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DETERMINING THE POSSIBILITY OF MAKING MULBERRY WINE BY USING THE OSMOTIC DEHYDRATION PROCESS

This study aimed to determine the possibility of using osmotic dehydration in the production of mulberry wine. Mulberry fruits (Mórus nígra L.) were mixed with 70 % sucrose solution and osmotic dehydration was carried out (τ=1 h, t=50±5 °C). At the stage of active fermentation, the osmotic solution separated from the fruits was added to the must (10 % by mass). Partially dehydrated mulberry fruits were infused for 12 hours in water at a temperature of 10–15 °C. The formed must was separated from the fruits, mixed with an osmotic solution, and a solution formed during pressing of dehydrated fruits. The mixture was fermented at 20±2 °C for 20 days under static conditions. At the end of fermentation, the young wine was kept at a temperature of 3–5 °C for 1 month. A second transfusion was performed, and its quality indicators were analyzed. It was established that the osmotic solutions formed during the osmotic dehydration of black mulberry fruits contain 42.60±0.25 mg/100 g of anthocyanins, which makes them an effective basis and additive for giving wine the desired sensory characteristics. The high content of anthocyanins in wine (35.8±0.5 mg/100 g) provides for its stable red-ruby color. As a result of hydrolysis, sucrose, which was the main component of the osmotic solution before mulberry dehydration, is transformed into glucose (27.74±0.05 g/100 g) and fructose (28.60±0.05 g/100 g). This significantly increases its biological value and gives the wine a harmonious taste characteristic of fruit wines. The wine made on the basis of mulberry fruit processing products is rated at 7.5 points. It had a pleasant taste and color, but a poorly developed aroma. Mulberry wine was classified as semi-dry because it had a low alcohol content (6±0.5 %), a low concentration of sugars (13.0±0.5 g/dm^3), and a high concentration of volatile acids (1.4±0.5 g/dm^3)

Keywords: black mulberry, mulberry wine, non-traditional raw materials, organoleptic indicators, osmotic dehydration

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1. Introduction

In recent years, there has been a notable consumer demand for black mulberry fruit due to its organoleptic characteristics and high phytochemical content. Mulberry fruit is rich in nutrients including fatty acids, amino acids, vitamins, minerals, and bioactive compounds such as anthocyanins, rutin, quercetin, chlorogenic acid, and polysaccharides [1].

The increased demand for high-quality black mulberry fruits is also due to a lower environmental burden during its cultivation [2]. Although mulberry (*Mórus nígra L.*) is nutritious and juicy, it has a short harvest season and is prone to spoilage during storage and transportation [3]. As a result, mulberry still remains an unconventional raw material. To fully utilize its consumer potential, it is usually processed into various products, including juice, jam, syrup, vinegar, and alcoholic beverages [4]. Mulberry fruits are characterized by a high content of useful compounds, such as phenols and polysaccharides [5], antioxidant, antiaging, anti-inflammatory, anticancer, hypoglycemic, and hypolipidemic properties [6]. In particular, it was established that the high concentration of anthocyanins in black mulberry fruits has an inhibitory effect on liver cancer cells [7]. However, most biologically active substances lose their properties during processing.

Considering that the biological value of the derived products of mulberry processing is significantly reduced during heat treatment, products made on the basis of fermentation, which is carried out at low temperatures, are of interest. In particular, wines are of interest. Mulberry wine is less studied than other fruit wines. Its properties have not been sufficiently studied. Therefore, it is a relevant task to carry out studies on devising a production technique and on investigating quality indicators of mulberry wine.

2. Literature review and problem statement

As a traditional fermented alcoholic beverage with significant territorial and socio-cultural significance, mulberry wine has a long history [8]. Although grape wines strongly dominate the market, mulberry fruits are used to make wines because of their distinctive taste and high content of polyphenolic phytochemicals and essential fatty acids [9]. In addition, the pulp formed during the production of mulberry wines is usually not subject to further processing but is disposed of. An option to overcome the relevant difficulties may be the processing of pulp into functional food additives or dyes.

