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SCIENTIFIC PAPER

UDC

EFFECT OF QUINCE POMACE ADDITION ON THE QUALITY OF QUINCE WINE

Highlights

- Maceration promoted a faster onset of fermentation
- Macerated quince wines (QWs) had higher methanol content
- Unmacerated samples had better antioxidant and antimicrobial characteristics
- Odor, taste, and typicity had the strongest influence on the sensory score of QWs
- Quince pomace showed the potential for application in QW production
- Maceration parameters need to be examined further

Abstract

Quince wine (QW) is produced using quince juice (QJ); however, the production process can be improved, for example, by macerating the juice with quince pomace (QP). Therefore, this study aimed to investigate the use of QP from the Leskovac cultivar as a fermentation substrate for QW production. Control samples were prepared using 100% QJ, with and without added sugar, while the treated samples were prepared by adding different amounts of QP to QJ. The addition of QP resulted in QW with physicochemical characteristics similar to those of the control samples, except for significantly higher methanol content in almost all macerated QW samples. The control samples exhibited considerably better antioxidant and antimicrobial properties than the macerated QW samples. The best antioxidant properties were observed in control samples B1 and C1, while control sample M1 showed the strongest inhibitory activity against the tested microorganisms. In some cases, the sensory properties of the macerated samples were better than those of the non-macerated samples. Samples C1, M4, and A3 achieved the highest overall sensory scores (18.6, 17.9, and 17.3, respectively). Overall, QP demonstrated potential for use in QW production; however, further investigation of the maceration parameters is necessary.

Keywords: quince cultivar Leskovac, maceration treatments, quince wine, bioactive properties, sensory analysis.

INTRODUCTION

Cydonia oblonga Miller belongs to the same family as apples and pears (*Rosaceae*) and produces bright golden-yellow pome fruit known as quince fruit (QF). Berktaş and Çam [1] stated that QF is characterized by its intense aroma and rich nutritional profile, as it is a good source of organic acids, sugars (primarily fructose, glucose, and sucrose), dietary fiber, pectin, and various vitamins, including vitamins A, B, C, and E, as well as minerals such as P, K, Na, and Ca. Different varieties contain about 1.2% organic acids, 2% pectin substances, 0.8% tannins, 5% reducing sugars, and 16 to 50 mg/100 g of vitamin C [2]. Moreover,

various studies have confirmed that QF is a rich source of bioactive compounds, including phenolic acids and flavonoids, which have diverse beneficial effects on human health, including antioxidant, antimicrobial, and antiulcerative effects [3,4].

QF is usually used in the production of jams, jellies, preserves, and juices, or as an addition to teas, yoghurts, lemonades, ice cream, or confectionery products [5]. The industrial manufacturing process of these products generates by-products, such as QP, which consists of the central part of the fruit with seeds and mucilage, small parts of the peel, and leaves. QP is rich in fiber, bioactive compounds, enzymes, etc., and can represent almost 35% of quince processed in the industry [6], but is usually not used and is discarded. Food waste causes adverse environmental problems, including food shortages, reduced food availability, and the release of greenhouse gases. In recent years, the food industry has focused on

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waste product valorization, both to prevent the loss of these valuable substances and to reduce environmental problems caused by such waste.

One of the ways in which QP can be used is in QW production. The production of QW is still poorly researched and is mainly based on the use of QJ, rather than the whole QF. However, QJ is not very suitable for QW production due to its strong sourness, associated with its extremely high acidity, high content of pectin substances, and astringency [4,6]. Production can be intensified by improving quality, such as by applying a maceration process with the addition of QP. Maceration refers to the period during which the solid parts of the fruit (the pulp, skin, seeds, and stems) are in contact with the fruit juice, allowing the extraction of nutrients, aromatic substances, and other components. It can also increase the concentration of phenolic compounds, as well as the antioxidant and antimicrobial activity of fruit wine [7].

However, there are no studies in the scientific literature providing detailed information on the production of macerated QW, although data can be found on the use of maceration in obtaining other alcoholic beverages, both from QF and from other fruit raw materials. Carbonell-Barrachina *et al.* [8] obtained quince liquors after macerating quinces from three varieties: Vranja, ALM3, and ZM2. Their results suggested that the highest contents of total polyphenols and antioxidant activity were found in liquors prepared using fruits with skin and a 50:50 quince ratio. The skin of quinces was the main source of phenolic acids and especially flavonols. In a study conducted by Bortolini *et al.* [7], it was found that macerated apple cider, compared to unmacerated cider, had a lighter color, lower intensity of sourness, higher bitterness, similar astringency sensations, and higher total phenolic content.

