Acta Sci. Pol. Technol. Aliment. 22(4) 2023, 375–384

www.food.actapol.net pISSN 1644-0730 eISSN 1898-9594 http://dx.doi.org/10.17306/J.AFS.2023.1161

ORIGINAL PAPER

Received: 03.08.2023
Accepted: 23.10.2023

THE FORMATION OF NATURAL FRUIT AND BERRY WINE FROM JOSTABERRIES

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ABSTRACT

Background. Jostaberry is a berry crop which is rich in bioflavonoids and ascorbic acid; it has a pleasant aroma and taste, and can be a good raw material for the production of natural fruit and berry wines. Jostaberries have not been sufficiently studied in the scientific sphere as far as their processing into natural wines is concerned. The studies presented in this paper explore the quality, biological value, and aroma of jostaberries and some aspects of the technology used to process them.
Material and methods. The materials were jostaberries grown in the conditions of the Central Forest Steppe zone of Ukraine, must in the process of fermentation, and wine from jostaberries with a volume fraction of ethyl alcohol not lower than 14%. Before fermentation, the must from jostaberries had a titrated acid content which was not higher than 8.3 g/dm^3 and a sugar content (in terms of inverts) of 242 g/dm^3.
Results. The duration of must fermentation was set at 52 days. For the purpose of timely and objective control over the must fermentation process, an equation was developed which allowed the volume fraction of ethyl alcohol during the fermentation process to be calculated with an accuracy of 0.65% using the parabola equation, and the intensity of the accumulation of ethyl alcohol to be calculated according to its derivative. It had already been established that jostaberries were rich in bioflavonoids and vitamin C, and the suggested technology for processing them made it possible to preserve polyphenolic substances and vitamin C in the wine as much as possible. Pomegranate proved to be a dominant descriptor in the aroma of jostaberry wine.
Conclusion. The presented studies show the prospects for processing jostaberries into natural wines, the latter being a high-quality and biologically valuable food product.

Keywords: jostaberries, natural wine, fermentation, aroma, polyphenols, ascorbic acid

INTRODUCTION

Fruit and berry wines are distinguished by the originality of their taste and their varietal and other qualities, which are known in folk traditions. The variety of raw materials makes it possible to manufacture a wide range of such wines (Moskalets et al., 2019).

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Jostaberry (*Ribes nidigrolaria*) is a berry culture bred by remote hybridization of blackcurrant and gooseberry in Germany at the institute named after Max Planck at the end of the 1970s (Hughes, 2023; Ünal, 2021). Outwardly, it resembles a blackcurrant with spreading shoots without thorns. It is an unpretentious, disease-resistant and high-yielding berry crop, which is rich in bioflavonoids and ascorbic acid; it also has a pleasant aroma and taste, and can be a good raw material for the production of natural fruit and berry wines (Gündeşli et al., 2019). Jostaberries are used both fresh, in the restaurant business (Lykholat et al., 2023), and in food production to flavor juices and drinks, and to make jams and desserts (Kalugina and Kalugina, 2017).

The complex of vitamins and mineral compounds found in jostaberries is not inferior to that found in the most useful and popular garden crops (Moskalets et al., 2019). Jostaberries contain valuable bioflavonoids (Pallah et al., 2019), including flavonols, isoflavones, anthocyanins, and proanthocyanidins, which have anti-inflammatory, antiviral and anti-carcinogenic properties (Okatan, 2020; Donno et al., 2018).

Researchers have shown that jostaberries are rich in ascorbic acid, the content of which varies from 42.27 ±6.63 mg/100 g FW (Donno et al., 2018) to 450 mg/100 g (Kalugina et al., 2017) and 591 mg/100 g (Karaagac et al., 2021), probably depending on the variety and cultivation conditions. Ascorbic acid exhibits a specific anti-radiation effect; it has a positive effect on the central nervous system and some antioxidant properties.

Several scientists have studied the aromatic complex of jostaberries and established that its aroma is caused by a set of substances, including terpene alcohols, aldehydes, and ethers. The dominant substances were found to be α-terpineol and 1.8-cineole, which have the aroma of lilac, honey and rose (Jung, 2018; Tokar et al., 2022).

In fruit and berry wine processing, the chemical composition of the raw materials is changed, and the methods of raw material processing, the fermentation conditions and other factors affect this change (Tokar et al., 2021). During processing, the mass concentration of phenolic substances is known to decrease and the losses of ascorbic acid can be significant, but the content of these substances remains high. For instance, the content of ascorbic acid in wines made from berries remains at a high level, despite a decrease in its concentration of more than 50% (Tokar et al., 2020).

