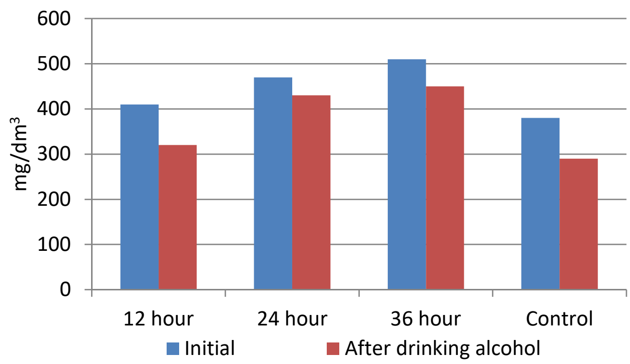

Fig. 2. Effect of carbon dioxide maceration time on the amount of anthocyanins

It has been found that the duration of carbon dioxide maceration, although it does not significantly affect other parameters, has a distinct impact on the amount of phenolic compounds. For instance, after 12 hours of maceration, the concentration of phenolic compounds was 1700 mg/dm^3 and the coloring substances (anthocyanins) 410 mg/dm^3, whereas at 36 hours of maceration these values reached 2150 mg/dm^3 and 510 mg/dm^3, respectively. The application of different technological methods in winemaking also caused changes in the amount of anthocyanins at various stages of production. In wine materials obtained through the red method (fermentation on the pomace), thermovinification (heat treatment of the pomace), the Kurdamir method, and the Kakhetian method (fermentation with stems), the anthocyanin content tended to decrease progressively during the successive stages of production (Fig. 3).

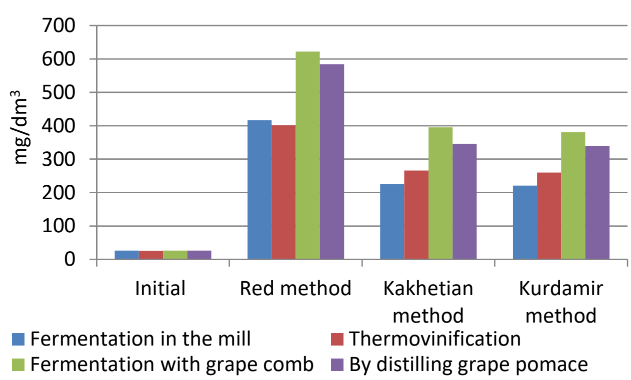

Fig. 3. Changes in the amount of anthocyanins (mg/dm^3) at different stages of wine production using different technological methods

During the different stages of wine production, the total amount of anthocyanins varied depending on the technological method applied: 221.1–416.5 mg/dm^3 for the red method, 260.0–401.2 mg/dm^3 for thermovinification, 340–584.0 mg/dm^3 for the Kurdamir method, and 381–622 mg/dm^3 for the Kakhetian method. A decrease in the amount of nitrogenous substances was observed during the fermentation process (Fig. 4). Compared with the control, it became clear that heat treatment of grapes intensifies the transfer of nitrogenous substances into the juice. While in the control the amount of total nitrogen before fermentation was 360 mg/dm^3, in the experimental variant it reached 410 mg/dm^3. However, the post-fermentation situation was somewhat different, with a greater decrease observed in the experimental variant.

As is well known, in wines particularly those belonging to the Cahors type the amount of phenolic compounds is one of the main indicators reflecting quality. Depending on the grape processing method, changes in the amount of anthocyanins and in color intensity were observed during the fermentation process of the obtained juice (Table 1).

It has been established that during the fermentation of juice obtained through heat treatment of grapes, a decrease in anthocyanins and color intensity is observed as fermentation approaches its final stage. In contrast, in wine material obtained by the red method, an increase in the amount of anthocyanins becomes noticeable. The studies showed that the use of different technological methods resulted in wine materials with diverse compositions (Table 2, Fig. 5).

Table 2

The effect of the extraction method on some compositional parameters of wine samples

Options for practice	Volume fraction of ethyl alcohol, %	Mass density					
		Sugars, g/dm^3	Titrating acids, g/dm^3	Volatile acids, g/dm^3	Polysaccharides, mg/dm^3	Extracted, g/dm^3
White method (control)	16.2	160.1	5.1	0.2	185	16.7
Red method	16.1	160.0	5.3	0.3	270	25.4
Thermovinification	16.0	160.1	4.9	0.4	396	35.2
Kurdamir method	16.2	160.2	5.0	0.3	294	32.8

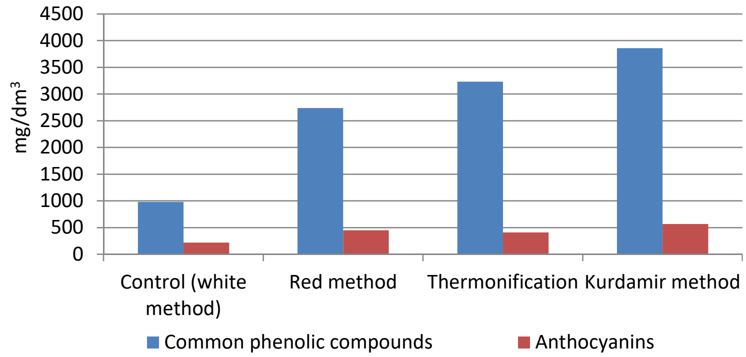

Fig. 5. Effect of extraction method on the amount of total phenolic compounds and anthocyanins in wine samples