To the authors' knowledge, this is the first study to systematically assess the influence of different temperatures and durations of maceration of fresh QP in QJ on the physicochemical, bioactive, and sensory properties of QW. Therefore, for this research, QF of the Leskovac cultivar was chosen, as it has a pronounced aroma, high sugar content, and balanced chemical composition, and is considered a standard variety for the production of high-quality quince brandy. The direct addition of fresh QP could represent a promising approach for the utilization of this by-product for QW production. This paper provides insights into the technological and functional potential of quince as a fermentation substrate and contributes to the development of fruit-based beverages with distinct sensory and functional properties.

MATERIALS AND METHODS

Maceration and fermentation conditions

QFs (*Cydonia oblonga* Miller) of the Leskovac cultivar were washed with tap water, and the stems were removed by hand. After washing, sorting, and separation of impurities and moldy or rotten fruits, QFs were crushed by hand and subjected to juicing using a JC800A juicer (Gorenje, Slovenia) under laboratory conditions, by which

the juice was separated from the pomace. Ten samples were prepared: six samples in which the influence of maceration parameters was examined (M2-M4, A2-A4), and control samples (B1, M1, A1, C1), where no maceration was performed. Figure 1 shows the samples and maceration parameters used: temperature, duration, and percentages of added QP. In addition to a certain amount of QP, the following were added to the macerated samples: potassium metabisulfite, 50 mg/L (MladegsPak, BiH); vitamin C, 50 mg/L (Enovitis, Serbia); maceration enzyme Endozym Cultivar, 4 g/100 L (AEB, Italy); yeast energizer, 0.1 g/L (Enovitis, Serbia); and rehydrated selected yeast SIHA Active Yeast 6, 0.3 g/L (Eaton, USA). In the control samples, all the above-mentioned substances were added, except for the maceration enzyme; in samples A1 and B1, 10% sugar was also added (AGRAGOLD, Bosnia and Herzegovina). After the maceration process was completed at 10 °C for 60 h, decantation and mild sulfiting with potassium metabisulfite (50 mg/L) were performed, and sample A4 was further fermented at 18 °C. After completion of maceration, decantation, and mild sulfiting, samples A2 and A3 were kept at 10 °C for the next 36 h and 12 h, respectively, and then the temperature was increased to 18 °C. Control samples A1 and C1 were fermented at 10 °C for 60 h after sulfiting and yeast addition, and then the temperature was increased to 18 °C. Each fermentation was carried out in duplicate using a system consisting of 250 mL flasks containing 180 mL of sample and fitted with an airlock to release CO₂ produced during fermentation. The dynamics of the fermentation processes were controlled by weighing the flasks every 24 h throughout alcoholic fermentation.

Determination of basic physicochemical parameters of QF

The analysis of QF quality was performed in triplicate. The following parameters were determined: dry matter content (%), total acidity (TA) (%), and pH value, according to the methods described by Najman *et al.* [4], and total and reducing sugars (%), according to the method recommended by Sood and Bhardwaj [5]. The estimation of L-ascorbic acid was estimated using a UV spectroscopic method according to Desai and Desai [9].

Determination of basic physicochemical parameters of QWs

The analysis of the basic physicochemical parameters of QWs was carried out according to the methods prescribed by the International Organization of Vine and Wine (OIV) [10]. The following parameters were analyzed: total acidity (g/L), volatile acidity (g/L), and pH value. The content of ethanol and methanol in wines was determined by the GC-FID method using a Clarus 680 PerkinElmer instrument with the FID detector, an Elite-Wax L 60 m column, ID 0.32, DF 0.5, absolute ethanol and methanol standards, with acetonitrile as the internal standard. The injector and detector temperatures were 250 °C, the sample volume was 0.5 µL, and the temperature regime was 45 °C (2 min), 45 °C/min to 245 °C (1 min). The total duration was 7.44 min, and the flow was 3 mL/min [11].

