Dealcoholized wine from the grape of the Citronny Magaracha variety: Physico-chemical parameters and the formation of a sensory profile

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Abstract

Introduction. The aim of the study was to determine the technology of dealcoholized wines produced from the Citronny Magaracha grape variety, ensuring maximum preservation of the natural sensory properties of the original wine.

Materials and methods. White dry wine from the grape of the Citronny Magaracha variety (Ukraine) was used. Dealcoholization was carried out using vacuum or osmotic distillation. The physico-chemical parameters of the dealcoholized wine were determined using nuclear magnetic resonance and chromatography. The sensory properties were evaluated using specialized methods.

Results and discussion. Complex physico-chemical processes occur during dealcoholization of wine. The removal of alcohol results in the concentration of both volatile (aldehydes, acids, higher alcohols, and ethers) and non-volatile (glycerol, organic acids, and amino acids) substances, which alters the overall flavor profile of the wine, causing flavor imbalances and sensory disharmony.

Concentration of organic acids increases during dealcoholization, which changes the acid balance and affects the microbiological stability of wine. Content of malic acid increases by 30-38%, which changes the acidity of the wine. Content of glycerin increases by 24-26%, which has a positive effect on the sensory characteristics of wine. Content of amino acid proline increases significantly after dealcoholization, which can affect the taste properties of wine. The presence of volatile components, such as acetaldehyde and 3-methyl-butanol, may contribute to the aromatic and taste characteristics of the wine. An important finding is also the reduction of methanol concentration during dealcoholization, which improves product safety.

Sensory evaluation showed that dealcoholization of wine obtained by two different methods (vacuum or osmotic distillation) did not have a significant effect on the peach, citrus or nutmeg aroma characteristic of the wine produced from the Citronny Magarach grape variety, and the main aromatic characteristics remained almost unchanged. However, dealcoholization significantly affected other sensory characteristics such as sweetness, acidity, bitterness, and wine body. Overall, the treated wines had less sweetness and bitterness, increased acidity, and reduced fullness.

Conclusion. The process of dealcoholization of wine changes its physical and chemical composition and sensory properties, which requires the improvement of technologies to preserve the taste balance.

Introduction

In recent years, there has been a significant increase in demand for non-alcoholic beverages, including non-alcoholic wines, which is associated with modern ideas about healthy lifestyle. In addition, non-alcoholic wines can be considered as drinks that can be an excellent alternative to alcoholic holiday drinks for drivers, pregnant women, athletes, and those consumers who, for various reasons or personal beliefs, do not drink alcohol (Uspalenko and Kucherenko, 2023).

According to the latest statistics and forecasts, the global non-alcoholic wine market is valued at 20 billion US dollars with a compound annual growth rate (CAGR) of more than 45% in 2018. It is projected to increase at a significant CAGR of more than 7% during the forecast period (2019-2027), reaching a value of more than 30 billion US dollars (Deore, 2024). According to other forecasts, the global market will continue to grow steadily, with a CAGR of 10.4% from 2021 to 2031, compared to a CAGR of 8.8% from 2016 to 2020. Therefore, in order for wine producers to meet consumer demands and adapt to the growing non-alcoholic wine market, they need to produce high-quality non-alcoholic or low-alcohol wines (Fact9199MR, 2023).

In view of this, there are many discussions at the legislative and scientific level regarding this type of drink. This therefore constitutes two important key aspects: legal constraints and technical challenges. Regarding the first, laws in different countries may determine the maximum permissible amount of alcohol in soft drinks, which limits the options of winemakers. Regarding the second, the technical difficulties are the difficulty of preserving the sensory characteristics of the wine after dealcoholization.

Despite the difficult path of legalization and production of non-alcoholic wine, the market still has a large range of products, creating competition among producers and pushing enterprises to constantly search for new and improved products. Currently, among the producing countries, Germany is the leader in the production of non-alcoholic wines (Schulz et al., 2023). Ukraine also has the potential for the development of this industry, especially in the aspect of creating these wines using its own aromatic grape varieties, which will favorably distinguish domestic non-alcoholic wines from foreign analogues. This direction in expanding the range of wine products is an important task for the further development of the Ukrainian grape and wine industry, especially during climate change and consumer preferences.