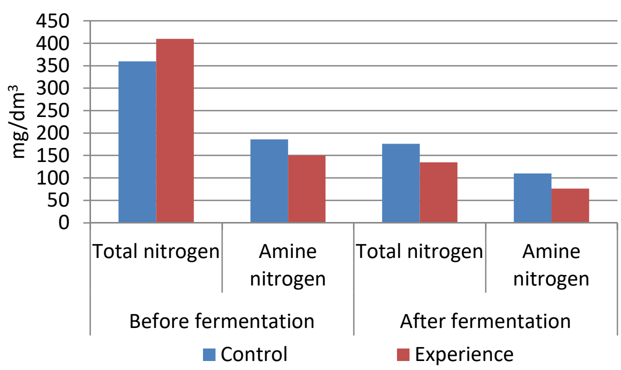

Fig. 4. Changes in the amount of nitrogenous substances during fermentation in samples prepared by different methods

Table 1

Anthocyanins and color intensity changes during fermentation

Preparation method and indications	The fermentation continues, day					
	0	0,5	1	3	5	The end of the ferment
Fermentation of juice obtained from hot processing of grapes: – anthocyanins, mg/dm^3	870	982	686	590	560	496
– color intensity	4.01	4.36	2.01	1.7	1.9	1.20
Red method (fermentation in the mash): – anthocyanin content, mg/dm^3	360	290	351	390	480	516
– color intensity	0.41	0.62	0.65	0.96	1.42	0.88

As can be seen, the wine samples do not differ significantly in terms of alcohol, sugar, and titratable acids. However, this cannot be said for phenolic compounds. For instance, while the total amount of phenolic compounds in the control variant was 980 mg/dm^3, in the sample prepared by the red method it reached 2740 mg/dm^3, during thermovinification it was 3230 mg/dm^3, and finally, in the material obtained through the Kurdamir method the amount rose to 3860 mg/dm^3. A similar situation, with some exceptions, was observed for color substances as well. One such exception is that during thermovinification, the amount of coloring substances was lower than in the second variant (the red method). This can be explained by the degradation of pigments under the influence of temperature during thermovinification.

5. 2. Determining the effect of heat treatment regimes on the physicochemical and organoleptic indicators of cahors wine material.

One of the modern methods used in Cahors wine production is thermovinification, which literally means "winemaking by heating". Even the ancient Greeks and Romans practiced heating crushed grapes in kettles. As a result, intensely colored juice with a high sugar content (due to gradual evaporation) was obtained. This process also contributed to the production of wines resistant to spoilage. Based on numerous studies, the heating of the mash was carried out under three regimes: at 55°C, 65°C, and 75°C. To clarify the effect of heat treatment on composition, a control mash without heating was maintained alongside the heated mash. As seen, in terms of the amount of phenolic and nitrogenous compounds as well as organoleptic quality, the third variant (65°C) yielded a more optimal composition (Fig. 6, 7).

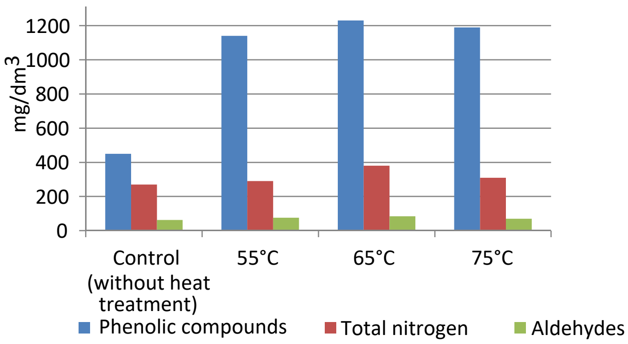

Fig. 6. Changes in some compositional parameters during thermovinification

Studies show that heat treatment of grape mash enhances the activity of the grape's pectolytic enzyme preparations. As a result, better clarification is observed in some wine material samples. In this case, oxidases are also activated. At 75–80°C, both enzymes become inactivated, and oxidation and pectolysis processes are eliminated. This negatively affects the clarification process of young wine material.

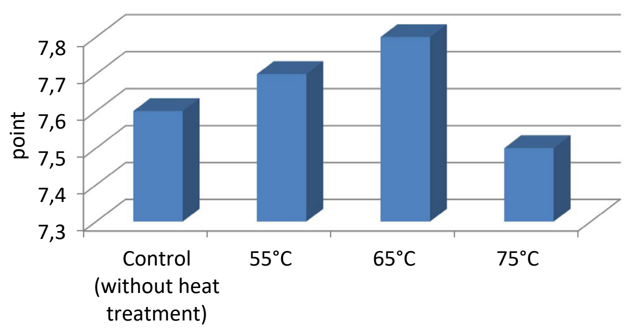

Fig. 7. Optimization of hot processing temperature of the pulp for organoleptic quality

During organoleptic analysis, this variant was evaluated 0.2 points higher than the control. However, heating at higher temperatures resulted in a decrease in organoleptic quality, with that variant being rated 0.1 points lower compared to the control. In determining the duration of heat treatment, the amount of phenolic compounds in the wine material played a decisive role (Fig. 8).