Fermentation plays an important role in developing good quality fruit-berry wines. The duration of the berry fermentation process must exceed that of the grape must fermentation, lasting several weeks; in particular, this is typical for crops with a high content of phenolic compounds (Punbusayaku, 2018). It is important to control the fermentation process with pure yeast to ensure complete fermentation of **must** sugars and to maintain a high content of phenolic compounds along with the formation of a pleasant aromatic profile and the preservation of varietal characteristics (Tokar et al., 2019). During fermentation, the aromatic profile of the wine is formed, and the aroma of the substances synthesized by the yeast during fermentation is superimposed on the varietal aroma (Bezusov, 2020).

Jostaberries have not been sufficiently studied in the scientific field, in particular in the area of their processing into natural wines. Research related to changes in the content of the biologically valuable components of jostaberries and the formation of the aromatic complex of natural wines from jostaberries, as well as the possibility of managing the process of obtaining high-quality fruit and berry wines with high organoleptic characteristics, is of considerable scientific interest.

The purpose of the study was to determine the main technological modes of production of natural wine from jostaberries and to evaluate the quality of the wine produced, its biological value and its specific aroma. As a result, the following tasks were planned: to investigate the fruit of jostaberries; to determine the criteria for the regulation of the must fermentation process; to study the organoleptic, physical-chemical indicators of the quality of wine materials and wines; to research the biological value of wine materials from jostaberries based on the study of the ascorbic acid and phenolic compound content; and to reveal the specificity of the aroma of natural wines from jostaberries by applying a descriptive analysis.

MATERIALS AND METHODS

The materials were jostaberries of the “Berry Pie” variety, grown in the Central Forest Steppe zone of Ukraine, and the products resulted from their processing – must and natural dry wines. These studies have been ongoing since 1993; the paper presents the data for the period 2019–2022.

Preparation of must

Jostaberries were harvested at a technical stage of ripeness on the experimental plots of Uman National University of Horticulture. Before processing, the berries were sorted, rinsed with water and exposed to inspection. An average sample of berries weighing 2 kg was taken, from which, after grinding and mixing, a pooled sample was formed to determine the berries' biochemical composition.

The content of sugars and titrated acids in the berries was determined, the must was normalized according to the concentration of titrated acids in the range of 5.3–8.3 gL^{-1} with prepared water, and it was sweetened with white sugar to a sugar concentration of 241–249 gL^{-1} to ensure a volume fraction of ethyl alcohol of 14.0–14.5% and a sugar content of no more than 3 gL^{-1}. To do this, the calculated amount of water was poured into the boiler and brought to the boil, and then the prepared berries and the calculated amount of sugar were added. The obtained must was pasteurized at a temperature of 85°C for 3 minutes according to the recommendations for must from fruits and berries in Ukraine. The purpose of pasteurization was the destruction of wild microflora and the inactivation of enzymes that could negatively affect the fermentation process and the quality of the future drink. The must was poured into the containers for fermentation. After cooling to a temperature of 20°C, a strain of pre-reactivated EC-1118 yeast (Saccharomyces bayanus, Institute of Champagne Winemaking, Epernay, France) was added. The dosage of yeast was determined according to the manufacturer's recommendations, namely, 2.5 g/dal. After the accumulation of alcohol in the must within the range of 14.0–14.5% vol. the mass was cooled to a temperature of no more than 4°C and the sediment was separated from the wine by filtration.