Mulberry wine has quality advantages among fruit wines and low alcohol content [10]. However, this is a problem because due to the low alcohol content, mulberry wine does not meet the requirements of the standards of most European countries.

Modern studies of mulberry wine production are mainly related to the analysis of volatile aromatic compounds, evaluation of color parameters and antioxidant activity, optimization of the fermentation process. The optimal yeast strain (L13) for fermentation of mulberry wine was determined in [11]. Yeast strains have a significant effect on oenological parameters, total anthocyanins, phenolic and flavonoid content, and antioxidant activity of mulberry wine [12]. However, according to the data, research on innovative methods of wine production without the use of heat treatment is limited.

In the process of investigating the peculiarities of fermentation of mulberry wines, it was proved that the metabolism of yeast significantly affects the final properties, appearance, taste, and aroma of wine [13]. However, the flavor profiles associated with microbiota changes during spontaneous fermentation have not yet been described in detail.

Current research on mulberry wine is also focused on the study of its clarification efficiency, processing methods, and functional properties [14]. It was found that during fermentation, the total content of anthocyanins, phenols, and flavonoids in mulberry wine slightly decreases. In addition, its antioxidant activity decreases [15]. The issue of preserving the biological value of mulberry wine remains unresolved.

The effect of microfiltration on wine quality was established, which ensures high transparency and polydispersity of mulberry wine with satisfactory microbiological stability and storage resistance [16]. At the same time, the main properties and content of organic acids in mulberry wine are preserved, which leads to a certain loss of volatile compounds, especially esters and alcohols. Obtaining long-term stable high-quality wine remains a challenge that requires urgent research.

Data available in the literature demonstrate the potential of mulberry as a raw material for wine production. Nevertheless, a review of relevant literature showed that a rational technology for obtaining wine from mulberry has not yet been proposed. No research results were found on the possibility of processing mulberry fruits by the method of osmotic dehydration and subsequent production of wine from the resulting derivative products. This allows us to state that conducting a study into the feasibility of using osmotic dehydration of mulberry fruits before using it in wine production is relevant.

3. The aim and objectives of the study

The purpose of our study is to determine the possibility of using osmotic dehydration in the production of mulberry wine. The results will become the basis for the commercial production of a drink with certain functional properties.

To achieve the goal, the following tasks are set:

– to determine the quality indicators of the osmotic solution formed during the osmotic dehydration of black mulberry fruits;

– to evaluate the organoleptic indicators of mulberry wine;

– to evaluate the physical and chemical parameters of mulberry wine.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our study is the solution formed after osmotic dehydration of mulberry fruits and mulberry wine made on its basis.

The subject of the research is the organoleptic and physical-chemical indicators of the quality of mulberry wine, physical-chemical indicators of the quality of osmotic solutions.

The research hypothesis is as follows. During the processing of black mulberry fruits by the method of osmotic dehydration, polyphenols and sugars of the cell juice, due to osmosis, are redistributed between the osmotic solution and partially dehydrated fruits. Since this method does not involve the use of high temperature treatments in processing products, a high content of biologically active substances is preserved. These products can be used as a basis for the production of wine, which will give it certain taste and aromatic flavors.

Adding osmotic solutions (syrups) to the wine must during the fermentation stage will provide sufficient nutrients for the normal development of the yeast and stabilize the color of the wine. And the pulp formed during the processing of mulberry can become a raw material for the production of natural food dyes.

4. 2. Materials

Ripe mulberry fruits (*Mórus nígra L.*) were collected in July 2023 in the territory of the Sumy oblast. Fruits without pretreatment were mixed with 70 % sucrose solution, preheated to 65±5 °C, in a ratio of 1:1. And osmotic dehydration of fruits was carried out in a laboratory dehydrator [17] for 1 hour. The temperature of osmotic dehydration was 50±5 °C. After that, the osmotic solution was separated from the fruits and stored in a sealed container at a temperature of 3–4 °C. Purified drinking water was added to partially dehydrated mulberry fruits in a ratio of 1:1 and infused for 12 hours at a temperature of 10–15 °C. Next, the formed must was separated from the fruits, mixed with the osmotic solution, and the solution formed when partially dehydrated fruits were pressed. The ratio of the components of the wine mixture is 1:0.5:0.5. The mulberry fruits, formed after infusion, were pressed using a laboratory screw press "Vilen" (Ukraine). The pulp was dried and ground into powder.