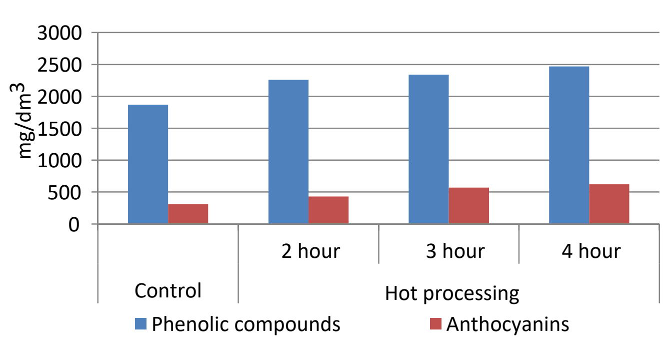

Fig. 8. Determination of thermovinification (heat treatment) time based on the amount of phenolic compounds

As can be seen, all experimental samples differed from the control by containing higher amounts of phenolic compounds and color substances. Under the influence of heat, the solid parts of the grape undergo faster maceration, the tissues soften, and phenolic compounds pass into the solution. Relatively long heat treatment (4 hours) was accompanied by a sharp caramelized tone in taste and was rated 0.2 points lower than the previous variant. In terms of quality, the second variant (3 hours) was evaluated more favorably, being awarded 8,7 points during tasting (Fig. 9).

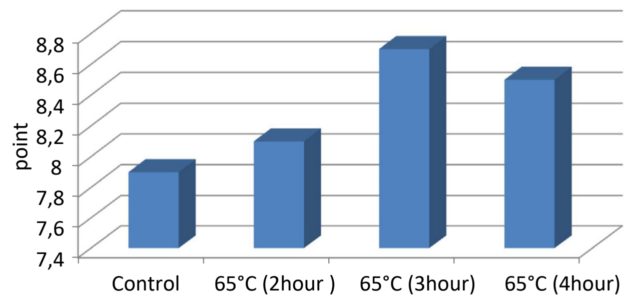

Fig. 9. Optimization of the hot processing time of the pulp for its effect on organoleptic quality

Thus, after heating, the juice acquires significant color intensity and a sufficiently high amount of anthocyanins, which can further increase during pressing (in fermentation without maceration). However, once fermentation begins, a continuous decrease in their amount is observed, which persists almost until the complete depletion of fermentable sugars. Heat treatment was reflected to varying degrees in the physicochemical and organoleptic properties of the wine material. When the grape mash was heated, the amount of tartaric acid in it nearly doubled, while the malic acid content showed a slight increase. As the heating temperature increased, diffusion intensified accordingly. A similar situation was observed with the main cations as well. Fermentation, accompanied by the formation of ethyl alcohol, also influenced this concentration (Fig. 10, 11).

The significant differences observed between organic anions and cations during fermentation and heating are associated with their localization in different parts of the grape berry (cell vacuole, pulp, skin, cellulose-pectin membrane, seed). At the same time, both in juice and wine, cations may be partially bound within colloidal macromolecules; by the end of fermentation, the percentage content of these components corresponds to that of their control samples (classical winemaking). Observations show that the decrease in tartaric and malic acids during fermentation occurs as follows: during mash fermentation, the concentration of tartaric acid increases until the second day, after which it begins to decrease until the end of fermentation. The amount of potassium reaches its maximum at the conclusion of fermentation. This clearly indicates that tartaric acid located in the skin diffuses into the juice at the beginning of fermentation simultaneously with potassium. With the formation of alcohol, potassium tartrate precipitates, but the precipitation of potassium bitartrate (wine stone) occurs only at the end of fermentation. On the other hand, pressing grapes after heating ensures the immediate extraction of skin components, which are subsequently found in the juice. At the very beginning of heating, the juice becomes enriched with calcium, after which a significant amount of tartaric acid anion precipitates together with Ca^{2+} and K^{+} ions. The concentration of calcium is higher at the start of fermentation but equals or falls below the wine content by the end of fermentation (in classical winemaking). Thus, the concentrations of tartaric acid and Ca^{2+} and K^{+} ions tend to equalize with their levels in wine by the end of fermentation. Studies aimed at determining the nature of color changes during alcoholic fermentation revealed that the intensity of color decreased more significantly in the juice obtained from heated grapes (Table 3). Unlike in classical winemaking, where the amount of anthocyanins increases proportionally along with the rise in color intensity, the fermentation of juice from heated grapes shows two phases. In the early hours of fermentation, the content of anthocyanins and color intensity remains stable, but during the first 24 hours a significant reduction in both is observed. The weakening of color during fermentation cannot be explained by adsorption on yeast, as its contribution does not exceed 2%.