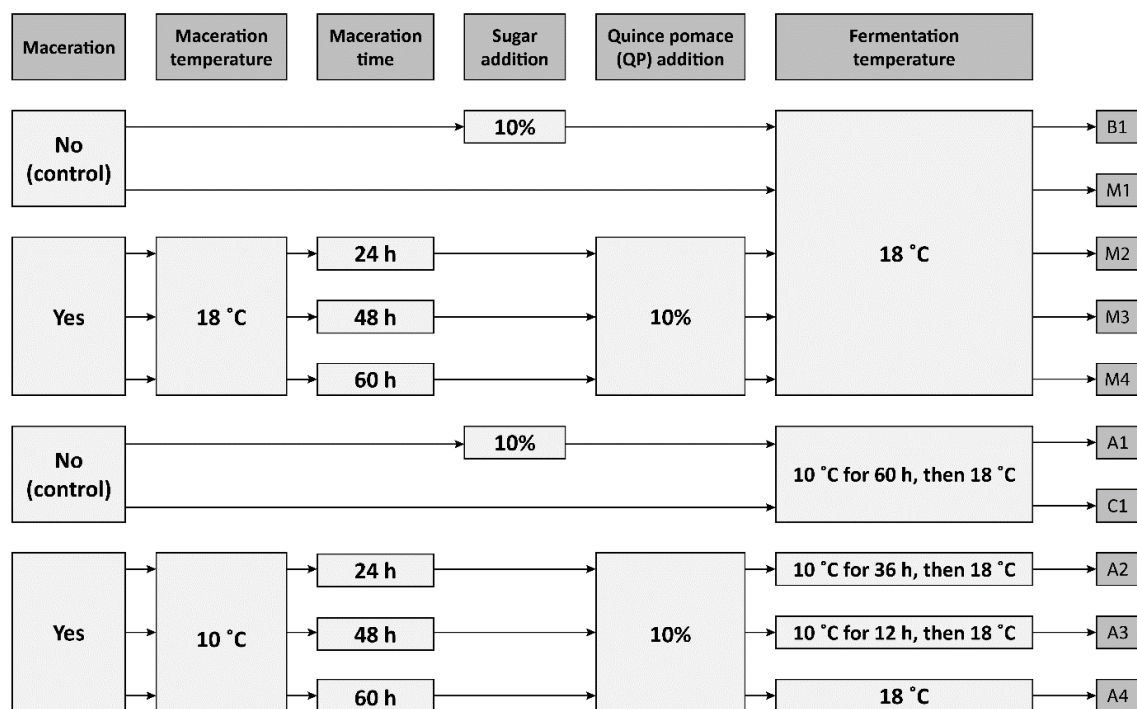


Figure 1. Overview of samples and maceration parameters used.

Determination of mineral content in QP and QWs

The content of different minerals in QP and QWs was determined using atomic emission spectrometry (ICP-OES), with an OPTIMA 8000 instrument (Perkin Elmer, USA). Instrument calibration was performed using the Instrument Calibration Standard 2 (Perkin Elmer, USA). All chemicals and reagents used were of analytical grade. Samples (100 g/L) were prepared by wet digestion using a mixture of nitric and perchloric acids. The concentrations of the elements used for the calibration curve were different: 15, 10, 5, 2.5 and 1 mg/L for macroelements and 5, 2.5, 1, 0.5 and 0.1 mg/L for microelements. These concentrations were determined according to preliminary measurements for the specified elements.

Determination of chromatic characteristics

The color of QW (in %) was determined spectrophotometrically based on the measured absorbance values (A) at wavelengths of 420 nm and 520 nm [12]. Color analyses of all tested wines were performed using an ONDA TOUCH UV-21 spectrophotometer (Giorgio Bormac, Italy).

Determination of antioxidant characteristics of QP and QWs

The TPC was determined using the Folin-Ciocalteu colorimetric method. The non-flavonoid content (NF) was determined by the formaldehyde method, whereas the flavonoid content (TF) was calculated as the difference between TPC and NF. The antioxidant activity analysis included 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2-azino-bis(3-ethylbenzothiazoline)-6-sulfonic acid (ABTS), ferric reducing antioxidant power (FRAP), and total antioxidant capacity (phosphomolybdenum test) assays. The obtained results for QP are expressed per gram of fresh weight

(g fw). The protocols for the above-mentioned methods are described in Kukavica *et al.* [13] and Jovanović-Cvetković *et al.* [14].

Determination of antimicrobial activity of QWs

In this study, the antimicrobial activity of QWs against six bacterial cultures, *Escherichia coli* WDCM 00013, *Pseudomonas aeruginosa* WDCM 00024, *Staphylococcus aureus* WDCM 00034, *Bacillus cereus* WDCM 00151, *Listeria monocytogenes* WDCM 00020, *Lactobacillus plantarum* 299v, as well as two yeast cultures (*Candida albicans* WDCM 00054 and *Saccharomyces boulardii* DBVPG 6763), was determined using the agar dilution method [14].

Sensory analysis

Sensory evaluation of the QWs was carried out using the Buxbaum positive ranking model [15]. The method assesses five sensory attributes with a total maximum score of 20 points: color (1 point), clarity (1 point), typicity (2 points), odor (6 points), and taste (10 points). The wine samples were evaluated by a panel of ten qualified assessors, all of whom had extensive experience in sensory analysis. All samples were bottled and stored at a temperature of 10-12 °C until sensory evaluation. Prior to assessment, the samples were tempered to room temperature (20 ± 2 °C) to ensure uniform tasting conditions [16].

Statistical analysis

The results were expressed as mean ± standard deviation. Statistical analysis was performed using one-way analysis of variance (ANOVA). To identify significant differences between the results, Tukey's multiple range test was used, with significance set at $p < 0.05$.

