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DEVISING A TECHNOLOGY FOR MANUFACTURING WINE FROM MULBERRY USING OSMOTIC DEHYDRATION

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The object of this study is a technique for making mulberry wine using osmotic dehydration. The task addressed is to establish the compliance of mulberry wine quality indicators with current standards. The quality of industrially produced red semi-sweet grape wine and mulberry wine made according to original technology using osmotic dehydration has been analyzed. Some physicochemical indicators of wine quality, color intensity, and antioxidant properties were investigated using standard methodology. It was found that the mass concentration of acids in mulberry wine is slightly lower (by 0.75 ± 0.05 g/l) than in grape wine, which leads to an increase in pH (3.93 ± 0.05). Due to the use of an osmotic solution obtained during the preliminary dehydration of mulberry fruits in the fermentation process of wine, its density (1.049 ± 0.05 g/cm^3) and the mass fraction of sugars (106.95 ± 0.05 g/dm^3) increase. The volume fraction of ethyl alcohol in mulberry wine is 5% lower than in grape wine, which makes the drink more acceptable for health-conscious consumers. The color of mulberry wine is more saturated. The color intensity of mulberry wine is 9.98 ± 0.05, which is typical for aged red wines. At the same time, the color intensity of grape wine is within 3.82 ± 0.05, which may indicate the beginning of oxidative processes in it. It has been established that mulberry wine has better antioxidant properties. The redox potential of mulberry wine (14.9 ± 0.05) is lower than that of grape wine (15.2 ± 0.05). The redox potential of mulberry wine is 23.8 ± 0.05 mV higher than that of grape wine. Mulberry wine has a lower concentration of components capable of oxidation. Thus, mulberry is a potentially important raw material for the development of winemaking

Keywords: mulberry wine, grape wine, osmotic solution, color intensity, redox potential indicator, redox

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1. Introduction

Wine is one of the oldest known fermented beverages whose production is closely linked to the culture and traditions of the region in which it is produced. The industry is extremely important for the economies of countries [1].

In addition, the positive effect of moderate wine consumption on overall health has been proven. Therefore, wine is a constant object of research among scientists. Research interests have mostly focused on the protective effect of bioactive compounds against the development of common diseases, such as cardiovascular, cancer, and neurodegenerative.

The main crop in wine production is grapes. The amount of wine produced from non-grape fruits is insignificant. However, in some countries and regions there is no industrial cultivation and processing of grapes due to climatic conditions. Also, a significant risk for viticulture is the increase in the sugar content of grapes due to global warming. As a result, in the future, grape wines may have a higher alcohol content. Excessively high alcohol content will significantly reduce the consumer appeal of grape wines and the profitability of viticulture.

A new trend worldwide is the consumption of fruit wines. Interest in them is caused by the growing diversity of consumer demand for wines with low alcohol content, different flavors, colors, and nutritional value. The main consumers of fruit wines are young and middle-aged people, especially women [2]. Alcohol and sugar content are among the key factors determining the preference of fruit wines for consumers.

In addition, the production of such wines requires the addition of water because the juice is difficult to extract directly from the fruit. High water content can lead to the development of microorganisms. In order to prevent spoilage of the must by microorganisms, potassium, or sodium metabisulfite is usually added before fermentation, which negatively affects the biological value of the resulting drinks.

An alternative may be osmotic dehydration – a method of partial removal of water from plant tissue using a hypertonic solution. Osmotic dehydration has a number of advantages, as the process makes it possible to remove up to 50% of moisture from fruit with minimal energy consumption. At the same time, the high concentration of dissolved substances in the solution prevents the development of microorganisms.

Therefore, it is relevant to study the potential of using the osmotic solution obtained after the processing of fruits and berries as an alternative raw material for wine production.

2. Literature review and problem statement

In [3] it is stated that the main components of fruit wines are carbohydrates and organic acids. It has been shown that they form their taste and aromatic properties. Additional study of the peculiarities of the formation of the taste of fruit wines made from uncultivated types of raw materials, which can become an alternative to traditional ones, is required.