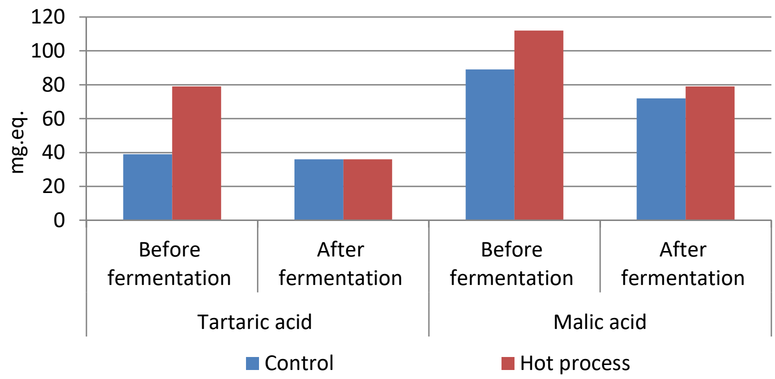

Fig. 11. Effect of heat treatment and non-treatment on the amount of anions in the fermenting material

The amount of anthocyanins in wine material obtained from heated grapes with added sugar increases with higher alcohol content. However, at 10% alcohol and above, stability or a slight decrease is observed. It can be assumed that phenolic compounds in general possess a certain solubility, but after a certain amount of alcohol, their concentration begins to decrease. If this factor is of a general nature, then a significant increase in color through grape heating should not be expected. Even if all coloring substances are extracted from the skins, this assumption remains valid. Anthocyanins and phenolic compounds are more or less condensed, interact with other molecules, dissolve to a greater or lesser extent, and also undergo chemical transformations, many of which are not yet sufficiently studied. Heating grapes enhances the solubility of non-colored phenolic compounds. This occurs to a greater extent in red winemaking (fermentation of the crushed mass without pressing) compared to winemaking without maceration (fermentation of the pressed juice). In the first case, three processes occur simultaneously: fermentation, maceration, and alcohol formation. The results are given in the table below (Table 4).

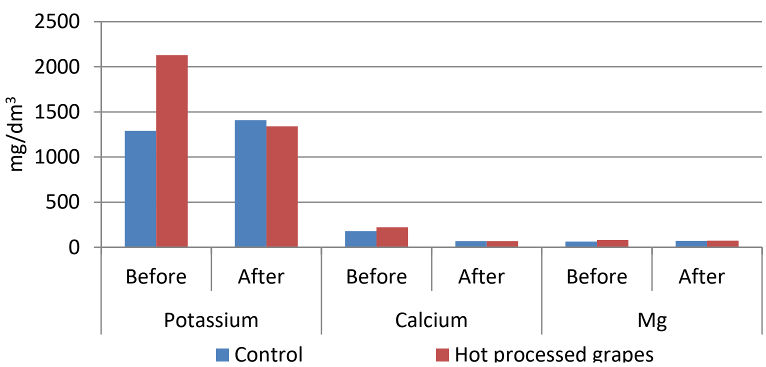

Fig. 10. Effect of heat treatment and non-heat treatment on the amount of cations in the fermenting material

Table 3

Effect of heat treatment on the amount of anthocyanins and color intensity in fermented juice

Continuation of fermentation, hour	Winemaking in the classical method		Fermentation of juice obtained from heated red grapes	
	Anthocyanin content, mg/dm^3	Color intensity	Anthocyanin content, mg/dm^3	Color intensity
0	252	0.37	816	3.08
3	248	0.45	810	2.98
6	244	0.47	824	3.35
10	200	0.48	936	3.36
24	260	0.51	596	1.23
72	302	0.81	508	1.00
96	400	1.16	540	1.20
The end of the ferment	468	0.75	476	0.92

Table 4

Effect of heat treatment on the content of colorless phenolic compounds in wine

Wine making method	Leucoanthocyanins, g/dm^3	Permanganate number	Folin number	Indicators at 280 nm
Fermentation of grapes without heating (fermentation on the press)	1.90	35	19	37
Fermentation of heated grapes (fermentation on the press)	2.68	46	25	47
Fermentation of pressed heated grapes (fermentation of the must using the white winemaking method)	2.01	42	24	43