Alcohol-free wine is not really a new type of wine, as it was first mentioned in 1869, when the American Thomas Bramwell Welch, a strong supporter of the alcohol moderation movement, produced alcohol-free wine by pasteurization. Later, in 1908, the German scientist Carl Jung managed to produce non-alcoholic wine without a "boiled" taste using vacuum distillation at a temperature of 35 °C (Schulz et al, 2023).

In Ukraine in the 1980s, during the anti-alcohol campaign, Ukrainian scientists conducted scientific research on the development of non-alcoholic beverage technology based on grape raw materials and grape wines but did not have significant success (Tyshchenko and Bozhko, 2023).

In addition, at the beginning of the war in 2022, the situation for Ukrainian winemaking was complicated by a complete ban by local military administrations on the sale of winemaking products in Ukraine for more than 40 days, which led to significant losses for winemaking enterprises that remained in operation.

Currently, various ways of reducing the alcohol content in wines are proposed. These are membrane distillation; reverse osmosis; vacuum distillation; dilution of wort with water;

application of the enzyme glucose oxidase in the wort before fermentation, which oxidizes the fermented sugars in the wort; the use of yeast, which contributes to the production of wines with a lower alcohol yield; ultrafiltration and nanofiltration by reducing the sugar content in the wort before fermentation (Heux et al., 2006; Röcker et al., 2016).

It is extremely important to form harmonious sensory characteristics in alcohol-free wines during dealcoholization or the use of other methods that contribute to the reduction of alcohol. The goal of the present study was determination of the technology of non-alcoholic wines from Citronny Magaracha grapes with maximum preservation of the natural sensory properties of the original wine.

Materials and methods

Materials

50 liters of processed dry white table wine made from white grapes of the Citronny Magaracha variety of Ukrainian selection and grown in the Zaporizhzhia region (Ukraine) were used.

Experimental setup and dealcoholization conditions

The trials were carried out at the Getränke Technologie Zentrum (GTZ) of Hochschule Geisenheim University, in Germany.

A Vacuum Distillation plant, Hei-VAP Industrial Rotary Evaporators (Heidolph Instruments GmbH & Co. KG; Walpersdorfer STR.12, D-91126, Schwabach, Germany), equipped with a Vacuum Pump, Hei-Vac Valve Industrial, a touch screen control panel displaying all process parameters, programmable ramps, an ascending condenser, a chilling system, Hei-Chill 3000, one 20 L evaporating flask, and two 10 L receiving flasks, was used for the dealcoholization of 18 L of wine. The wine was divided into three batches for the distillation. The rotation of the flask was set at 60 rpm, the water bath temperature at 40°C, the vacuum pressure at 50 mbar, and the condensation temperature was kept constant at 1.8°C throughout all dealcoholization experiments. Each dealcoholization process was completed in 2 hours after reaching the set temperature and pressure indicated above. This process resulted in 12 L of dealcoholized wine at 0.18% vol and 5.5 L of spirits at 43.49% vol. The spirits were then redistilled under the same conditions as the previous distillations, but with a water bath temperature of 50°C. This resulted in 1 L of water at 0.20% vol and 4 L of spirits at 59.75% vol. The latter were blended with the dealcoholized wine, resulting in 13 L of dealcoholized wine.