They also include other nutrients, in particular, various types of phenolic compounds [4]. Phenolic compounds in fruit wines include flavonoids (anthocyanins, flavonols, flavonols, etc.), as well as derivatives of cinnamic and benzoic acids and stilbenes, such as resveratrol. It is phenolic compounds that form the color of wines and affect their shelf life. However, during the processing of fruit raw materials, their amount is significantly reduced. The amount and composition of wine polyphenols depend on many factors, such as variety, crop, geographical growth zone, degree of ripeness at the time of harvest, environmental factors, especially conditions and methods of winemaking and storage. Despite modern winemaking techniques, the issue of preserving the biological value of the raw material remains unresolved.

Unlike grape juice, which is naturally suitable for winemaking and does not require significant processing before fermentation, other fruit and berry raw materials, other than grapes, almost always require adjustment. In addition, the addition of water to fruit wines is mandatory. The main reason for adding water is to reduce the high acidity of some fruits or to avoid a rich or tart taste.

During heat treatment, these nutrients are partially destroyed or lose their properties, which leads to a decrease in the biological value of products made from them. Fermentation, which is the main process in wine production, is carried out at low temperatures. At the same time, the content of biologically active components is preserved in wine. Osmotic dehydration is also a non-thermal process. Thus, the technology that involves the combination of these two processes can positively affect not only the organoleptic properties of wines, but also their biological value. However, such studies have not been conducted and require careful investigation.

Despite the difficulties in processing, edible fruits are good raw materials for winemaking since they are characterized by a high content of phenolic compounds. In particular, in work [5] it is shown that edible fruits contain antioxidants. Therefore, it is necessary to investigate the influence of individual types of fruit raw materials, in particular, non-wood forest resources.

Mulberry deserves special attention. Mulberry fruit is considered a good material for fruit winemaking. The results of studies [6] indicate that they contain organic acids (malic, tartaric). Due to the content of organic acids, the pH of the juice is 3.5–4.0. The main pigments of mulberry, which form the color of the fruit, are cyanidin-3-rutinoside and cyanidin-3-glucoside. Mulberry fruit contains 0.5–1.4% protein, 7.8–9% carbohydrates, a small amount of fatty acids (linoleic, oleic, palmitic, stearic), vitamins C, A, and some B. The most common amino acid in mulberry is glutamic acid, which accounts for approximately 20% [7]. It is a neurotransmitter and is able to activate numerous receptors of the nervous system. This gives reason to assume that wine made from mulberry will be popular among consumers due to its taste. However, the issue of ensuring physicochemical indicators that would meet current standards remains unresolved.

Mulberry wine is rich in antioxidants, known for its anti-aging and antiviral effects, which contributes to its growing popularity among consumers [8]. Despite the progress in mulberry processing technologies, current research is focused on identifying the optimal varieties for winemaking and improving the technological parameters of the processing process. In particular, no technologies have been identified that would involve osmotic dehydration in the production of mulberry wine.

The main raw material in the production of mulberry wine is the seedless black mulberry strains, which show noticeable differences in quality compared to white mulberry [9]. Mulberry wine contains higher alcohols, which form its taste and aroma properties. However, when the content of higher alcohols is too high, it has a bitter, strong, tart, and spicy taste, which not only affects the quality and taste of the wine but is also harmful to human health [10]. Therefore, it is important to regulate the alcohol content during the fermentation of mulberry wine. The osmotic solution formed during osmotic dehydration could become an effective raw material that can be used at different stages of fermentation, regulating the level of sugar, and as a result, alcohol.

All this gives grounds to argue that it is advisable to conduct research aimed at devising a technology using osmotic dehydration. The comprehensive use of derivatives of all derivative products formed during dehydration of mulberry sap could ensure high quality and biological value of mulberry wine, which would not be inferior to grape wine.

3. The aim and objectives of the study

The aim of our research is to devise a technology for making mulberry wine using osmotic dehydration and to assess its quality in comparison with grape wine. The results to be obtained could make it possible to substantiate the feasibility of using mulberry as a raw material in wine production.