Hot processing enhances the solubility of colorless phenolic compounds in grapes. It should be noted that, compared to the white method (fermentation of pressed juice), in the red method (fermentation of the crushed mass without pressing), more of such compounds pass into the wine material. This is because, in the first case, heating, maceration, and alcohol formation occur simultaneously. When grapes are fermented without heating, the amount of leucoanthocyanins is 1.90 g/dm^3; when fermented with heating, this figure increases to 2.68 g/dm^3; and when processed with heating using the "white method", it reaches 2.01 g/dm^3. As can be seen, hot processing has a significant effect on the amount of leucoanthocyanins, as well as on the permanganate index, the Folin index, and indicators determined at a wavelength of 280 nm. Another influential factor is whether the product is fermented by the white or red method. The results show that these indicators are higher when heated grape mash is fermented. During fermentation of juice obtained from heated grapes, a decrease in total and amino nitrogen was observed. Thermal treatment of grapes enriches the wine with nitrogen, including free amino acids (arginine, histidine, and lysine) and peptides. It is assumed that peptides, which quantity increases significantly during heating, play an activating role in yeast propagation. Compared to wines produced by classical methods, wines obtained from heated grapes are usually not completely transparent, and their turbidity remains for a long time. This fact, also confirmed by other researchers, can be explained by the breakdown of natural pectolytic enzymes in grapes during heating. In classical winemaking, these enzymes hydrolyze pectin, thereby ensuring clarification. Wines from heated grapes are richer in colloids, some of which possess strong protective properties that prevent the sedimentation of suspended particles. The addition of pectolytic enzyme preparations to juice obtained from heated grapes reduces turbidity and improves filtration, but the results still do not match the control samples made from unheated grapes. In some cases, after not excessively long storage or sufficient aging, wines from heated grapes can become clear, producing a wine that is fine and delicate like the control. Such wines are fuller-bodied, more velvety, and smoother in texture. Thus, there is no general rule regarding the influence of grape heating on the organoleptic properties of wine. The result seems to depend on the composition of the skins and seeds from which the substances are extracted during heating. On the other hand, over time the taste improves, and certain artificial notes (including amino-like flavors) diminish. Compared with the control, the color acquires brick-red shades more rapidly.

6. Discussion of the results on some factors affecting the composition and quality of Cahors wine materials

The effect of maceration time in a carbon dioxide environment on the amount of phenolic compounds was determined. It was found that as the maceration time increased, the amounts of total phenolic compounds and anthocyanins also increased. Changes in the amount of anthocyanins and nitrogenous compounds were studied during the different technological stages of wine sample preparation.

In wines obtained from both preheated and non-heated grapes, it was revealed that as fermentation of the juice approached completion, the content of colored phenolic compounds and color intensity decreased. However, in wines obtained by fermenting the must, the amount of anthocyanins increased. The thermal treatment of the must was carried out at 55°C, 65°C, and 75°C. Processing at 65°C resulted in wine with a more optimal composition, which was evaluated 0.2 points higher than the control. Prolonged heating (4 hours) caused a strong caramelized taste, and this variant was evaluated 0.2 points lower than the previous one. In terms of quality, the second variant (3 hours) was rated the best, with a score of 8.7 points. The physicochemical and organoleptic properties of the heated samples reflected these differences to varying degrees. Heating the grapes enhances the dissolution of colorless phenolic substances. In red winemaking, such compounds are extracted in greater amounts compared to the white method. Unlike wines made by the classical method, wines obtained from heated grapes were less transparent and retained their turbidity for longer periods.

The type of alcohol and the method of alcohol enrichment have also been shown to affect the composition and quality of Cahors wine material. As can be seen, this research work is aimed at solving a complex problem by covering only part of the factors involved. During the study of the effect of fermentation carried out in a carbon dioxide environment on composition indicators, it was found that an increase the maceration time from 12 to 36 hours leads to a noticeable increase in the total amount of phenolic compounds and anthocyanins (Fig. 1, 2). Changes in anthocyanin were observed under various technological methods, including the "red" method, "thermovinification", "Kurdamir" and "Kakheti" methods.

These processes was also observed during the production of wine material from juice and during clarification and filtration operations.

Compared with the "red" method and the amount of anthocyanins in the obtained juice decreased during "thermovinification". Although an increase in this amount was observed in the "Kakheti" method with, a similar situation was also observed in the "Kurdamir" method with pomace fortification. After fermentation, although a several-fold increase in anthocyanin content was observed in the samples compared to the juice, across the variants the values still tended to return to levels similar to those in the juice. Clarification and filtration processes also led to a decrease in anthocyanin content (Fig. 3). During fermentation, the amount of nitrogenous substances decreased, and this decrease was much greater in the heated must compared to the control. This is explained by the reducing effect of heat treatment on nitrogenous compounds, as they undergo decomposition and reactions with other compounds to form complexes (Fig. 4). It was found that changes in anthocyanin content during fermentation were more intensive in juice obtained from heated grapes compared to fermentation in the must. In contrast, in the must fermentation variant, the anthocyanin content increased toward the end of fermentation. If the anthocyanin content in the unfermented sample was 360 mg/dm^3, by the end of fermentation this amount reached 516 mg/dm^3. A similar trend was observed in color intensity across the variants (Table 1). The study of the effect of processing methods on the physicochemical indicators of wine samples revealed that compared to the "white" method, the "red" method, "thermovinification," and "Kurdamir" method resulted in increased amounts of total phenolic compounds and color substances (Tables 2, 5). The study of the effect of thermal treatment regimes of the must on the physicochemical composition of the samples showed that, in terms of phenolic and nitrogenous compound content as well as organoleptic quality, the third variant, i.e., heating of the must at 65°C, produced the most optimal composition. Heating at higher temperatures, however, resulted in a decline in organoleptic quality (Fig. 6, 7).