The content of dry soluble substances was determined using a RAL-3 refractometer (Japan) at a temperature of 20°C. The device was checked using distilled water, then 2–3 drops of juice were applied and the mass of dry soluble substances collected was recorded from the indicators of the device. To determine the amount of sugars, a certain amount of wine material was measured with a pipette into a flask with a capacity of 200 cm^3 based on the calculation of the sugar concentration of 2–3.5 g/dm^3. 50 cm^3 of distilled water and 3 cm^3 of concentrated hydrochloric acid were added and the mixture was kept in a water bath (67–69°C) for 5 minutes. It was then cooled to 20°C, and the control thermometer was washed with distilled water in the flask. 1–2 drops of phenolphthalein were added and neutralized with sodium hydroxide solution (concentration 20%). The solution was brought to the mark and mixed. Then the solution was poured into a burette and a mixture of Fehling's solutions was titrated with it (consisting of: I. a solution of chemically pure recrystallized copper sulfate; and II. a solution of chemically pure sodium potassium tartrate and sodium hydroxide). The titer of the mixture had previously been determined by titration with a solution of inverted sucrose. The titration was carried out in the presence of the methylene blue indicator. The mass concentration of residual sugars was determined by direct titration, pre-clarified with neutral lead acetate and wine material. The content of titrated acids was determined by titration with 0.1 N NaOH in a chemical beaker with a capacity of 100 cm^3 of filtered water extract from berries in the amount of 50 cm^3 or 10 cm^3 of the wine material to be investigated with 50 cm^3 of distilled water after mixing, boiling and cooling. The hydroxide solution was added to the glass from the burette and mixed, and the indicators of the pH meter were observed while the electrodes connected to it were in the glass. The titration was completed at a pH of 8.0 (pH-meter AD-130). The mass concentration of the titrated acids was determined in terms of malic acid. The volume fraction of alcohol was determined in the distillate after wine distillation with an ASP-2 alcohol meter with a measurement limit of 11–16% and a division price of 0.1%. To determine the content of volatile acids, 10 cm^3 of wine material was introduced into a distillation flask with a separatory funnel. After 6 cm^3 of distillate had been collected in the receiving cylinder, 6 cm^3 of boiled distilled water was added to the distillation flask. Distillation was completed when 24 cm^3 of distillate had been collected in the receiving cylinder. The distillate was transferred to a conical flask for titration; the cylinder was rinsed three times with distilled water, which was poured into the flask. The obtained solution was heated to 60–70°C; 2 drops of phenolphthalein were added, titrated with 0.1 N

NaOH until a light pink color appeared and remained for 30 seconds. The mass concentration of volatile acids was determined in terms of acetic acid.

The mass concentration of the residual extract was calculated as the difference between the total extract and the content of sugars and titrated acids. The content of the total dry extract was determined by the relative density of the wine material and the water-alcohol mixture from it at 20°C. The total content of phenolic compounds was determined spectrophotometrically at a wavelength of 680 nm using the Folin-Chocalteu reagent with conversion to gallic acid, spectrophotometer (Ulab 101, China). To construct a calibration graph for gallic acid concentrations of 60, 120, 180, 240, 300, 360, 420, and 600 mg/dm^3, the optical density of solutions was determined in a cuvette with a distance between faces of 10 mm. 1 cm^3 of wine material diluted 5 times was measured into a measuring flask with a capacity of 100 cm^3. 15–20 cm^3 of water, 1 cm^3 of Folin-Chocalteu reagent, and 10 cm^3 of Na_2CO_3 solution with a concentration of 200 g/dm^3 were added and brought up to the mark with water, and after 30 minutes the optical density was measured. Phenolic substances were determined according to the calibration schedule (the data were multiplied by the dilution factor – 5). The content of ascorbic acid was determined by titration with potassium iodate. To determine the redox potential (RP), a potentiometric method was used, based on the conversion of the electromotive force (EF) of the corresponding electrode systems into a direct current proportional to the measured value. Measurements were performed on a pH-meter-millivoltmeter (pH-meter AD-130) using a platinum electrode (measuring) and an electrode made of silver or mercury chloride (comparison) (Method OIV-MA-AS2-06). To obtain the value of the intensity indicator and the shade of the wine material, the optical density was measured at wavelengths of 420 and 520 nm. The measurement was carried out in quartz cuvettes with a distance of 1 mm between the working faces. The control solution was distilled water. The intensity indicator I was determined as the sum of the optical densities at the wavelengths D_{420}, D_{520} and D_{620}. The shade index T was calculated as the ratio of D_{420} to D_{520}, spectrophotometer (Ulab 101, China). The determination of all indicators was carried out in three repetitions.

Sensory evaluation

The organoleptic analysis of the samples of wine materials was carried out according to the traditional rules of wine tasting. A descriptive method was used to create aromatic profiles of wine materials. A rating scale from 0 to 5 was used with the following descriptors: pomegranate, cherry, blackberry, blackcurrant, gooseberry, raspberry, rose, honey, pear, pineapple. 36 respondents took part in the research.

Data processing

The statistical processing of the results was achieved by a dispersion correlation analysis with the use of special software packages (Excel, DAD). The data were expressed as mean ±SEM. The effects were deemed to be significant at $p < 0.05$, and a trend was noted when at $p < 0.10$.