To achieve the goal, the following tasks were set:

– to design a technological scheme for wine from mulberry fruit;

– to investigate the physicochemical quality indicators of mulberry and grape wines;

– to assess the color intensity of mulberry and grape wines;

– to determine the redox potential and oxidation-reduction potential of mulberry and grape wines.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our study is the technique of making mulberry wine using osmotic dehydration.

The subject of the study is the quality indicators of mulberry wines made using osmotic dehydration.

The hypothesis of the study is as follows. It is assumed that mulberry wine made using a unique technology using osmotic dehydration has a quality that meets the requirements of current regulatory documents, better antioxidant and biological potential, compared to grape wine made using traditional technology.

4. 2. Materials

The red semi-sweet grape wine Ah Noir (ordinary table wine) with a note of blackberry and raspberry, TM TIZIANO (Ukraine), was studied.

Mulberry wine was produced independently, using the deised technology. Ripe mulberry fruit (*Mórus nígra* L.) collected in July 2023 in the Sumy oblast was used as raw material. During fermentation, a solution formed during osmotic dehydration of mulberry fruit was added to the wine must. After fermentation, the young wine was removed from the yeast, aged at a temperature of 3–5°C for 1 month, and a second racking was performed. The study of wine quality indicators was carried out after 1 year of aging.

4. 3. Investigating the physicochemical quality indicators of mulberry and grape wine

The total acidity of the wine was determined by titration with a 0.1 N sodium hydroxide solution, pH – with a pH-150 ionometer.

The density of the wine was determined by the aerometric method.

The mass fraction of sugars was investigated by the refractometric method using an RL2 refractometer.

The volume fraction of ethyl alcohol was determined by a laboratory hydrometer ASP-3.

4. 4. Methodology for assessing the quality of wine by its color

The color intensity was determined by the photocolorimetric method, which is based on measuring the intensity of light absorption in a certain range of wavelengths using a KFK-2 photocolorimeter.

Radiation in the yellow (420 nm), red (520 nm), and blue (620 nm) ranges was used for analysis. The yellow range characterizes the "maturity" of the wine, the level of polyphenol oxidation. Red is the color intensity, the main contribution of anthocyanins to the formation of the color of the wine. The blue range makes it possible to establish the proportion of anthocyanins associated with tannins.

The total color intensity (CI) was determined as the sum of optical density at 420 nm, 520 nm, and 620 nm. Tint (T) – as the ratio between the absorption in the yellow and red zones.

4. 5. Investigating the redox potential and oxidation-reduction potential of mulberry and grape wines

To assess the antioxidant properties of wines, the redox potential and oxidation-reduction potential were determined.

The measurement of the oxidation-reduction potential (ORP) of aqueous solutions was carried out using an I-160MI ionomer with a working (platinum) electrode and a silver chloride reference electrode. The rH_2 potential was calculated using the following formula

$$rH_2 = \frac{Eh}{29} + \text{pH} \cdot 2, \quad (1)$$

where *Eh* is the redox potential (mV); pH is acidity; 29 and 2 are the specified coefficients.

The redox potential is a quantitative measure of the chemical activity of elements or their compounds in reversible chemical processes associated with a change in the charge of ions in solutions. It characterizes the degree of activity of electrons in redox reactions.

The higher the concentration of components capable of oxidation in relation to the concentration of components that can be reduced, the higher the redox potential.

The redox potential in aqueous systems reflects the redox state of the environment and the ratio between the oxidized and reduced forms of substances. rH_2 is a dimensionless quantity that is related to ORP (*Eh*), proton activity (pH), and partial pressure of hydrogen (PH_2). The rH_2 value allows us to assess the redox balance in aqueous solutions: the lower the rH_2, the higher the reducing power of the solution.

4. 6. Statistical analysis

The results of oour studies are expressed as the mean±-standard deviation of measurements from three separate extracts, three different studies. The Student's *t*-test was used to compare the mean values. Statistical significance was accepted at $p \leq 0.05$.