In order to correctly determine the duration of heat treatment, experiments were carried out with samples processed for 2, 3, and 4 hours. The amount of phenolic compounds in the wine material played a decisive role in determining the duration of heat treatment. Studies have shown that prolonged heating (4 hours) creates a sharp caramelized tone in taste and was evaluated 0.2 points lower than the previous variant (3 hours of heat treatment). The second variant (3 hours of heat treatment), considered better in terms of quality, was awarded 8.7 points during tasting (Fig. 8, 9). The heat treatment of the mash also affects the amount of cations and anions. During heating, the amount of tartaric and malic acids increased, in other words, the higher the temperature, the greater the increase. During the process, a decrease in the amount of anions and cations was observed, in some cases nearly twice (Fig. 10, 11). Studies conducted to determine the nature of color change revealed that during fermentation of juice obtained from heated grapes, the intensity of color decreased more significantly. While in classical winemaking the amount of anthocyanins and color intensity increase evenly, in the fermentation of juice obtained from heated grapes, the anthocyanin content and color intensity remained stable during the first hours but significantly decreased within the first 24 hours (Table 3). Heat treatment enhanced the dissolution of non-colored phenolic compounds in grapes. In this case, wines obtained using the "red" method contained more such compounds compared to the "white" method. This is because, in the first case, heating, maceration, and alcohol formation occur simultaneously (Table 4). During the fermentation of juice obtained from heated grapes, the total and amino nitrogen content decreased. Although before fermentation the nitrogen content of heat-treated samples was higher than the control, after fermentation it was lower. Compared to wines produced by classical methods, wines from heated grapes were usually not completely transparent and remained cloudy for a long time. This may be explained by the decomposition of natural pectolytic enzymes of grapes during heating.

The limitations of this study are following:

– the study was conducted only on certain grape varieties, and the influence of other varieties was not considered. This limits the generalization of the results;

– climatic and soil conditions were assumed to be constant, and the impact of different agro-climatic zones was not separately investigated;

– since the technological processes were carried out under laboratory or semi-industrial conditions, different results may be obtained at an industrial scale;

– fermentation and thermal processing parameters were studied within a limited range. Different results are possible over a wider range of parameters;

– sensory analyses were conducted by a limited number of experts, and the element of subjectivity in these evaluations was not completely eliminated;

– the storage period covered a relatively short duration, and the effects of long-term aging processes were not fully assessed.

In future research, it is considered appropriate to expand work in the following directions:

– investigation of a wider range of grape varieties and comparative analysis of their effects on the quality of Cahor wine material;

– study of the influence of different climatic and soil conditions (terroir factors) on the chemical and sensory characteristics of wine material;

– modeling of production processes at an industrial scale and conducting comparative analysis with laboratory results;

– application of mathematical models and statistical methods for optimizing fermentation and thermal processing parameters;

– comprehensive investigation of the effects of long-term storage and aging processes on quality.

7. Conclusions

1. Compared to the "white method", wine samples obtained by variants involving contact with solid parts contained higher amounts of extractive substances, including phenolic compounds and nitrogenous components. During 12-hour CO_2 maceration, the amount of phenolic compounds was 1700 mg/dm^3 and anthocyanins were 410 mg/dm^3, whereas during 36-hour maceration these indicators were 2150 mg/dm^3 and 510 mg/dm^3, respectively. The total amount of anthocyanins varied between 221.1–416.5 mg/dm^3 in the red method, 260.0–401.2 mg/dm^3 in thermovinification, 340–584.0 mg/dm^3 in the Kurdamir method, and 381–622 mg/dm^3 when obtained by the Kakheti method. Compared with the control, it becomes clear that the heat treatment of grapes intensifies the transfer of nitrogenous substances into the juice. If the total nitrogen content before fermentation in the control was 360 mg/dm^3, in the experimental variant it was 410 mg/dm^3. However, the post-fermentation situation was somewhat different, with a greater decrease observed in the experimental variant.

2. Optimal parameters of mash heat treatment were determined. Wine samples prepared with 3-hour heat treatment at 65°C stood out in terms of composition and quality and received 0.8 points higher than the control and 0.2–0.6 points higher than other analogs during organoleptic evaluation. Lower temperatures did not provide the desired effect, while higher temperatures resulted in a sharp burnt tone and deterioration of organoleptic quality.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, whether financial, personal, authorship or otherwise, that could affect the study and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

Data will be made available on reasonable request.

Use of artificial intelligence tools

The authors confirm that they did not use artificial intelligence technologies in creating the submitted work.

Authors' contributions

Hasil Fataliyev: Writing – review & editing, Project administration, Writing – original draft; **Vugar Mikayilov:** Conceptualization, Investigation, Writing – original draft; **Mehman İsmayilov:** Validation, Investigation, Writing – review & editing; **Elnur Heydarov:** Investigation, Methodology, Conceptualization; **Natavan Gadimova:** Investigation, Methodology, Conceptualization; **Shabnam Fataliyeva:** Conceptualization, Methodology, Investigation.