RESULTS AND ANALYSIS

Jostaberries, grown in the conditions of the Central Forest Steppe zone of Ukraine, accumulated dry soluble substances ranging from 12.8 to 15.2% of their volume (Table 1); these substances contained sugars in the range of 8.6–10.8% and titrated acids in the amount of 2.9–3.2%.

Table 1. Content of the components in jostaberries (n = 3, $p \leq 0.05$)

Harvest year	Content, %			Content, mg/100 g	
	dry soluble substances	Sugars	titrated acids	ascorbic acid	polyphenols
2019	12.8 ±0.2	8.6 ±0.1	2.9 ±0.2	146 ±2	180 ±5
2020	13.6 ±0.1	9.1 ±0.1	3.0 ±0.2	125 ±3	192 ±4
2021	15.2 ±0.1	10.8 ±0.1	3.2 ±0.1	98 ±6	220 ±6

The content of the components of the berries changed during the years under study, and this change was associated with different weather conditions in the growing season. In particular, a change in the content of ascorbic acid (98–146 mg/100 g) and polyphenols (180–220 mg/100 g) was recorded; according to the content of these components, jostaberries could be

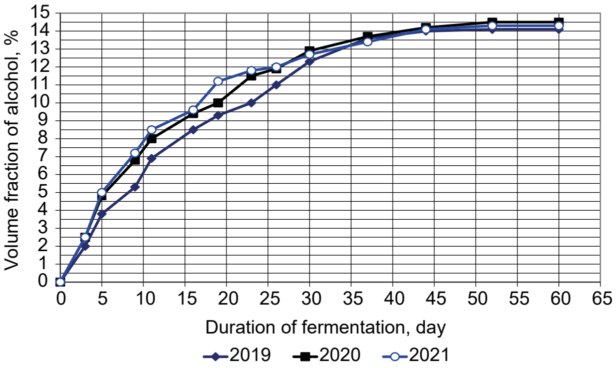

Fig. 1. Dynamics of the ethyl alcohol accumulation in jostaberry must

classified as rich in ascorbic acid and polyphenols, and this is very much consistent with other scientific data (Kalugina et al., 2017).

Another stage of the work was focused on the analysis of the fermentation dynamics of jostaberry must. The results of the research showed that the fermentation of sugars in jostaberry must lasted for up to 52 days (Fig. 1). It should be noted that the fermentation intensity varied slightly in different years of the study. But on the 44th day of the fermentation, all samples had an alcohol concentration of about 14.0% vol. Thereafter, fermentation slowed down significantly, and the process ended on the 50th–52nd day, with an alcohol concentration equal to 14.1–14.5% vol.

The effect analysis of the factors (Fig. 2) of the fermentation duration and the conditions of the harvest year showed the predominant influence of the duration of must fermentation on the volume fraction of ethyl alcohol in must made from jostaberries. The factors had a similar effect on the intensity of the fermentation process (Fig. 3). The intensity of the process differed depending on the day of fermentation and the year.

The period of development of the must fermentation lasted three days and its intensity did not differ from the period of violent fermentation, which lasted up to 11 days, when the accumulation intensity of ethyl alcohol was equal to 0.7–0.8% vol./day. During the period from the 12th to the 23rd day, the intensity of the process decreased and the fermentation period began at an intensity of 0.2–0.3% vol./day; the process continued with this intensity until the 30th day in