5. Results of devising the technology of mulberry wines made using osmotic dehydration

5. 1. Technological scheme for the production of wine from mulberry fruits

A feature of the proposed technological scheme for the production of wine from mulberry fruits (Fig. 1) is their preliminary dehydration by the method of osmotic dehydration and the use of an osmotic solution in the fermentation process.

According to this technological scheme, a 70% osmotic solution is prepared from granulated sugar and drinking water in an osmotic dehydration apparatus [11]. In the same apparatus, the solution is heated to a temperature of 65 ± 5°C. After reaching the required temperature, black mulberry fruits are loaded into the apparatus in a ratio of 1:1. Osmotic dehydration is carried out for 1 hour with constant stirring and a temperature of 50 ± 5°C.

The osmotic solution is separated from the partially dehydrated fruits and sent for reservation. A constant temperature of 3±2°C is maintained in the solution reserve tank.

Partially dehydrated fruits remain in the same apparatus. 100% purified drinking water is added to them. Partially dehydrated mulberry fruits are infused for 12 hours at a temperature of 10–15°C in order to extract soluble substances. For greater efficiency of the infusion process, the fruit is mixed with the extractant.

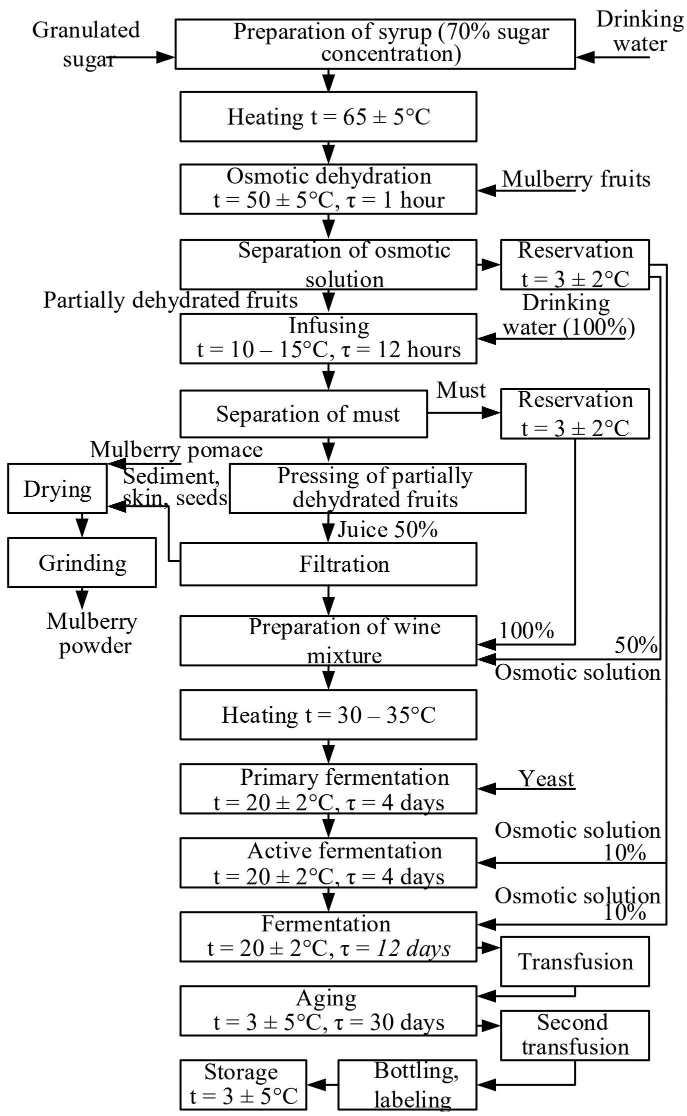

Fig. 1. Technological scheme for making mulberry wine

At the stage of active fermentation (on the 4th day), 10% (by weight of the must) of osmotic solution is added to the fermenter. After 4 days, another 10% of osmotic solution is added and fermentation takes place for 12 days. After the end of fermentation, the young wine is poured (removed from the yeast) into another container, aged at a temperature of 3–5°C for 30 days. After 30 days, the wine is poured a second time, after which it is packed in consumer containers, labeled, and sent for storage.