References

1. Miele, A. (2021). Wine composition of Merlot and Cabernet Sauvignon vine clones under the environmental conditions of Serra Gaúcha, Brazil. Food Science and Technology, 41, 116–122. https://doi.org/10.1590/fst.10520
2. Zhang, K., Zhang, Z.-Z., Yuan, L., Gao, X.-T., Li, Q. (2021). Difference and characteristics of anthocyanin from Cabernet Sauvignon and Merlot cultivated at five regions in Xinjiang. Food Science and Technology, 41, 72–80. https://doi.org/10.1590/fst.11020
3. Arslan Kulcan, A., Öziyci, H. R., Tetik, N., Karhan, M. (2015). Changes In Turbidity, Total Phenolic And Anthocyanin Contents Of Clear Red Grape Juice During Processing. Gida / the Journal of Food, 40 (6), 311–317. https://doi.org/10.15237/gida.gd15029
4. Mota, R. V. d., Peregrino, I., Silva, C. P. C., Raimundo, R. H. P., Fernandes, F. d. P., Souza, C. R. d. (2021). Row orientation effects on chemical composition and aromatic profile of Syrah winter wines. Food Science and Technology, 41 (2), 412–417. https://doi.org/10.1590/fst.38219
5. Liu, C., Wang, L., Wang, J., Wu, B., Liu, W., Fan, P., Liang, Z., Li, S. (2013). Resveratrols in Vitis berry skins and leaves: Their extraction and analysis by HPLC. Food Chemistry, 136 (2), 643–649. https://doi.org/10.1016/j.foodchem.2012.08.017
6. Bayram, M., Kayalar, M., Kaya, C., Topuz, S. (2016). Şarapta Fenolik ve Aroma Bileşikleri Üzerine 'Teruar'ın Etkisi. Gaziosmanpaşa Bilimsel Araştırma Dergisi, 13, 35–46. Available at: https://izlik.org/JA87MM97SC
7. Jara-Palacios, M. J., Hernanz, D., González-Manzano, S., Santos-Buelga, C., Escudero-Gilete, M. L., Heredia, F. J. (2014). Detailed phenolic composition of white grape by-products by RRLC/MS and measurement of the antioxidant activity. Talanta, 125, 51–57. https://doi.org/10.1016/j.talanta.2014.02.065
8. Guler, A. (2023). Effects of different maceration techniques on the colour, polyphenols and antioxidant capacity of grape juice. Food Chemistry, 404, 134603. https://doi.org/10.1016/j.foodchem.2022.134603
9. Baron, M., Kumsta, M., Sumczynski, D., Mlcek, J., Jurikova, T., Sochor, J. (2018). Einfluss der Dauer der Mazeration auf den Gehalt von Antioxidantien im Traubensaft. Erwerbs-Obstbau, 60, 37–45. https://doi.org/10.1007/s10341-018-0385-7
10. Puzovic, A., Mikulic-Petkovsek, M. (2024). Comparative Evaluation of Conventional and Emerging Maceration Techniques for Enhancing Bioactive Compounds in Aronia Juice. Foods, 13 (20), 3255. https://doi.org/10.3390/foods13203255
11. Puzovic, A., Pelacci, M., Simkova, K., Hudina, M., Rusjan, D., Veberic, R., Mikulic-Petkovsek, M. (2024). Effect of Heat Pasteurization and Enzymatic Maceration on Yield, Color, Sugars, Organic Acids, and Phenolic Content in the 'Merlot Kanthus' Grape Juice. Beverages, 10 (3), 66. https://doi.org/10.3390/beverages10030066
12. Błaszak, M., Lachowicz-Wiśniewska, S., Kapusta, I., Szewczuk, M., Ochmian, I. (2025). Enhanced Extraction of Polyphenols, Physicochemical Properties, and Microbial Control in Vitis vinifera L. Juice Using Ultrasound-Assisted Maceration. Molecules, 30 (3), 587. https://doi.org/10.3390/molecules30030587
13. Gu, X., Liu, Y., Suo, R., Yu, Q., Xue, C., Wang, J. et al. (2025). Effects of different low-temperature maceration times on the chemical and sensory characteristics of Syrah wine. Food Chemistry, 463, 141230. https://doi.org/10.1016/j.foodchem.2024.141230
14. Wojdyło, A., Samoticha, J., Chmielewska, J. (2021). Effect of different pre-treatment maceration techniques on the content of phenolic compounds and color of Dornfelder wines elaborated in cold climate. Food Chemistry, 339, 127888. https://doi.org/10.1016/j.foodchem.2020.127888
15. Mallard, J., Valentin, D., Ballester, J. (2025). Oxidation in white wine: The point of view of winemakers from areas with different oenological practices. Food Research International, 199, 115341. https://doi.org/10.1016/j.foodres.2024.115341
16. Benucci, I., Cerreti, M., Esti, M. (2024). Dosing oxygen from the early stages of white winemaking: Effect on oxidation–reduction potential, browning stability, volatile composition, and sensory properties. Food Chemistry, 432, 137243. https://doi.org/10.1016/j.foodchem.2023.137243
17. Ailer, Š., Jakabová, S., Benešová, L., Ivanova-Petropulos, V. (2022). Wine Faults: State of Knowledge in Reductive Aromas, Oxidation and Atypical Aging, Prevention, and Correction Methods. Molecules, 27 (11), 3535. https://doi.org/10.3390/molecules27113535
18. Mercanti, N., Macaluso, M., Pieracci, Y., Brazzarola, F., Palla, F., Verdini, P. G., Zinnai, A. (2024). Enhancing wine shelf-life: Insights into factors influencing oxidation and preservation. Heliyon, 10 (15), e35688. https://doi.org/10.1016/j.heliyon.2024.e35688
19. Fia, G., Bucalossi, G., Proserpio, C., Vincenzi, S. (2021). Unripe grapes: an overview of the composition, traditional and innovative applications, and extraction methods of a promising waste of viticulture. Australian Journal of Grape and Wine Research, 28 (1), 8–26. https://doi.org/10.1111/ajgw.12522
20. Olejar, K. J., Ricci, A., Swift, S., Zujovic, Z., Gordon, K. C., Fedrizzi, B. et al. (2019). Characterization of an Antioxidant and Antimicrobial Extract from Cool Climate, White Grape Marc. Antioxidants, 8 (7), 232. https://doi.org/10.3390/antiox8070232
21. Ferreira, R. M., Costa, A. M., Pinto, C. A., Silva, A. M. S., Saraiva, J. A., Cardoso, S. M. (2023). Impact of Fermentation and Pasteurization on the Physico-Chemical and Phytochemical Composition of Opuntia ficus-indica Juices. Foods, 12 (11), 2096. https://doi.org/10.3390/foods12112096