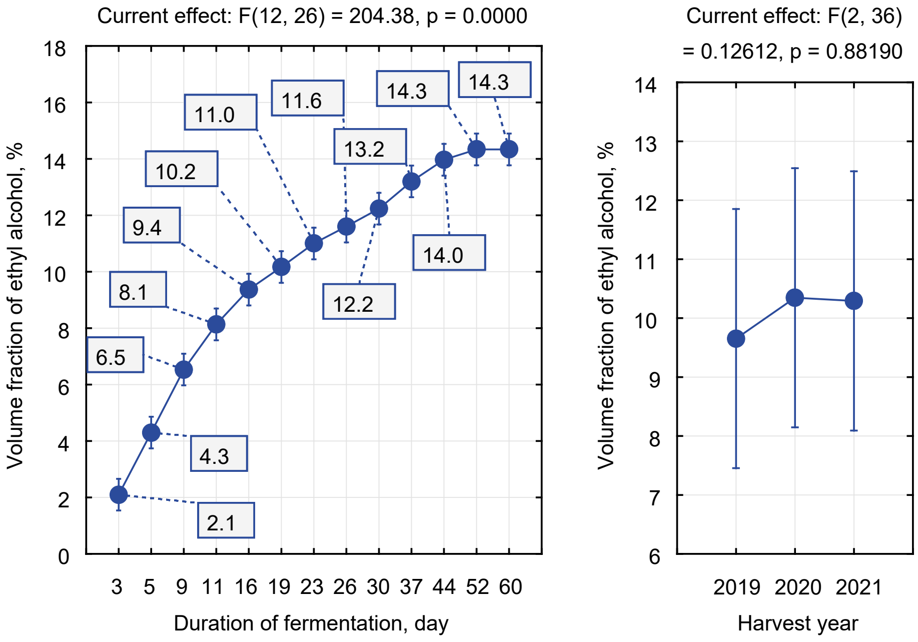

Fig. 2. Volume fraction of ethyl alcohol in must made from jostaberries depending on the influence of the factors (average over three years)

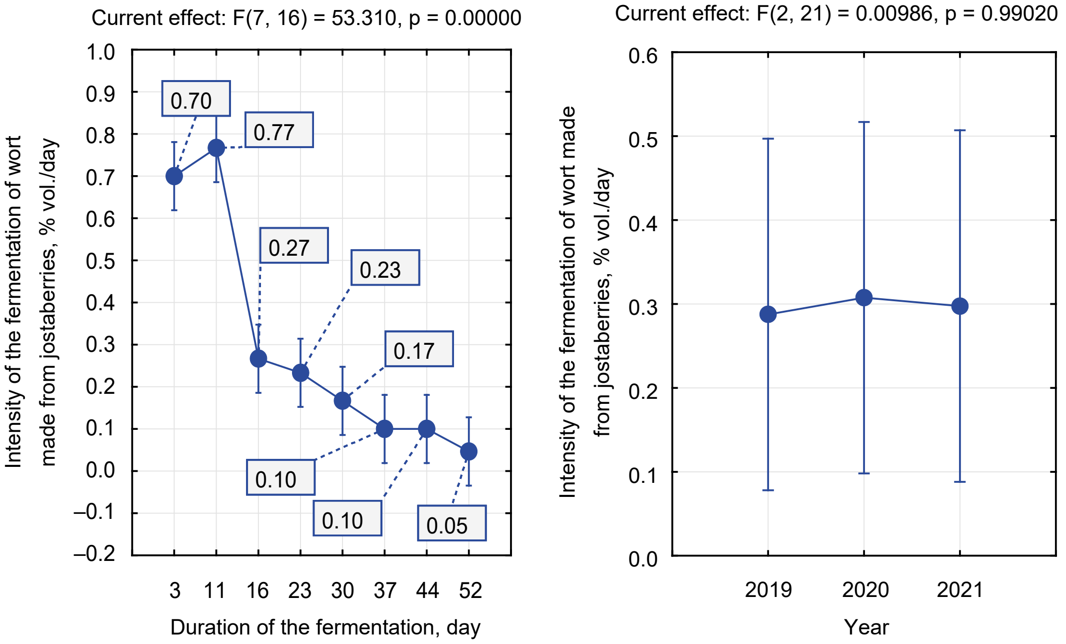

Fig. 3. Intensity of the fermentation of jostaberry must (average over three years), % vol./day. Intensity of the fermentation of must made from jostaberries, % vol./day

2019. In other years, the intensity of the process was 0.1% volume/day. The same intensity continued until the 44th day, and in 2020 and 2021 it was even lower before the end of fermentation.

The change in the intensity of the must fermentation (Fig. 3) was identical to the curves which described the change in the release intensity of carbon dioxide and yeast biomass in the process of the must fermentation. The duration of the fermentation appeared to be the predominant factor which had an effect on the accumulation of ethyl alcohol (99%), so the following stage of the analysis concentrated on the mathematical processing of the data for the three years of the research. The statistical processing of the averaged experimental data, presented in Figure 1, made it possible to establish the relationship between the volume fraction of alcohol and the duration of the process, which resulted in the derivation of a polynomial equation (Eq. 1):

$$y = -0.01x^2 + 0.56x + 1.23 \quad (R^2 = 0.98) \qquad (1)$$

where

y is the volume fraction of ethyl alcohol in the must, %
x is the fermentation time of the must.

Using the derived equation, we found the theoretical value ($\bar{Y}_x$) and performed the necessary mathematical and statistical calculations according to the known methods. Since the actual Student's test $t_{\text{ŋ}} = 9.8$ was higher than $t_{0,95} = 2.2$ and $t_{0,99} = 3.11$, the relationship was reliable at both significance levels.