5. 2. Results of the assessment of physicochemical quality indicators of mulberry and grape wines

The basic physicochemical indicators that form the quality of wine are total acidity, pH, density, and mass concentration of sugars. These indicators determine its taste and stability during storage.

The results of our study of the physicochemical quality indicators of experimental wine samples are given in Table 1.

Acidity is the main driving force of important technological measures related to the risks of wine contamination. The results showed that the mass concentration of acids in mulberry wine is slightly lower (by 0.75 g/l) than in grape wine.

In addition, the pH level of mulberry wine slightly exceeds the regulatory value. Given that these indicators are within the permissible limits, it can be assumed that mulberry wine is stable during storage.

The addition of an osmotic solution contributes to an increase in the density of the wine and the sugar content. The density (1.049 ± 0.05 g/cm^3) and the mass fraction of sugars (106.95 ± 0.05 g/dm^3) of mulberry wine are higher than those of grape wine. The high sugar content (10.1 ± 0.05 %) gives the wine a sweet and rich taste and also contributes to the stability of the wine during storage after opening the container.

At the same time, the volume fraction of ethyl alcohol in it is less by 5 % vol/vol, which makes the drink more acceptable for consumption for people who care about their health.

After infusing, mulberry fruit pulp is pressed using pneumatic presses. The juice formed as a result of pressing is filtered and sent to prepare a wine mixture. The pulp is dried at a temperature of 65 ± 5°C in vacuum dryers and ground into powder. The resulting powder from mulberry fruits can be used as a natural food coloring.

The must formed during the infusing process is separated from the pulp and sent to reserve at a temperature of 3 ± 2°C.

The wine mixture is prepared from the must (100%), spent osmotic solution (50%), and juice formed during the pressing of partially dehydrated mulberry fruits (50%). The mixture is slowly fermented at a temperature of 20 ± 2°C under static conditions for 4 days. Before fermentation, the mixture is heated to a temperature of 30–35°C and dry wine yeast (2% by weight) is added to it.

Table 1

Physical-chemical quality indicators of mulberry and grape wines

Indicator ID	Normative value	Actual value		Difference	$HIP_{0,05}$
		Mulberry wine	Grape wine		
Mass concentration of acids, g/l	1–7	5.25 ± 0.05	6.0 ± 0.05	–0.75	4.726
pH	3.7–3.9	3.93 ± 0.05	3.38 ± 0.05	0.55	7.883
Mass fraction of sugars, g/dm^3	2–300	106.95 ± 0.05	62.24 ± 0.05	44.71	23820.977
Sugar content, %	5.0–12.9	10.1 ± 0.05	6.3 ± 0.05	3.8	69.048
Density, g/cm^3	0.990–1.050	1.049 ± 0.05	0.988 ± 0.05	0.061	21.410
Volume fraction of ethyl alcohol, % vol./vol.	5–28	6.0 ± 0.5	11.0 ± 0.5	–5	93.915

5. 3. Results of assessing the quality of mulberry and grape wines by color

Red wines contain anthocyanins, flavonoids, tannins, and other polyphenolic compounds, which give them a characteristic color. The higher the color intensity, the richer the color of the wine.

The results of the study are given in Table 2.

The results showed that the highest optical density (0.491 ± 0.05D) of mulberry wine is observed at a wavelength of 520 nm, i.e., in the red range, which indicates a high content of anthocyanins.