22. Fataliyev, H., Malikov, A., Lezgiyev, Y., Gadimova, N., Musayev, T., Aliyeva, G. (2024). Identifying of the wine-making potential of the autochthon madrasa grape variety of different colors and quality. Eastern-European Journal of Enterprise Technologies, 2 (11 (128)), 56–63. https://doi.org/10.15587/1729-4061.2024.302971
23. Fataliyev, H., Malikov, A., Lazgiyev, Y., Haydarov, E., Agayeva, S., Baloghlanova, K. et al. (2023). Effect Of Maceration Regime On Phenolic Compound Quantity And Color Quality Of Madrasa Wine Samples. Food Science and Technology, 17 (4). https://doi.org/10.15673/fst.v17i4.2784
24. Fataliyev, H., Lezgiyev, Y., Aghazade, Y., Gadimova, N., Heydarov, E., Ismailov, M. (2024). Identifying the influence of various technological techniques on the indicators of the composition of bunches and wine samples of the madras grape variety. Eastern-European Journal of Enterprise Technologies, 6 (11 (132)), 50–62. https://doi.org/10.15587/1729-4061.2024.318532
25. Fataliyev, H., Aghazade, Y., Heydarov, E., Gadimova, N., Ismayilov, M., Imanova, K. (2025). Identifying the factors affecting the production of juice and wine from the autochthonous Bayanshira grape variety. Eastern-European Journal of Enterprise Technologies, 1 (11 (133)), 38–50. https://doi.org/10.15587/1729-4061.2025.323382
26. Fataliyev, H., Isgandarova, S., Gadimova, N., Mammadova, A., Ismailov, M., Mammadzade, M. (2024). Identification of the effect of ripening conditions on the yield of rose hips and their processed products. Eastern-European Journal of Enterprise Technologies, 4 (11 (130)), 26–35. https://doi.org/10.15587/1729-4061.2024.309597
27. Fataliyev, H., Mammadzade, M., Ismayılov, M., Gadimova, N., Mammadova, N., Musayev, T. (2025). Identifying the factors affecting the preparation of wine material from cherry fruits. Eastern-European Journal of Enterprise Technologies, 2 (11 (134)), 77–88. https://doi.org/10.15587/1729-4061.2025.326471
28. Gadimova, N., Fataliyev, H., Heydarov, E., Lezgiyev, Y., Isgandarova, S. (2023). Development of a model and optimization of the interaction of factors in the grain malting process and its application in the production of functional beverages. Eastern-European Journal of Enterprise Technologies, 5 (11 (125)), 43–56. https://doi.org/10.15587/1729-4061.2023.289421
29. Gadimova, N., Fataliyev, H., Allahverdiyeva, Z., Musayev, T., Akhundova, N., Babashli, A. (2022). Obtaining and investigation of the chemical composition of powdered malt and polymalt extracts for application in the production of non-alcoholic functional beverages. Eastern-European Journal of Enterprise Technologies, 5 (11 (119)), 66–74. https://doi.org/10.15587/1729-4061.2022.265762
30. Salimov, V., Huseynova, A., Guliyeva, A., Alizade, S., Mammadova, R. (2025). Assessment of Biomorphological and Economically Important Traits of some Local Grape Varieties and Clones of Azerbaijan. Advances in Biology & Earth Sciences, 10 (2), 303–313. https://doi.org/10.62476/abes.102303
31. Fataliyev, H. K. (2012). Winemaking practicum. Baku: Elm, 328. Available at: http://anl.az/el/Kitab/2013/Azf-272480.pdf
32. Sheskin, D. J. (2020). Handbook of Parametric and Nonparametric Statistical Procedures. Chapman and Hall/CRC. https://doi.org/10.1201/9780429186196