The mean square deviation σ for the derived equation was ±0.65% vol., which was not more than 5%, allowing the use of the equation in practice to control the fermentation of must during any period of the process. The dynamics of the accumulation of ethyl alcohol were described by a quadratic parabola, which had the following general form: $y = Ax^2 + Bx + C$. The intensity (speed) of the process (y') was derived from the equation and could be determined on any day (x) according to the equation: $y' = 2Ax + B + 0$. In particular, when the fermentation of jostaberry must occured: $y' = 0.56 - 0.01x$.

Therefore, by the accumulation of the volume fraction of ethyl alcohol (y), the fermentation process of jostaberry must could be described by the derived equation of the parabola when the initial sugar content in must was 258 g/dm^3, the duration was x = 0...52nd

Table 2. Physical-chemical indicators of the wine materials from jostaberries (n = 3, $p \leq 0.05$)

Harvest year	Ethanol, %	Content, gL^{-1}			
		residual sugars	titrated acids	volatile acids	residual extract
2019	14.0 ±0.2	9.0 ±2.5	8.0 ±0.3	0.33 ±0.06	16.55 ±0.48
2020	14.5 ±0.1	4.0 ±1.5	7.8 ±0.2	0.26 ±0.02	17.40 ±0.85
2021	14.4 ±0.2	5.3 ±2.3	8.0 ±0.2	0.36 ±0.04	16.25 ±0.88

Table 3. Ascorbic acid and polyphenol content in jostaberry wines and their preservation in relation to the content in the fruit (n = 3, $p \leq 0.05$)

Harvest year	Ascorbic acid		Polyphenols	
	content, mg/100 g	preservation, %	content, mg/100 g	preservation, %
2019	34	23.3	68	24.3
2020	32	25.6	98	31.6
2021	28	28.6	70	29.2

(day) and the mean square deviation was 0.65% vol. The resulting equations were of practical importance and could be used as criteria for a timely evaluation of the progress of the fermentation process in wine production.

Physical-chemical indicators of the quality of wine materials and wines

The analysis of the physical-chemical quality indicators of the samples of wine materials from Jostaberries received over three years (Table 2) made it possible to establish that the obtained wine materials met the requirements for natural semi-dry wine materials: the volume fraction of ethyl alcohol amounted to 14.5%, the mass concentration of titrated acids was equal to 5...8 gL^{-1}, the volatile acids were not higher than 1.2 gL^{-1}, and the residual extract was at least 12 gL^{-1}.

Biological value of wines

Jostaberry wines contained 28–34 mg/100 g of ascorbic acid and 68–98 mg/100 g of polyphenols (Table 3).

The decrease in content in relation to fresh fruit was due to the dilution with water to obtain the required concentration of titrated acids and sugar for the increase of the initial concentration of sugars in must before fermentation. Some losses of ascorbic acid and polyphenols occurred during the preparation and fermentation of must (Fig. 4–5).

The decrease in the content of ascorbic acid and polyphenols (Fig. 4–5) in wine materials due to normalization by the mass concentration of titrated acids and an increase in the mass concentration of sugars in must could not be considered as losses, as the amount of product increased during these technological techniques. Therefore, there was a reduction in content rather than a loss of ingredients. During the preparation, the must fermentation and the sweetening of wines, the losses of ascorbic acid ranged from 4.8 to 10.4% and those of polyphenols from 4.0 to 6.4%. In general, according to the average data, 25.8% of ascorbic acid and 28.4% of polyphenols were preserved in wines as compared with their content in jostaberries (Table 3). Therefore, according to the average data, the consumption of 150 cm^3 of natural wine from jostaberries could satisfy 58% of an adult's daily need for vitamin C, since the daily dose of vitamin C was 70–90 mg per day (German Nutrition Society, 2015).