The osmotic distillation was conducted with the WineBrane Lab Gas/Alc plant (Inoxpa Deutschland, C/Telers 60, 17820, Banyoles, Spain), equipped with a membrane contactor, Liqui-Cel® 2.5x8 (3M Deutschland GmbH, Ohder STR.28, 42289, Wuppertal, Germany). The membrane was always stored and cleaned according to the manufacturer's instructions. The feed solution, wine, was pumped by a membrane pump Flojet (Flojet Corporation, Icon 20, 92610, Foothill Ranch, U.S.A.) with a capacity of 300 L/hour, and the stripping solution, distilled water, was performed by a peristaltic pump (Verder Deutschland GmbH & Co. KG, Retsch-Allee 1-5, 42781, Haan Germany) with a capacity of 83 L/hour. The temperature of the two liquids during the trials was 20°C. The experiment needed 23 L of wine and two batch of 100 L each of distilled water. Due to the processing time (2 days), there was a problem of turbidity caused by microbiological contamination. To avoid possible blockage of the machine, it was decided to finish the last 2.21% vol by Vacuum Distillation (as described above). The 19 L of wine were divided into four batches, resulting in 4.3 L of dealcoholized wine (0.12% vol) per batch. Another distillation was performed for further concentration of spirits, resulting in 0.6 L of water at 0.15% vol and 1.2 L of spirits at 33.20 % vol from 1.8 liters of spirits. These were blended with the dealcoholized wine, yielding 17.8 L of dealcoholized wine.

An addition of SO_2 in liquid form was made to bring the free SO_2 to 30 mg/L in both types of dealcoholized products. In order to stabilize the dealcoholized wines, they were bottled using an instantaneous liquid heater, Getrankedurchlauferhitzer 03-0318 (Schankanlagen Koch GmbH, Dagstuhler STR.62, 66687, Wadern-Morscholz, Germany), bringing the temperature to 62°C. The wine was bottled into 750 mL brown glass bottles, corked with a screw cap, and stored in a warehouse at temperatures between 12 and 15°C for further analyses.

Setting up the experiment

During the experiment, the physico-chemical and sensory indicators of the quality of non-alcoholic wines obtained by various methods of dealcoholization were studied in comparison with the control wine:

- **control** – wine with an alcohol content of 13.41% vol;
- **wine 1** – dealcoholized wine by vacuum distillation with an alcohol content of 0.18% vol.;
- **wine 2** – dealcoholized wine by osmotic distillation with an alcohol content of 0.12% vol.

The first stage of the experiment was the production of dealcoholized wine by two different methods: vacuum or osmotic distillation.

At the second stage, a physico-chemical analysis using NMR and a sensory analysis by a specialized tasting commission were carried out.

Determination of sensory properties

Tastings took place in a special room equipped with individual booths and air conditioning at 20 °C. The testing was conducted by two independent tasting commissions.

For wine tasting, a standard tasting glass made of thin, clean, transparent glass with a capacity of 210–220 mL was used, which makes it possible to operate 60–70 mL of wine for a comprehensive sensory assessment of all elements of quality.

Wine with alcohol content and de-alcoholized wine were evaluated according to the Standards of the International Organization of Vine and Wine (Resolution OIV/Competition ECO 332A/200). The maximum tasting rating of the experimental wines was 100 points and was determined as the sum of points for each indicator: appearance (transparency, color) – 14; aroma (authenticity, intensity, quality of aroma) – 30; taste (authenticity, intensity, harmonic stability, taste quality) – 44; harmony (general impression) – 11.

To create the aromatic profiles of the experimental wines, a descriptive method was used according to a 10-point rating scale based on the following descriptors: citrus, fruity, nutmeg, floral, sweetness, acidity, bitterness, body/fullness, intensity, astringency. Graphical representations of experimental data were performed using Microsoft Excel 2010.

Comparing the profiles of the experimental wines made it possible to determine their differences and draw conclusions about the change in wine quality during dealcoholization.

Determination of physical and chemical parameters

Determination of physical and chemical parameters was carried out in accordance with the methods and regulations of the International Organization of Grapes and Wine (OIV). Standard protocols and analytical methods recommended by the OIV were used to conduct the research, ensuring the accuracy and reproducibility of the results obtained.

Processing research results

Determination of physico-chemical indicators of non-alcoholic wine wines was carried out in two repetitions. Results are shown as mean, including standard deviation.

Statistical data processing

Statistical data processing was performed, including determination of mean content and standard deviation (±SD), with four replicates (four collections) for the main compounds identified in all four collections analyzed. Statistical data processing was carried out using Excel 2007 (Microsoft Corporation, USA)

Results and discussion

Changes in the physical and chemical parameters of wine during dealcoholization

Changes of ethanol content, % vol., in wine during osmotic distillation is shown in Figure 1.