The wine mixture was fermented at 20±2 °C for 20 days under static conditions. Before starting fermentation, the mixture was heated to a temperature of 30–35 °C and dry wine yeast Hot Rod Aromatic Wine Complex (2 % by weight) was added.

At the stage of active fermentation (on the 4th day), an osmotic solution (10 % by weight of the must) was added to the fermented must and the fermentation was continued for another 4 days. After that, another 10 % of the osmotic solution was added to the must, and fermentation was continued for 12 days. At the end of fermentation, the young wine was removed from the yeast, poured into another airtight container, kept at a temperature of 3–5 °C for 1 month. The second transfusion was carried out and the content of anthocyanins, organoleptic and physicochemical indicators of its quality were studied.

4. 3. Determining the quality indicators of solutions obtained after osmotic dehydration of mulberry fruits

The active acidity of the osmotic solution was determined by the potentiometric method using a laboratory pH-meter pH-500.

The mass fraction of dry substances in osmotic solutions was determined using a laboratory refractometer. Before measurement, the solution was cooled to 20 °C. The mass fraction of carbohydrates was determined by HPLC using a Shimadzu LC 20A chromatograph (Japan) with a refractometric detector (HP 75 column in Ca++ form).

The content of anthocyanins was determined and investigated by the method of high-performance liquid chromatography (Agilent Technologies 1200, detector with UV-Vis Abs, detection at λ=520 nm. Anthocyanins were separated using an Agilent TC-C18 column (5 µm, 4.6 mm×250 mm) at 25 °C. The results were represented in mg/100 g.

4. 4. Evaluation of organoleptic parameters of wine made from mulberry fruits

The organoleptic evaluation of the wine was carried out according to a ten-point system at a temperature of 10–13 °C by 10 non-professional tasters. Descriptors of evaluation were transparency, color, taste, bouquet and aroma.

Table 1

Point assessment of wine quality

Indicator	Points
Clarity	
Completely clean, with a crystal shine	0.5
Clean, without shine	0.3
Opalescent	0.2
Turbid	0.1
Color	
Full compliance with the color of the type, type and age of the wine	0.5
A slight deviation of the color from the color characteristic of a wine of this type and age	0.4
Significant deviations from normal color	0.3
Significant deviations from normal color	0.2
Extraneous tones	0.1
Wine bouquet	
Very fine, well developed, suitable for the type and age of the wine	3.0
Well-developed, suitable for the type of wine, but rough	2.5
Underdeveloped	2.0
Not completely clean (there are shades not characteristic of this type of wine)	2.0
Not suitable for the type of wine	1.5
Extraneous odors are present	0.6
Taste	
Harmonious, subtle, suitable for the type and age of the wine	5.0
Harmonious	4.0
Harmonious, but not suitable for the type of wine	3.0
Inharmonious, but without extraneous flavors	2.5
Simple, ordinary, with a slight aftertaste	2.0
With a foreign taste	1.0
Typicality	
Full conformity to type	1.0
Slight deviation from type	0.75
Unusual wine	0.5
Completely uncharacteristic	0.25

4. 5. Studying the physicochemical properties of wine from mulberry fruits

The study of the volume fraction of ethyl alcohol was carried out using an ASP-3 laboratory hydrometer. The mass concentration of sugars was determined by the Bertrand method. The mass concentration of the titrated acids, in terms of tartaric acid, was determined by the method of direct titration with a 0.1 N solution of NaOH using an indicator of 0.4 % bromomethyl blue. The mass concentration of volatile acids, in terms of acetic acid, was determined by the Mathieu method.

4. 6. Statistical analysis

Final results were expressed as mean±standard deviation of measurements from three separate extracts, and measurements were performed in three different studies. Comparison of group means and significance of differences between groups were tested by Student's *t*-test. Statistical significance was set at $p \leq 0.05$.