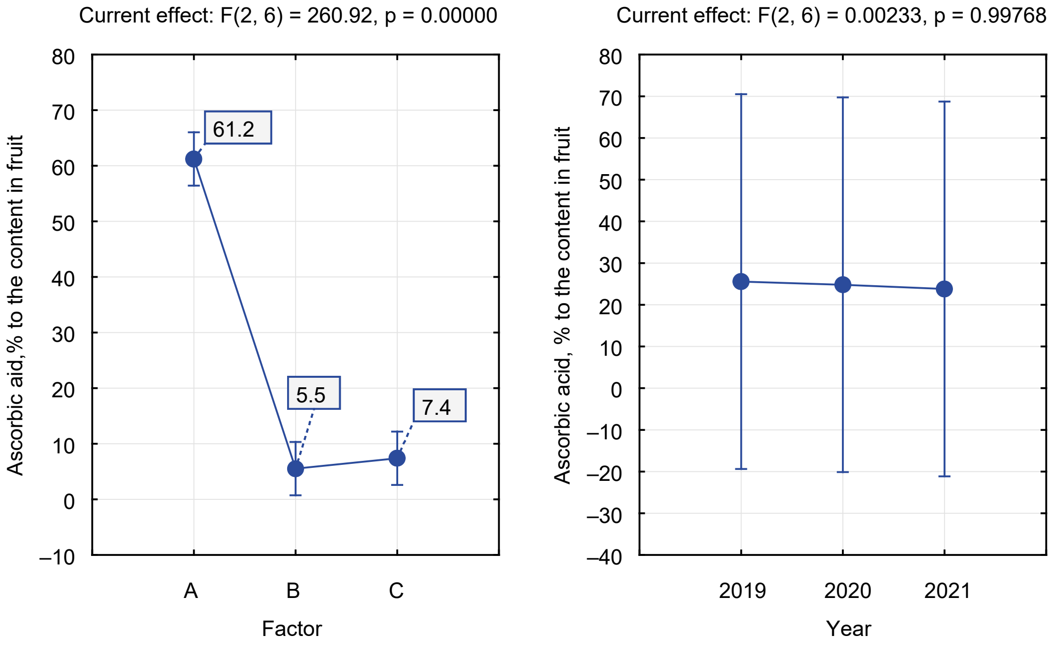

Fig. 4. Influence of the factors which reduced the content of ascorbic acid in natural wines from jostaberries: A – normalization of must by the mass concentration of titrated acids; B – increase in the mass concentration of sugars in must; C – losses during preparation, fermentation of must and sweetening of wines, % of the content in fruit

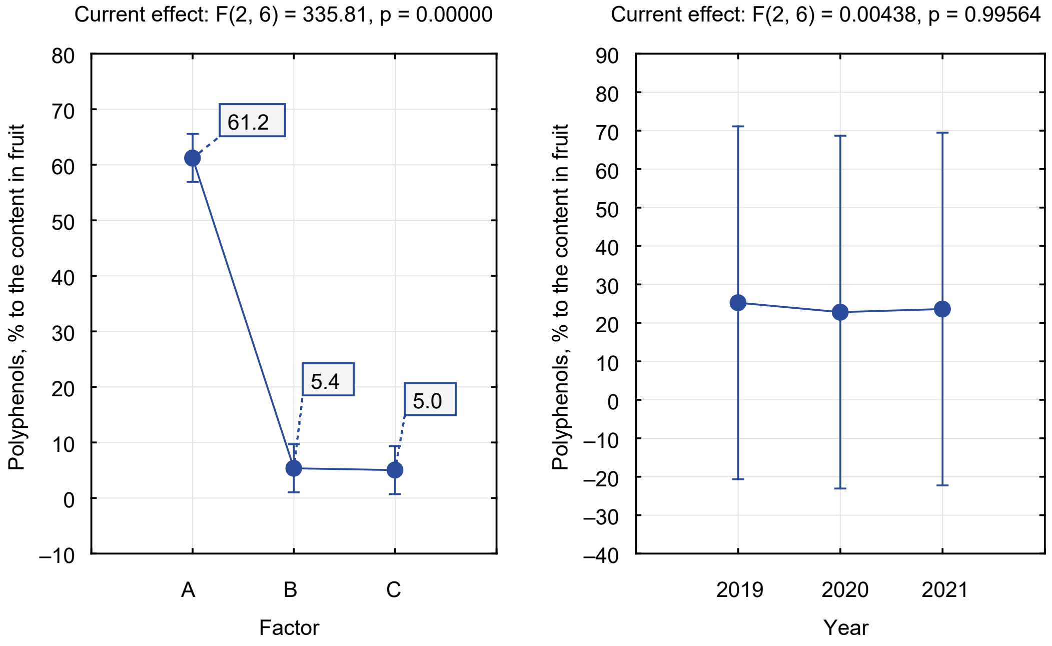

Fig. 5. Influence of the factors which reduced the content of polyphenols in natural wines from jostaberries: A – normalization of must according to the mass concentration of titrated acids; B – increase in mass concentration of sugars in must; C – losses during preparation, fermentation of must and sweetening of wines, % of the content in fruit