RESULTS AND DISCUSSION

The results of basic chemical components of QF are presented in Table 1. The dry matter content of QF was 13.5%. Higher values for this parameter were reported by Radović *et al.* [17] (16.20%) and Rop *et al.* [2] (15.9%). The dry matter content depends largely on the degree of fruit ripeness and agroecological growing conditions. Total and invert sugar contents were relatively low (7.83 and 7.02%, respectively). Radović *et al.* [17] reported higher results than those obtained in this study (9.15 and 8.28%, respectively), which can be associated with the significantly higher dry matter content in their sample (16.20%). The TA content in QF was 0.87%, which was lower than the value found by Radović *et al.* [17] (0.99%). In addition to soluble solids and sugar content, TA content is a very important parameter of fruit quality. Fruits with low TA content decay faster and have lower storability, so they must be processed quickly after harvest. The pH value was relatively low (3.10). Rasheed *et al.* [18] determined higher pH (3.43) and TA (1.25%) values as average in their analysis of quinces collected from different places. Low fruit pH usually corresponds to high TA. Vitamin C content in QF was 0.108 mg/g. The result obtained in this study was lower than the result reported by Sood and Bhardway [5] (0.156 mg/g). Vitamin C content is significantly affected by the quince variety, and Rop *et al.* [2] found that in Czech cultivars it ranged between 0.05 and 0.08 mg/g.

Table 1. Basic chemical components and antioxidant properties of quince fruit (QF).

Parameter	Result
Basic chemical components	
Dry matter content (%)	13.5
Total sugars content (%)	7.83 ± 0.31
Reducing sugars content (%)	7.02 ± 0.02
TA (%)	8.7
pH value	3.1
Vitamin C (mg/g)	0.11 ± 0.03
Antioxidant properties	
TPC (mgGAE/g fw*)	0.41 ± 0.06
NF (mgGAE/g fw)	0.37 ± 0.02
TF (mgGAE/g fw)	0.04 ± 0.05
DPPH (mmol TE/g fw)	0.95 ± 0.12
ABTS* (mmol TE/g fw)	3.07 ± 0.24
FRAP (μmol Fe ²⁺ /g fw)	6.6 ± 0.77
TAC (mg AAE/g fw)	13.30 ± 0.27

* fw - fresh weight.

The results of testing the antioxidant properties of QF are presented in Table 1. TPC in QF was 0.4087 mgGAE/g fw. Phenolic compounds play a protective role against heart diseases and are very important for health because they show high antioxidant activity. Göksel [19] obtained slightly

higher results than those obtained in this study when testing the total phenolic content values of 36 different quince cultivars. The content of polyphenolic compounds in her study ranged from 0.65-1.67 mg GAE/g fw, which was attributed to many factors, such as genetic and environmental factors. Regarding the ratio of flavonoid and non-flavonoid content in this study, it was found that the non-flavonoid content was almost ten times higher than the flavonoid content (0.368 ± 0.017 and 0.039 ± 0.051 mg GAE/g fw, respectively).

Antioxidant activity of QF was tested using the FRAP, ABTS, DPPH, and TAC methods, and the results are shown in Table 1. The antioxidant capacity obtained using the FRAP test was 6.6 μmol Fe²⁺/g fw, indicating strong activity. The results obtained were lower than those reported by Göksel [19], who tested antioxidant activity values in 36 different quince cultivars, which ranged from 11.33 to 20.73 μmol TE/ g fw. The result obtained using the DPPH test was 950.9 μmol TE/g fw. This result was much higher than those reported by Göksel [19], which ranged from 60.16 to 158.62 μmol TE/g fw. The result obtained using the ABTS method was 3.0695 mmol TE/g fw and was much higher than those reported by Göksel [19], which ranged from 0.014 to 0.073 mmol TE/ g fw. The result obtained using the TAC test was 13.2977 mg AAE/g fw. Due to its hydrogen- and electron-donating ability, the TAC test detects antioxidants such as carotenoids, ascorbic acid, tocopherol, certain phenolics, cysteine, and aromatic amines [13]. The antioxidant effects of QF are due to the presence of polyphenolic substances [3], such as flavonoids, quercetin, rutin, kaempferol, etc. [5]. Wojdyło *et al.* [6] measured antioxidant activity in 22 quince cultivars and reported that the differences in antioxidant activity results varied according to both cultivar differences and phenolic matter content. The fermentation velocity is presented in Figure 2.

From the results presented in Figure 2, it was evident that there were considerable differences in fermentation velocity among the samples. In the samples macerated at 18 °C, the onset of fermentation was much faster than in the samples macerated at 10 °C, which was accompanied by a greater change in the mass of the fermentation vessels. Sample M1 fermented the fastest, while the largest change in the mass of bottles in the macerated samples was achieved in samples where maceration lasted for a shorter time. Prezioso *et al.* [20] and Bortolini *et al.* [7] found in their studies that maceration encouraged a faster start of fermentation in the production of white wine and cider, most likely due to the extraction of assimilable nitrogen and other cofactors essential for the growth and development of yeast cells. Furthermore, pectinase, or a maceration enzyme, such as Endozym cultivar, which was used in this study, causes the breakdown of pectic compounds and gives yeast better access to nutrients in the juice. Therefore, to avoid sluggish fermentation due to the lack of nutrients, the addition of QP to QJ could be a good solution.