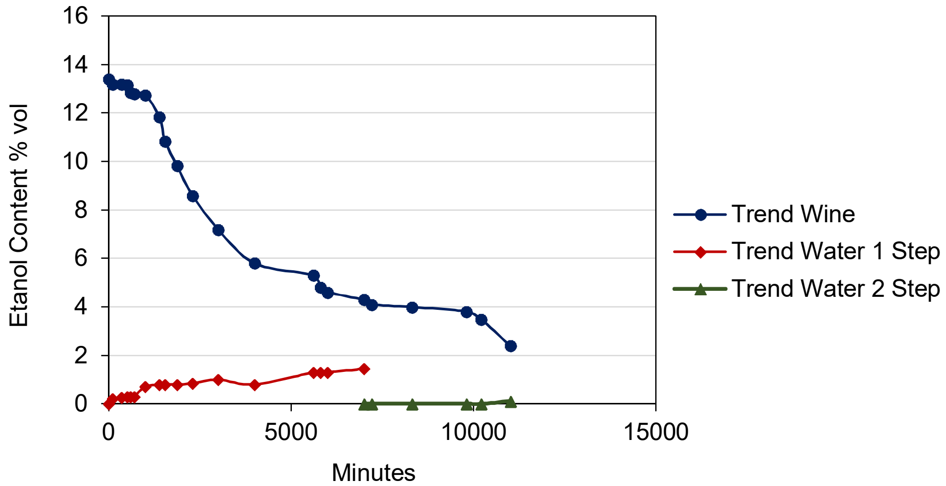


Figure 1. Changes of ethanol content, % vol., in wine during osmotic distillation

During dealcoholization of wine, complex physico-chemical processes take place in which, in addition to the removal of ethyl alcohol, other components of wine undergo changes

– both volatile – aldehydes, acids, higher alcohols, ethers, acetates, and non-volatile – glycerol, organic acids, and amino acids (Diban et al., 2008).

The alcohol content during the experiment, as expected, was reduced from 13.29% vol. (control) up to 0.18% vol. (wine 1 – dealcoholized wine by vacuum distillation) and 0.12 % vol. (wine 2 – dealcoholized wine by osmotic distillation).

It should be noted that because of removing alcohol from wine, wine components were concentrated, because of which the concentration of non-volatile compounds increased (Table 1).

Table 1

Comparison of physical and chemical parameters of the studied wines

Indicator	Control	Dealcoholized wine	
		1	2
Total alcohol, mg/L	105872.75±0.10	1402.15±0.10	966.35±0.10
Total alcohol, % vol.	13.39±0.07	0.18±0.07	0.11±0.07
Organic acids, mg/L:	4820.85±0.02	5866.53±0.02	5797.21±0.02
Glycerin, mg/l	4761.70±0.02	5853.95±0.02	5923.60±0.02
Alcohols, mg/L:			
– Methanol	50.22±0.20	<30	<30
– Proline	592.76±0.10	724.52±0.10	711.38±0.10
– 2-phenylethanol	<25	31.80±0.30	26.86±0.30
– 2,3-butanediol	384.25±0.20	483.95±0.20	467.36±0.20
– 3-methyl-butanol	141.00±0.70	<100	<100
Acetaldehyde, mg/L	232.09±0.40	238.19±0.40	166.93±0.40
Acetoin, mg/L	21.20±0.40	20.52±0.40	15.48±0.40
Trigonelline, mg/L	13.58±0.70	17.26±0.70	17.93±0.70
Energy value, kJ/L	3241.88±0.03	147.28±0.03	135.92±0.03

The total content of organic acids undergoes significant changes during dealcoholization, this is due to the change in concentration caused by the removal of ethanol and water. Glycerin content increases by 24-26%, which has a positive effect on the feeling of the wine extract. Amino acids are the main component of nitrogen compounds in grapes and wine, and make up approximately 50% of the total nitrogen content. They play an important role in shaping the sensory properties of wine, its stability and biological value. The study of amino acid content in wine is an important aspect for understanding the chemical processes that occur during wine production and storage.