Table 4. Intensity and shade of the colour of jostaberry wines (n = 3, $p \leq 0.05$)

Harvest year	Redox potential, mV	Active acidity pH, un.	Optical density			Colour intensity, I	Shade of color, T
			D_{420} ±0,02	D_{520} ±0,01	D_{620} ±0,01		
2019	208 ±5	3.23 ±0.02	0.80	0.65	0.50	1.95	1.23
2020	196 ±5	3.07 ±0.03	0.68	0.58	0.46	1.72	1.17
2021	220 ±5	3.31 ±0.02	0.58	0.47	0.40	1.45	1.23
Average	208	3.20 ±	0.69	0.57	0.45	1.71	1.21

Indirect indicators of wine quality

The indirect quality indicators of the natural wines made from jostaberries, which characterize the intensity and directionality of reducing-oxidizing (redox) processes in wines, are shown in Table 4. Wines from jostaberries could be attributed to the non-oxidized type, which was indicated by the value of redox potential Eh – 196–220 mV. The active acidity varied within 3.07–3.31 pH units, and this range of values of this indicator would be favourable for the support of the restored state of the wine system, which, in turn, would have a positive effect on the organoleptic properties of the wine.

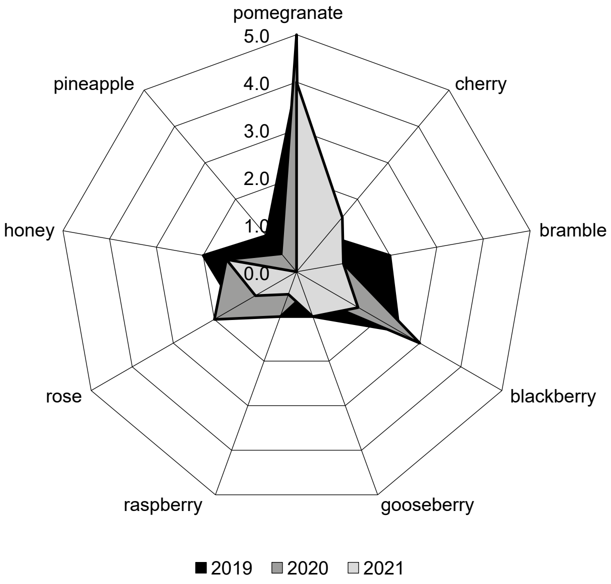

Fig. 6. Aroma profile of wine made from jostaberries in 2019–2021

The wines had a rich red colour. According to the average data, the colour intensity was 1.71, and the shade was 1.21, which is typical for young red wines (Fan et al., 2023).

Organoleptic evaluation of wines

The study of the results of the sensory evaluation of the wine material aroma during the three years of the research established the tone of pomegranate as a dominant specific descriptor in their aroma. The main tone was accompanied by shades of honey, blackcurrant, rose and blackberry (Fig. 6). This aroma was probably the result of the availability of terpene alcohols, which jostaberries contain (Karaagac et al., 2021), as well as a set of secondary products and by-products synthesized by yeast during fermentation.

CONCLUSIONS

1. Jostaberries, grown in the Central Forest Steppe zone of Ukraine, contained 12.8–15.2% of dry soluble substances, of which 8.6–10.8% were sugars and 2.9–3.2% were titrated acids. Jostaberries were rich in ascorbic acid (98–146 mg/100 g) and polyphenols (240–310 mg/100 g).
2. To produce a natural wine from jostaberries, it is necessary to normalize the mass concentration of titrated acids, bringing it to a level which is not higher than 8.3 gL^{-1}, and to increase the mass concentration of sugars in the must to 242 gL^{-1} using white sugar before fermentation. We recommend that the must is pasteurized and EC-1118 yeast is used (*Saccharomyces bayanus*, Champagne Winery Institute, Epernay, France) for fermentation. It is advisable to monitor the fermentation; to control

this, one should use the equation that describes the process, according to which the volume fraction of ethyl alcohol (y, %) can be calculated on any day (x): $y = -0.01x^2 + 0.56x + 1.23$. The range is 0–52 days, and the deviation is 0.65%.

3. The natural jostaberry wines in this study contained 28–34 mg/100 g of ascorbic acid and 68–98 mg/100 g of polyphenols. The wines were slightly oxidized. They had a red color and a specific aroma with shades of pomegranate.

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