The results of the basic parameter analysis of QWs are given in Table 2. The obtained pH values and the total acidity (TA) were similar for the macerated and control samples.

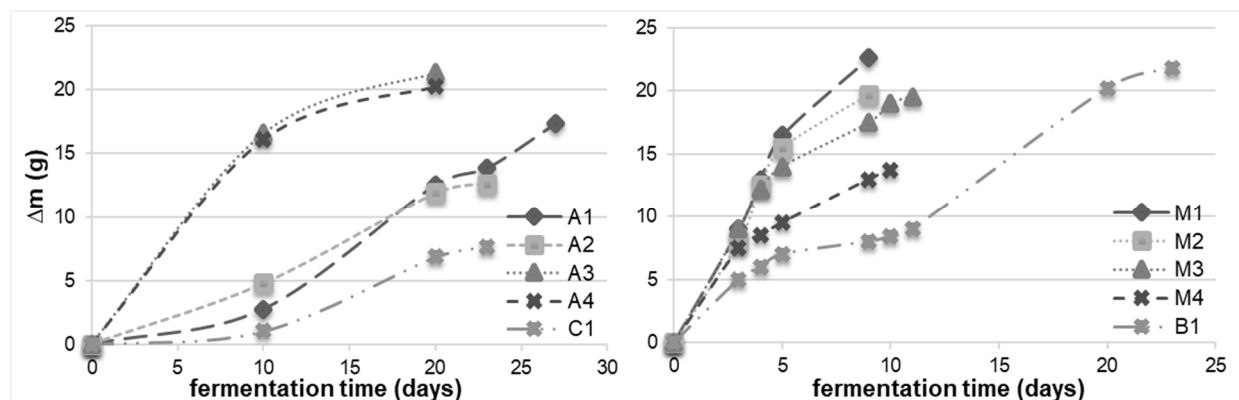


Figure 2. Fermentation velocity.

Table 2. Basic quince wines (QWs) analysis.

Sample	pH	TA (g/L)	Volatile acidity (g/L)	Yellow color (%)	Red color (%)	Ethanol (%vol.)	Methanol (%vol.)
B1	3.43	5.89 ^a ±0.2	0.61 ^{ab} ±0.04	82.24	13.13	8.40 ^a ±0.18	0.0002 ^a ±0.0003
M1	3.35	6.70 ^b ±0.2	0.69 ^{ab} ±0.04	77.91	16.56	6.28 ^{bc} ±0.02	0.0010 ^{bc} ±0.0000
M2	3.38	6.34 ^c ±0.2	0.61 ^{ab} ±0.04	69.44	19.44	5.97 ^{cd} ±0.09	0.019 ^d ±0.0000
M3	3.35	6.07 ^d ±0.2	0.54 ^{ab} ±0.04	72.93	18.34	6.26 ^{bc} ±0.05	0.0050 ^e ±0.0000
M4	3.36	5.89 ^a ±0.2	0.49 ^a ±0.04	69.35	24.12	6.30 ^{bc} ±0.02	0.0010 ^{bc} ±0.0000
A1	3.43	6.25 ^c ±0.2	0.49 ^a ±0.04	78.49	15.14	6.93 ^b ±0.36	0.0001 ^a ±0.0001
C1	3.40	6.70 ^b ±0.2	0.69 ^{ab} ±0.04	74.55	17.56	5.40 ^d ±0.09	0.0001 ^a ±0.0001
A2	3.45	5.89 ^a ±0.2	0.63 ^{ab} ±0.04	82.27	13.64	5.59 ^{cd} ±0.43	0.0003 ^{ab} ±0.0000
A3	3.38	6.34 ^c ±0.2	0.72 ^b ±0.04	75.11	20.09	6.21 ^{bc} ±0.05	0.0015 ^c ±0.0003
A4	3.41	6.07 ^d ±0.2	0.72 ^b ±0.04	74.26	20.05	6.18 ^c ±0.02	0.0037 ^f ±0.0002

^{a-f} mean values with different letters in the same column differ statistically significantly with 95% probability ($p < 0.05$).