In the study, the concentrations of amino acids such as alanine, arginine, and proline were determined in wine wines before and after the dealcoholization process. The results showed that the content of alanine and arginine remained stable and did not undergo significant changes after dealcoholization. This indicates that these amino acids are not subject to significant losses or transformations during this technological process.

However, the concentration of proline in the wines after dealcoholization increased. In the wine where vacuum distillation was applied, the proline content increased by 22%, and in the second wine after membrane distillation – by 20%. This may be due to various factors, such as changes in the distribution of amino acids between the liquid and solid phases or other chemical reactions occurring during the removal of alcohol from the wine. A higher proline content can influence the taste properties of wine, as proline is an important metabolite in winemaking and can affect the formation of aromatic compounds.

Concentrations of volatile substances also changed after dealcoholization of wines. For example, the content of acetaldehyde increased slightly when vacuum distillation was used, but after membrane distillation it decreased by 28%. Aldehydes play an important role in the formation of sensory indicators of wine (aroma, taste). One of the main aldehydes formed during fermentation is acetaldehyde. An increase in the content of this aldehyde gives the wine a sharp smell that has shades of toasted bread, but a decrease led to less expression of fruity aromas and flavors, making it less saturated and complex in sensory perception (Sam et al., 2021).

Trigonelline, an alkaloid, an aromatic compound that is not an important component, but also plays a role in the formation of aroma and taste, giving the wine light tones of roasted coffee, and acts as a natural biological stabilizer of wine during dealcoholization in both wines, respectively, its content increased by 1.27 and 1.32 times.

The dealcoholization process also affects other volatile compounds that affect the aroma and taste of wine. Wine contains more than 1,000 volatile compounds of various chemical classifications (alcohols, esters, fatty acids, aldehydes, terpenes, ketones, sulfur compounds), where about 400 volatile compounds are formed during wine fermentation (Esteras-Saz et al., 2021). Higher alcohols in wine are formed during alcoholic fermentation, which is carried out by yeast. They are by-products of yeast metabolic processes. Higher alcohols can be formed from amino acids via the so-called Ehrlich pathway. During this process, amino acids are deaminated to the corresponding aldehydes, which are then reduced to higher alcohols.

A representative of monoatomic alcohols is methyl alcohol, which is synthesized before and during alcoholic fermentation due to the hydrolysis of pectin's by methylpectinesterase, which is contained in grapes. Pectinase catalyzes the cleavage of ester bonds in pectin, resulting in the formation of methyl alcohol and pectinic acid (Kucherenko and Bilko, 2020). It is known that methanol is a toxic substance that can accumulate in the body and have a harmful effect on various organs and systems. In white wines, the methanol content is up to 250 mg/L, the results of the study showed the methanol content in the control wine – 50.22 mg/L, which is 4.97 times less than the maximum permissible level, and both non-alcoholic wines have an even lower methanol content – < 30 mg/L. This indicates that methanol is removed along with ethyl alcohol during the dealcoholization process of the wine.

During dealcoholization, the 3-methyl-butanol content of both wines decreased by a factor of 1.41, thereby reducing the fruity and floral notes compared to the original control wine. The volatile compound 2,3-butanediol at low concentrations can give aromatic notes of caramel or honey, but higher values can lead to a feeling of immaturity of the wine and to too high acidity, as can be seen from Table 1, the content of 2,3-butanediol increased in wines 1 and 2 on 1.26 and 1.22 times, respectively, it could be influenced by the fact that this substance was formed as a result of yeast metabolism under the influence of stress (for example, under the influence of high temperatures).

Dealcoholization also has a significant effect on the change in energy value. According to the research results, the energy value in the control wine was 3241.88 kJ/L, while in experimental wines 1 and 2 it was 147.28 kJ/L and 135.92 kJ/L, respectively, that is, the decrease occurred in 22.02 and 23.85 times, respectively. The most obvious decrease in energy value is a significant decrease in alcohol concentrations. This emphasizes the dominant effect of alcohol on energy content.