5. Results of determining the derivatives and processing products of mulberry fruits

5. 1. Results of determining the quality indicators of solutions obtained after osmotic dehydration of mulberry fruits

At the first stage of the research, the quality of osmotic solutions, which were used as one of the components in wine production, was analyzed. The results of our study are given in Table 2

Table 2

Results of quality indicators of the solution obtained after osmotic dehydration of mulberry fruits

Indicator ID	Value
Mass fraction of dry substances, %	56.34±0.05
pH	4.52±0.05
Mass fraction of glucose, g/100 g	27.74±0.05
Mass fraction of fructose, g/100 g	28.60±0.05
Anthocyanin content, mg/100 g	42.60±0.25

The results of the study showed that due to osmotic dehydration, the mass fraction of dry substances in solutions decreases by 13.66 % due to the transition of cell juice. The content of anthocyanins, which cause the bright dark red, almost black color of the osmotic solution, is 42.60 mg/100 g.

Color stability is probably also caused by the moderate acidity of the solution (pH=4.52±0.05).

Due to osmotic dehydration, the sucrose contained in the initial solution, probably under the catalytic action of acids contained in mulberry fruits, undergoes complete hydrolysis during osmotic dehydration. As a result of acid hydrolysis, glucose (27.74±0.05 g/100 g) and fructose (28.60±0.05 g/100 g) are formed, which significantly increases the biological value of the solutions. Monosaccharides play an important role in shaping the organoleptic qualities of wines, they soften the taste and give them a sweet taste.

5. 2. Results of organoleptic evaluation of mulberry wine

Wine quality is a multidimensional, complex concept that can be considered both from the point of view of the consumer and from the point of view of the wine sector. From the point of view of the consumer, several aspects are covered in the literature [18]. In particular, the difficulty of assessing wine quality, as it is a matter of experience, in which it is necessary to distinguish between perceived and objective quality. Consumers evaluate the quality of wine according to their preferences and individual experience.

Since color, taste, and aroma are among the influencing factors in the formation of consumer interest in wine, its organoleptic characteristics were evaluated (Table 3).

Based on the sensory evaluation, it was obvious that the wine made on the basis of mulberry fruit processing products was rated at 7.5 points. The drink had a shine characteristic of quality wines and a rich ruby-red color. The color of wine is one of the most important indicators of quality, and often speaks about its aromatic and taste properties. High color saturation characterizes the resulting sample as a high-quality wine. The light taste of the wine indicated its low alcohol content, which was confirmed by the results of the analysis of physical and chemical parameters (Table 3). However, the aroma of the experimental sample of wine was poorly developed, not sufficiently pronounced, atypical for grape wines.

Table 3

Results of organoleptic evaluation of mulberry wine

Indicator ID	Characteristics	Point assessment
Clarity	Without sediment and foreign inclusions, with a shine	0.5
Color	Rich, ruby red	0.5
Taste	Harmonious, similar to mulberry juice, with a sharp tartness characteristic of young wines. Light, low-alcohol	4.0
Aroma	Weakly developed, with a fruity undertone	2.0
Evaluation of typicality of wine	Unusual wine	0.5

5. 3. Results of the physicochemical evaluation of mulberry wine

The results of the physicochemical evaluation of mulberry wine are given in Table 4.

Table 4

Results of physicochemical evaluation of mulberry wine

Indicator	Value
Volume fraction of ethyl alcohol, %	6.0±0.5
Mass concentration of sugars, g/dm^3	13.0±0.5
Mass concentration of titrated acids, in terms of tartaric acid, g/dm^3	6.0±0.5
Mass concentration of volatile acids, in terms of acetic acid, g/dm^3	1.4±0.5
Anthocyanin content, mg/100 g	35.8±0.5

According to the result of our physical and chemical evaluation, it was established that the wine made from mulberry fruits was characterized by a low alcohol content (6±0.5 %). Considering the rather low concentration of sugars (13.0±0.5 g/dm^3), the experimental sample can be classified as semi-dry wines. This is evidenced by the high concentration of volatile acids (1.4±0.5 g/dm^3). Glucose and fructose, which were contained in the osmotic solution, are almost completely utilized by yeast cells due to fermentation. But due to the additional addition of 10 % osmotic solution to the must after the end of the period of active fermentation, probably part of the fructose is preserved in it, which gives the wine a harmonious taste (Table 2). The high content of anthocyanins ensures a stable red-ruby color of the wine.