The lowest pH values were obtained in samples M1 and M3 (3.35), while the highest pH value was obtained in sample A2 (3.45). The lowest TA value was obtained in samples B1, M4, and A2 (5.89 g/L), while the highest TA value was obtained in control samples M1 and C1 (6.70 g/L). The obtained results are not in accordance with the results reported by Bestulić *et al.* [21], who found that total acidity values increased while pH decreased in macerated white wines compared to unmacerated samples. Bortolini *et al.* [7] used dry apple pomace during cider making and obtained similar results to Bestulić *et al.* [21], while Castro *et al.* [22] obtained the opposite results, namely a reduction in total acidity. According to Scutarasu *et al.* [23], during fermentation, yeast not only converts fermentable sugars into ethanol but also produces organic acids such as lactic acid, tartaric acid, and malic acid.

The volatile acidity in QWs macerated at 18 °C was lower than in control samples B1 and M1, while in samples macerated at 10 °C, it was mostly higher than in control samples A1 and C1. Higher values of volatile acidity were measured in samples macerated at 10 °C. In samples macerated at 18 °C with extended maceration duration, there was a decrease in the content of volatile acids, while in samples macerated at 10 °C, the opposite trend was observed. The lowest volatile acidity was obtained in samples M4 and A1 (0.49 g/L), while the highest value was obtained in macerated samples A3 and A4 (0.72 g/L). Palomo *et al.* [24] reported a decrease in volatile acidity in wines obtained by maceration treatment compared to the control wine, while in the study conducted by Bestulić *et al.* [21], there was no significant difference between macera-

ted wines and the control wine. The principal component of volatile acidity in wines and fruit wines is acetic acid, which is primarily produced by yeasts during the early stages of alcoholic fermentation through the conversion of glucose and other sugars. Moderate levels of acetic acid contribute to overall balance, while excessive accumulation is considered an organoleptic defect [25].

The color values recorded at 420 nm, as an indication of yellow color in wine, and at 520 nm, as an indication of red color in quince wines [12], are presented in Table 2. In all wines, higher values were measured for yellow color compared to red color. Macerated samples, regardless of the maceration temperature, had a higher proportion of red color compared to the control samples (except sample A2). Contrary to our results, Bortolini *et al.* [7] reported that ciders fermented with apple pomace were the lightest in color compared with juice-fermented ciders. Olejar *et al.* [26] stated that during prolonged maceration, longer exposure to skins and the generation of ethanol promoted the extraction of phenolic substances from the seeds and skin, consequently affecting wine color.

The ethanol concentration obtained in QWs ranged from 5.40% vol. in C1 to 8.40% vol. in B1. The highest ethanol contents were measured in control samples B1 and A1 (8.40 and 6.93% vol., respectively) due to the addition of 10% sugar, while in control sample C1, the ethanol content was much lower, indicating some problems during fermentation, as reflected by higher total and volatile acidity. The highest ethanol content among the macerated samples was obtained in sample M4 (6.30% vol.), and the lowest in sample A2 (5.59% vol.). Sugar content, dissolved

oxygen, temperature, yeast, and nutrients are the main fermentation parameters affecting the alcohol content of the final product [22]. Conflicting results can be found in the literature regarding the effect of pomace addition on the ethanol content of wines. In a study conducted by Bestulić *et al.* [21], ethanol content decreased in almost all macerated white wines compared to the control (C) wine, probably due to the formation of esters with tartaric, malic, and lactic acids or oxidation during fermentation. Castro *et al.* [22] used various amounts of apple pomace during cider production and found a significant ($p < 0.05$) increase in alcohol by volume (ABV) for ciders fermented with apple pomace. According to these authors, the increase in ABV could be due to higher nutrient levels during fermentation provided by apple pomace, such as sugars and nitrogen, and its incorporation into apple juice can increase the levels of these nutrients.

Methanol content in macerated wines ranged from 0.003% vol. (23.67 mg/L) in sample M4 to 0.019% vol. (149.9 mg/L) in sample A2, while in control samples, the content was, in most cases, lower, ranging from 0.0001% vol. in C1 and A1 (7.89 mg/L) to 0.001% vol. in M1 (78.9 mg/L). Extended maceration at 18 °C resulted in a decrease in methanol content, while extended maceration at 10 °C resulted in an increase in methanol content. A higher methanol content in macerated QWs was expected because the main precursor of methanol, pectin, is mostly present in QP. The methanol content of QWs was not

excessively high, although the average pectin content of QF is quite high [2]. Methanol content in control samples originates mainly from the activation of endogenous pectinesterase, which occurs naturally in fruits and is responsible for the release of methanol in fruit juices and wines without the addition of pectinase. Wei *et al.* [27] found an increasing trend in methanol content with increases in fermentation temperature, maceration time, and pectinase content, while little effect was observed when different yeasts were used.