Impact of dealcoholization on content of organic acids in wine

Organic acids are an essential group of compounds in wines, as they influence the physicochemical and microbiological stability of wines, as well as their sensory properties (Coelho et al., 2018).

Table 2

Change in the content of organic acids in dealcoholized wines compared to control

Organic acids, mg/L	Control	Dealcoholized wine	
		1	2
Tartaric acid	2184.15±0.04	2408.60±0.04	2425.80±0.04
Citric acid	284.93±0.30	362.97±0.30	388.82±0.30
Caftaric acid	119.10±0.80	150.44±0.60	152.32±0.60
Succinic acid	361.71±0.20	459.19±0.20	445.37±0.20
Acetic acid	237.03±0.40	267.39±0.40	297.13±0.40
Malic acid	1430.45±0.06	1977.75±0.06	1855.15±0.06
Galacturonic acid	203.48±0.40	240.19±0.40	232.62±0.40

Thus, the intent of tartaric acid increases by 10–11%, acetic acid by 12–25%, malic acid by 30–38%, citric acid by 27–34%, caftaric acid by 26–27%, succinic acid by 24–27%. Such transformations lead to a change in the general taste profile of non-alcoholic wine, which is expressed in the imbalance of taste and disharmony of sensory perception of wine. Thus, some researchers observed that dealcoholized wines have higher acidity and less bitterness compared to the original (control) wine (Corona et al., 2019).

However, organic acids have the ability to interact with alcohols, forming complex esters that add a rich aroma and taste to wines. They create taste harmony, which is critically important for consumers' perception of wine quality.

In addition, these acids affect not only the acidity and taste, but also the stability and microbiological safety of wine. For example, acetic acid can be formed in wine during the process of aerobic bacterial activity, which can lead to undesirable sensory characteristics, such as a strong vinegar smell. At the same time, low concentrations of organic acids can contribute to the formation of a pleasant aroma and taste.

Thus, the content of tartaric acid increases by 10–11%, acetic acid by 12–25%, malic acid by 30–38%, citric acid by 27–34%, caffeic acid by 26–27%, and succinic acid by 24–27%. These transformations lead to changes in the overall flavor profile of non-alcoholic wine, resulting in taste imbalance and sensory disharmony. Some researchers note that dealcoholized wines exhibit higher acidity and less bitterness compared to the original (control) wine (Corona et al., 2019).

It is worth noting that organic acids can interact with alcohols to form complex esters, which contribute rich aromas and flavors to the wine. These acids create a harmonious taste, which is critical to consumers' perception of wine quality.

These acids also influence not only the acidity and taste but also the stability and microbiological safety of the wine. For instance, acetic acid can develop in wine through aerobic bacterial activity, potentially causing undesirable sensory traits, such as a strong vinegar aroma. At the same time, low concentrations of organic acids may enhance the aroma and flavor profile.

During dealcoholization, the galacturonic acid content remained relatively unchanged. This is because galacturonic acid forms through the degradation of pectin substances, which occurs at elevated temperatures. However, the relatively low temperature during dealcoholization does not promote intensive pectin breakdown or a significant increase in galacturonic acid (Robles et al., 2019).

A slight increase, compared to other acids, was observed in tartaric acid, which helps maintain acidity, reduce pH, inhibit bacterial growth, and preserve long-lasting freshness in the wine. Additionally, tartaric acid is essential for enhancing the structure and flavor profile of the wine (Yang, 2021).

Acetic acid also significantly affects the sensory profile and stability of wine. In low concentrations, up to 300 mg/L, it is a natural component of wine, adding subtle, pleasant acidic notes that lend freshness. However, concentrations above 600–700 mg/L can cause off-flavors and aromas, such as vinegar or what is commonly known as "volatile acidity" (Vilela-Moura et al., 2010). Studies have shown that with both methods of dealcoholization, the acetic acid content increased but remained within low levels, providing pleasant acidic notes to the non-alcoholic wine.