6. Discussion of results of investigating the antioxidant potential of *Aronia melanocarpa* fruit processing derivatives

The most important results of this study were the demonstration that osmotic dehydration can be used for the pretreatment of mulberry fruits. According to the results given in Table 1, osmotic solutions contain a sufficiently high amount of glucose, fructose, and anthocyanins. It is anthocyanins that determine the bright ruby-red color of wine, which is a decisive regulatory factor for controlling its quality [19].

According to the literature [20], the content of anthocyanins in mulberry fruits is 206 mg/100 g, however, 17 % of these coloring substances remain in the wine (Table 3). Usually, anthocyanins are more stable in an acidic environment [21] at lower temperatures and higher concentrations [22]. According to our results (Table 1), the osmotic solutions obtained during dehydration had moderate acidity (pH=4.52±0.05), and the dehydration temperature was 50±5 °C, but only 21 % of anthocyanins passed into the osmotic solution: the results are given in Table 1. Probably most of them remain in the fruit because they are not crushed before dehydration. Therefore, the pulp obtained after pressing the berries should be dried, ground into powder, and used as a natural food dye.

It is known that during wine maturation, the content of monomeric anthocyanins in red wines constantly decreases, which is caused by the formation of pyran anthocyanins and polymeric anthocyanin pigments [23]. At the end of fermentation, the young wine was kept in a hermetic container at a temperature of 3–5 °C for 1 month, and only then was its quality analyzed. At the same time, it retained a fairly high content of anthocyanins (35.8±0.5 mg/100 g), which indicates the stability of mulberry wine based on osmotic solutions.

Due to the introduction of an osmotic solution into the must during the fermentation process, the wine is given a special taste and aroma (Table 2). Considering the fact that the obtained wine was semi-dry, the perception of sweetness was determined not by the residual sugar content but by the higher fructose content (28.60±0.05 g/100 g) in the osmotic solutions, which were added in several stages to the must. The presence of fructose tends to increase the perception of sweetness in the production of grape wines [18].

The practical significance of our study is the possibility of expanding the range of fruit wines based on raw materials of regional importance.

The limitations of this study include the lack of normative technological documentation for the production of wine from mulberry fruits. In addition, the use of wild raw materials requires a more effective countermeasure for its safety.

In Ukraine, there are no mass areas of industrial cultivation of black mulberry. In most areas, this raw material is a wild plant. Therefore, there may be problems with its preparation. However, the proposed technique for processing mulberry fruits is low-waste and will provide for the production of two types of products at once: wine and natural food dyes.

Further research will be aimed at developing the technology of mulberry wine using osmotic dehydration, studying its shelf life, as well as vitamin content in it.

7. Conclusions

1. It has been established that the osmotic solutions formed during the osmotic dehydration of black mulberry fruits contain 42.60±0.25 mg/100 g of anthocyanins, which makes them an effective additive for giving wine the desired sensory characteristics. In addition, as a result of acid hydrolysis, sucrose is transformed into glucose (27.74±0.05 g/100 g) and fructose (28.60±0.05 g/100 g), which significantly increases the biological value of the solutions.
2. The wine made on the basis of mulberry fruit processing products is rated at 7.5 points. It had a pleasant taste and color but a poorly developed aroma.
3. The mulberry wine was characterized by a low alcohol content (6±0.5 %), a low concentration of sugars (13.0±0.5 g/dm^3), and a high concentration of volatile acids (1.4±0.5 g/dm^3); therefore, the experimental sample can be attributed to semi-dry wines.

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 and the results reported in this paper.

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Data availability

All data are available 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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