Methanol is usually produced from the demethoxylation of pectin by yeast or pectinolytic enzymes during alcoholic fermentation and is present in alcoholic beverages at concentrations that depend on the raw material used in their production [11]. Various factors can affect the methanol content of wines and fruit wines, such as grape and fruit variety, especially grape and fruit skins, which contain high pectin content, sanitary state, maceration conditions, fermentation temperature, the use of pectinolytic enzymes, etc. [28]. The main concern with methanol content in alcoholic drinks is that it is converted into formaldehyde and formic acid in the human body, both of which are toxic metabolites [28]. Because of this, the OIV recommends maximum methanol concentrations of 250 mg/L for white and rosé wines and 400 mg/L for red wines [29]. The results of determining the parameters related to the antioxidant characteristics of QWs are presented in Table 3.

Table 3. Antioxidant properties of quince wines (QWs).

Sample	TPC	NF	TF	FRAP	DPPH	ABTS	TAC
		mg GAE/L		mmol Fe ²⁺ /L	mmol TE/L		g AAE/L
B1	1684.42 ^a ±29.92	512.48 ^a ±19.04	1171.94 ^a ±10.88	44.82 ^a ±0.88	8.18 ^a ±0.16	22.17 ^a ±0.74	10.83 ^a ±0.07
M1	855.19 ^b ±7.48	171.78 ^b ±5.10	683.41 ^b ±12.58	14.85 ^b ±2.35	3.00±0.10	8.12 ^b ±1.02	1.94 ^{bc} ±0.05
M2	365.77 ^c ±15.64	225.87 ^{cd} ±13.60	139.90 ^c ±2.04	6.10 ^c ±0.08	1.17 ^c ±0.06	2.88 ^c ±0.29	1.10 ^b ±0.00
M3	332.12 ^c ±2.04	186.20 ^{bc} ±1.70	145.91 ^c ±3.74	5.42 ^c ±0.99	1.03 ^c ±0.09	2.40 ^c ±0.11	1.16 ^b ±0.06
M4	371.54 ^c ±7.48	192.21 ^{bc} ±17.00	179.33 ^c ±9.52	6.70 ^c ±0.02	1.13 ^c ±0.15	1.81 ^c ±0.54	1.18 ^b ±0.10
A1	1521.92 ^d ±77.51	558.39 ^e ±2.38	963.53 ^d ±75.13	39.22 ^d ±0.31	6.66 ^d ±0.23	18.47 ^{ad} ±2.51	19.02 ^d ±1.42
C1	1570.96 ^{ad} ±16.32	629.07 ^d ±4.42	941.89 ^d ±11.90	46.74 ^a ±0.03	7.80 ^a ±0.01	16.73 ^{de} ±1.60	8.85 ^e ±0.02
A2	1169.04 ^e ±32.64	545.65 ^{ae} ±19.04	623.38 ^b ±51.67	34.47 ^e ±2.15	5.44 ^e ±0.04	13.70 ^e ±0.00	6.85 ^f ±0.39
A3	623.85 ^f ±4.08	256.95 ^d ±0.34	366.89 ^e ±3.74	9.59 ^c ±0.20	2.09 ^d ±0.01	5.66 ^{ce} ±0.13	3.11 ^c ±0.02
A4	566.15 ^f ±6.80	206.47 ^{bc} ±6.46	359.68 ^e ±13.26	7.85 ^c ±0.28	1.67 ^d ±0.07	4.92 ^{ce} ±0.04	2.70 ^{bc} ±0.00

Based on these results, it can be concluded that maceration did not improve the antioxidant characteristics of the samples. It can be observed that, in all macerated wines, there was a decrease in TPC compared to the control samples, and the highest value was measured in control sample B1 (1684.4 mg GAE/L), which was fermented with the addition of 10% sugar at 18 °C. The lowest TPC values were obtained in samples that were macerated for the longest time at 18 °C. Flavonoids were dominant in most of the samples, and the highest content was obtained in sample B1 (1171.9 mg GAE/L). The values obtained using the FRAP test were significantly higher in the control samples than in the macerated samples, and the highest value was measured in sample C1, which was fermented at 10 °C (46.74 mmol Fe²⁺/L). Among the macerated samples, the highest FRAP value was obtained in sample A2 (34.47 mmol Fe²⁺/L), which was macerated and fermented at 10 °C. The lowest FRAP values were obtained in the samples that were macerated for the

longest time at 18 °C. The same trend observed for FRAP values was also observed for the DPPH and ABTS test results, except that sample B1 showed the strongest activity. When all antioxidant test values are compared, it is evident that the best results were achieved in control sample B1, which was fermented with the addition of 10% sugar at 18 °C. As for the macerated samples, the best results were achieved when a temperature of 10 °C was applied, with a 24 h maceration period. Regarding the TAC test, the best results were, in most cases, achieved in the control samples. In general, it can be concluded that the addition of QP did not increase the antioxidant properties of QWs.