As shown in Table 2, malic acid increased by 30–38% during dealcoholization. This may lead to the formation of lactic acid, which negatively affects wine stability and can introduce an unpleasant bitter taste. Therefore, it is essential to control malic acid levels during dealcoholization.

Other acids, such as citric, caffeic, and succinic acids, were affected by a process of preservation, resulting from the simultaneous removal of ethanol with water and certain volatile compounds. This led to an imbalance in acidity levels, making these acids appear more acidic to consumers (Gawel et al., 2013).

Changes in sensory parameters of wine during dealcoholization

During the study, no changes in the color of the wine were observed compared to the initial (control) wine. Wine 1, obtained by vacuum distillation, retained its light straw color and transparency, remaining unchanged. Meanwhile, wine 2, obtained by osmotic distillation, also showed no color changes but exhibited slight turbidity (Figure 2). The turbidity arose due to a shift in the colloidal equilibrium of the system following the removal of alcohol, which was associated with the treatment duration of two days. Further technological stabilization processes will help achieve the desired appearance, clarity, and stability of wine.

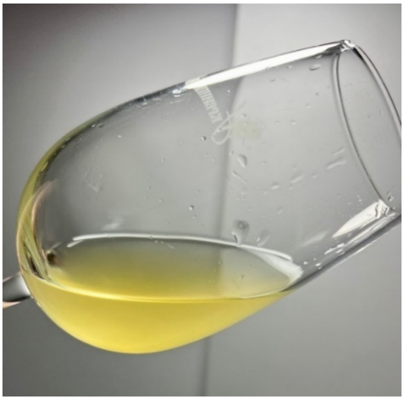
However, the greatest impact of dealcoholization was found on the wine's aromatic and flavor characteristics, highlighting the importance of selecting processing methods that preserve the sensory properties of the product.

The results of the tasting analysis of the experimental wines showed that dealcoholization using two different methods did not lead to a significant change in the perception of peach aroma in wines (Figure 3).

A careful analysis of the changes in the main descriptors of the experimental wines made it possible to establish the following. Dealcoholization of wine is generally associated with the loss of volatile aromatic components (Kumar et al., 2024). On the other hand, decreasing ethanol levels enhances the perception of aromatic components, which can compensate for aroma losses (Escudero et al., 2007; Goldner et al., 2009). In this case, both effects probably resulted in the perception of the peach aroma not being significantly altered.

Control

Wine 1



Wine 2

Figure 2. Comparison of the color of the control with the dealcoholized wines

Both treated wines showed similar expressions of citrus tones. Dealcoholized wines were generally described as having a slightly reduced, but not significantly altered, intensity of this descriptor.

Nutmeg tone was rated almost equally for both dealcoholized wines. Unprocessed wine showed a more pronounced sense of this descriptor, although not at a significant level.

The overall floral sensation was scored higher for the untreated control wine compared to the dealcoholized variants, which again showed similar expressions.

The dominant aromatic attributes investigated were rated almost identically for the dealcoholized wines and did not differ significantly from the original untreated wine (Schmitt et al., 2023).