Table 2

Wine color determination results

Wine	Optical density, *D*			*CI*	*T*
	420 nm	520 nm	620 nm		
mulberry	0.4 ± 0.05	0.491 ± 0.05	0.107 ± 0.05	9.98 ± 0.05	0.814 ± 0.05
grape	0.173 ± 0.05	0.164 ± 0.05	0.045 ± 0.05	3.82 ± 0.05	1.055 ± 0.05
difference	0.227	0.327	0.062	6.16	–0.241
$HIP_{0,05}$	37.999	39.314	42.951	64.970	23.961

Grape wine had the highest optical density (0.173 ± 0.05 D) in the yellow range (420 nm), which characterizes its maturity and the level of oxidation of polyphenols.

The color intensity of mulberry wine (9.98 ± 0.05) is significantly higher than the color intensity of grape wine TM TIZIANO (3.82 ± 0.05). That is, mulberry wine has a more saturated color.

By color intensity, it can be characterized as an aged red wine ($CI = 8–12$). The tint $T > 0.8$ is characteristic of wines with signs of aging or oxidation. Considering that CI within 4–6 indicates the beginning of oxidation, it can be assumed that oxidative processes have begun in grape wine.

5. 4. Results of investigating the redox potential and oxidation-reduction potential of mulberry and grape wines

The results of our study of the antioxidant activity of wine are given in Table 3.

Table 3

Results of a study of the antioxidant properties of wines

Wine	*Eh*, mV	rH_2
Mulberry	237.2	14.9
Grape	213.4	15.2
Difference	23.8	–0.3
$HIP_{0.05}$	101.230	18.678

Analysis revealed that the redox potential rH_2 of mulberry wine (14.9) is lower than that of grape wine (15.2). This means that mulberry wine has a lower concentration of components capable of oxidation in relation to the concentration of components that can be reduced. As a result, the redox potential (*Eh*) of mulberry wine is 23.8 mV higher than that of grape wine.

Based on our results, the antioxidant properties of mulberry wine are better than grape wine. Probably due to the high content of anthocyanins.

6. Discussion of results based on the study of the quality of mulberry wine produced using a new technology

The devised technological scheme for the production of mulberry wine (Fig. 1) is waste-free. Compared to existing ones, the proposed technology involves the use of a significantly smaller amount of sugar since it is used only for the preparation of an osmotic solution and is not supplied in several stages during the fermentation process [10]. To stop fermentation, unlike existing technologies [10, 12], carbon dioxide is not used. The process is regulated by adding an osmotic solution formed during the preliminary dehydration of mulberry fruits. The advantage of the proposed technology is also that the yield of the finished product increases by 120 %.

Our analysis of physicochemical parameters revealed (Table 1) that the mass concentration of acids in mulberry wine is slightly lower (5.25 ± 0.05 g/l) than in grape wine (6.0 ± 0.05 g/l). The decrease in acidity is a serious problem for winemaking. The level of titrated acidity of the must, together with changes in other parameters, such as the concentration of potassium cations and pH, directly affects the quality of the wine. When the values of these parameters go beyond the optimal ranges, they have a detrimental effect on the microbial and sensory quality of the finished wines. In particular, wines with high pH values are more susceptible to microbial contamination [13]. It is worth noting that the pH level (3.93) of mulberry wine decreased during storage. After two months of fermentation, it was 4.52 ± 0.05 [14]. This indicates that fermentation continued during wine storage. Despite this, the physical and chemical quality indicators of mulberry wine are stable and comply with the current regulatory documentation (DSTU 6036:2008 Fruit and berry wines. General technical conditions).

The addition of an osmotic solution during the fermentation of mulberry wine contributed to an increase in its density (1.049 ± 0.05 g/cm^3) and the mass fraction of sugars (106.95 ± 0.05 g/dm^3). This provides good taste and aromatic properties of the wine and leads to a decrease in its alcohol content. The volume fraction of ethyl alcohol in mulberry wine is 6.0 ± 0.5% vol./vol., which is 5% lower than in grape wine. Given that the demand for low- or even non-alcoholic wines is growing as more people opt for "responsible" consumption, mulberry processing could become a sustainable practice. Mulberry wines are of interest to consumers who are looking to reduce the health risks associated with alcohol consumption while still enjoying the taste and social aspects of wine consumption.