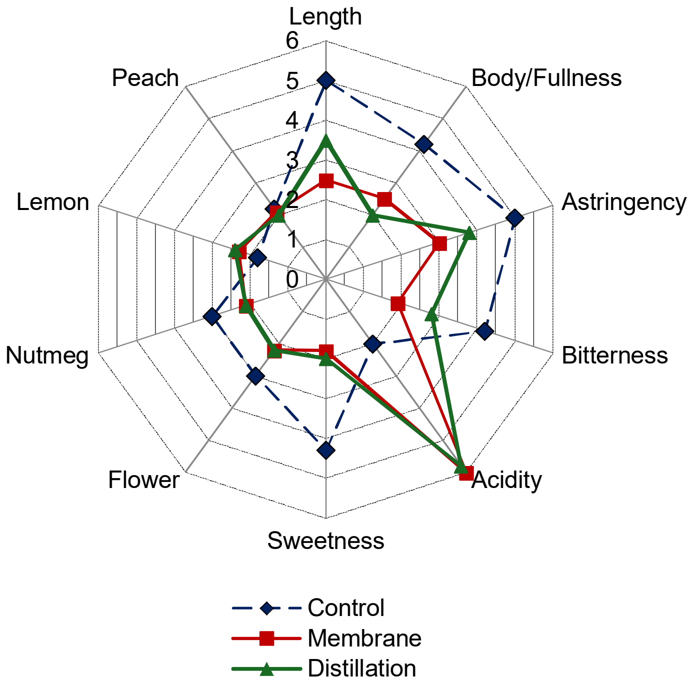


Figure 3. Profilogram of aroma and taste of dealcoholized wines

Sweetness perception was clearly altered by dealcoholization. Dealcoholized wines had significantly less sweetness compared to the original wine. This is due to the direct sensory effects of ethanol, which adds sweetness to wine (Martin and Pangborn, 1970; Nurgel and Pickering, 2006). Based on this, it becomes clear why de-alcoholized wines are usually produced with an increased level of sugar, that is, semi-dry or semi-sweet. To compensate for this change due to dealcoholization, average residual sugar in dealcoholized wines is around 40 g/L (Schmitt, 2023). Perception of acidity was rated significantly higher for dealcoholized wines. Both wines had almost the same indicators. This increase in perceived acidity is consistent with a direct effect of ethanol in wine, as alcohol reduces perceived acidity in wine (Fischer and Noble, 1994). In addition, the loss of volume during dealcoholization increases the acidity value even more. Therefore, when choosing wines for dealcoholization, this factor should be considered and wines with lower than usual acidity values should be chosen to obtain a balanced product.

The bitterness of the initial wine was significantly higher compared to the two dealcoholized variants. A direct effect of ethanol in wine is to increase bitterness (Noble, 1994).

Regarding astringency, tasters rated the initial wine as having the highest level of this sensation. The distilled version scored the second highest, while the membrane-processed version scored the lowest for astringency. Some scientists report a decrease in astringency with increasing alcohol levels in model wine solutions. Wines were used in this study, and the treatment was accompanied by a concentration effect. Further research should focus on how the complex perception of astringency is modified by wine dealcoholization to optimize the sensory characteristics of still wines (Fontion et al., 2008).

The perception of body and fullness in wine is clearly correlated with alcohol content (Amerine and Roessler, 1983; Gawel et al., 2007; Grainger, 2009; Yu, 1998). The higher the alcohol content, the higher this perception. The results of this study show a significant difference between the treated variants and the original wine. As body and fullness are clearly considered positive sensory characteristics for wine (Hoffmann and Szolnoki, 2008), oenological strategies such as adding mannoproteins or tannins can partially compensate for the reduction of these sensory parameters due to dealcoholization. Similarly, tasters noted that the initial wine had significantly more aftertaste compared to the treated wines. This corresponds to the findings obtained using the method of assessing the temporal dominance of sensations in partially dealcoholized wines (Meillon et al., 2009).

The study shows that dealcoholization of wine significantly affects its sensory characteristics. The differences between the two processing methods were not so pronounced. The sensory characteristics of the aromatic parameters were changed less than the attributes affecting the perception of the wine on the palate. The main effects of dealcoholization are consistent with the complex sensory characteristics of ethanol in wine.

Conclusions

1. The process of dealcoholization is accompanied by complex physical and chemical changes in the composition of wine, which affects its sensory properties. Reducing the alcohol content to the level of 0.18% or 0.12% in the wine led to the concentration of other wine components, which, in turn, affected the balance of taste and the harmony of sensory perception.
2. The study confirmed that various methods of dealcoholization, such as vacuum or osmotic distillation, had its own influence on wine quality. However, with the decrease in the level of alcohol, an increase in the concentration of non-volatile compounds was recorded, which required further improvement of technologies to preserve the harmony of taste.
3. The results show the need for further research to optimize dealcoholization technologies to preserve the natural sensory properties of wine.
4. To ensure the stability of non-alcoholic wines, all stages of the technological process must be considered, including the addition of stabilizers such as SO_2 and the storage conditions. This will help preserve the quality of dealcoholized wine during its storage.

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