One of the stages of wine quality assessment was the determination of its color. The highest optical density (0.491 ± 0.05D) of mulberry wine is observed at a wavelength of 520 nm (Table 2), i.e., in the red range, which indicates a high content of anthocyanins. Similar results were obtained in other studies [6]. The reason for the preservation of anthocyanins during wine fermentation may be the periodic introduction of an osmotic solution with a high sucrose content (50–60%) into the must. Sucrose is known to have a protective effect on the level of anthocyanins [15]. In addition, additional sugar increases the accumulation of volatile odor components, in particular alcohols and esters, which gives mulberry wine unique taste and aromatic properties.

Mulberry wine had a richer color (T = 0.814 ± 0.05) and higher color intensity (9.98 ± 0.05), typical of aged wines. High color intensity (CI) is associated with a high content of phytochemicals produced in the wine. In contrast, grape wine showed signs of aging. In particular, its color intensity was only 3.82 ± 0.05. The yellow range (420 nm), in which grape wine had the highest optical density (0.173 ± 0.05 D), characterizes its maturity and the level of polyphenol oxidation. Its anthocyanin content is significantly lower compared to mulberry since the key factor contributing to the wide range of colors is the high concentration of anthocyanins [7].

According to our results (Table 3), mulberry wine had better antioxidant properties. The redox potential of mulberry wine was 14.9, which is 0.3 lower than that of grape wine (15.2). This indicates that mulberry wine has a higher concentration of substances that form the antioxidant properties of fruit wines. These include anthocyanins, phenols, and flavonoids [16]. Mulberry wine had a high redox potential (237.2 mV), which indicates antioxidant capacity.

The results obtained give grounds to argue that the proposed technology is effective since it makes it possible to obtain wine that is not inferior in quality to grape wine. The practical significance of our study is that a comparative analysis of the quality of grape wine (middle price segment) and mulberry wine revealed that mulberry wine has higher quality in some indicators. This confirms the feasibility of its industrial production.

Our results can be used in practice. They could become the basis for the development of winemaking in regions where there is no industrial cultivation and processing of grapes due to climatic conditions. This would also contribute to the sustainable development of local communities through the use of non-derivative forest resources.

The limitations of this study include the fact that grape wine from a specific producer was used for comparison. When analyzing other types of grape wines, the results may differ. Mulberry is a wild raw material, which requires more effective control over its safety.

The disadvantage of the proposed technology is that mulberry is a perishable raw material, so difficulties may arise with its procurement and storage.

It remains necessary to investigate the influence of these factors on the chemical composition, microbiological indicators, and safety indicators of mulberry wines. This will give winemakers fundamental knowledge about their quality and allow them to regulate quality through various strategies and technologies.

7. Conclusions

1. A technological scheme for the production of mulberry wine has been designed, the uniqueness of which is the use of the osmotic dehydration process. The advantage of the proposed technology is the preservation of the antioxidant properties of wine during the fermentation process due to the gradual introduction of an osmotic solution into the must. In addition, this technology is waste-free since it involves processing the pulp into powders that can be used as food dyes.

2. Analysis of physicochemical indicators revealed that mulberry wines are not inferior in quality to grape wines. Their values are within acceptable standards. Compared with grape wines, mulberry wine had a lower acid concentration (5.25 ± 0.05 g/l), a higher sugar content (10.1 ± 0.05 %), and a lower alcohol content (6.0 ± 0.05 % vol./vol.).

3. Mulberry wine had a more saturated color (T = 0.814 ± 0.05) and a higher intensity (9.98 ± 0.05), typical of aged wines. High optical density in the red range indicates a high content of anthocyanins in it. The color of grape wine was less saturated, and the color intensity (3.82 ± 0.05) indicates the beginning of oxidation.

4. The redox potential of mulberry wine (14.9) was lower than that of grape wine (15.2), which indicates its higher resistance to oxidation. The redox potential of mulberry wine is 23.8 mV higher than that of grape wine. Thus, mulberry wine has better antioxidant properties.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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