In the scientific literature, results related to the influence of maceration on the antioxidant characteristics of wines and fruit wines can be found. Bortolini *et al.* [7] and Castro *et al.* [22] found that the addition of apple pomace to the must had a positive influence on antioxidant activity in the final cider, which is not consistent with the results of this

study. Castro *et al.* [22] prepared four different ciders: without apple pomace (control), from juice with 20% (Cider 20), 35% (Cider 35), and 50% (Cider 50) of added apple pomace, respectively. Their results indicated that Cider 35 and Cider 50 contained significantly higher ($p < 0.05$) levels of phenolic compounds compared to the control, while Cider 20 also showed a higher phenolic content than the control, but the increase was not statistically significant. Based on their results, they concluded that the presence of apple pomace during fermentation increased the levels of phenolic compounds in the ciders, resulting in the observed increase in TPC. Phenolic extraction likely occurred through initial cellular leakage from broken fruit skin cells during milling, followed by diffusion during fermentation, as the pomace remained in contact with the fruit juice [22]. Zhang *et al.* [30] reported that skin-contact fermentation and maceration conditions can increase the antioxidant capacity of wines. A combination of cold maceration for 24 h at 10 °C and skin fermentation for 30 h of Solaris white wines resulted in a higher total polyphenol index (Folin-Ciocalteu index) compared to cold maceration alone or a shorter cold maceration time (6 h). However, prolonged maceration can affect the sensory characteristics of white wine. An increase in polyphenol concentration causes an astringent and bitter taste, which is usually undesirable in white wines [21]. Therefore, maceration parameters must be clearly defined in order to avoid such problems.

The results of antimicrobial activity of QWs are presented in Table 4. QWs showed the highest antimicrobial activity against *P. aeruginosa*, with MIC values of 10% for all analyzed samples. MBC values were 20%, except for samples M1 and M4, where they were the same as the MIC value, while sample A1, with an MBC value of 30%, had the weakest bactericidal effect on this bacterium. *E. coli* was much less sensitive and had an MIC value of 20%, except for samples M4 (30%) and A1-A4 (>30%). MBC values were higher than 30% for most samples, except for samples M1 (20%), M2-M4, and A4 (30%). Gram-positive bacteria *B. cereus* and *S. aureus* differed in their sensitivity. The MIC value for *B. cereus* was 10% of wine concentration for all samples, except for samples A1, B1, and C1, where the MIC value was 5%, while MBC values were above 30%. However, *S. aureus* had higher MIC values: 30% for samples A1-A3 and C1, 10% for M1, and 20% for the other samples. MBC values were 30% and above 30%. Other tested microorganisms, *L. monocytogenes*, *L. plantarum*, *C. albicans*, and *S. boulardii*, did not show sensitivity to the tested wine concentrations.

In the available scientific literature, information about the antimicrobial activity of QWs is rather scarce, while the biological activity of extracts from different parts of quince, including leaves, peel, seeds, and fruits, has been extensively researched. Due to the content of bioactive components in QF, pulp and peel extracts have shown pronounced antioxidant and antimicrobial activity. According to research conducted by Fattouch *et al.* [3], a higher content of polyphenolic components can be associated with better antioxidant and antimicrobial effects of various pulp and skin extracts of QF. At the same time, peel and pulp extracts had stronger antioxidant activity than the sum of

the individual phenolic components tested at the concentrations present in the extract. Antimicrobial activity against *E. coli*, *S. aureus*, *P. aeruginosa*, and *C. albicans* was also more pronounced in extracts with a higher content of phenolic components. However, the inhibitory activity of certain phenolic components from the extract varied depending on the type of bacteria [3].

The order of MIC values of QWs in this research was as follows: *B. cereus* ≤ *P. aeruginosa* < *S. aureus* < *E. coli* < other tested microorganisms. The order of MBC values was different: *P. aeruginosa* < *S. aureus* ≤ *E. coli* < *B. cereus*. The juice of whole QF inhibited the growth of several types of bacteria that cause food poisoning, among which *B. cereus*, *Proteus mirabilis*, and *P. aeruginosa* showed the largest inhibition zones. Vaz *et al.* [31] tested the survival of vegetative cells and spores of two strains of *B. cereus* in red wine, in a combination of different acids (tartaric acid, acetic acid, lactic acid, and citric acid) and ethanol, as well as in all these acids and ethanol at concentrations present in wine. According to their research, the number of vegetative cells of both strains of *B. cereus*, inoculated with an initial cell density of 10^7 - 10^8 cfu/mL, in red wine and wine diluted 1:4 and 1:8, fell below the detection limit in 10, 20, and 40 s, respectively. The same wine concentrations did not affect the spores of either strain. The combination of certain organic acids had a weaker effect on vegetative cells than the combination of all acids and ethanol, which led to a decrease in the number of vegetative cells by 3.6 log units in 40 seconds, while the extracted phenolic components contained in red wine had no effect. QWs in this study did not inhibit the growth of *L. monocytogenes*, *L. plantarum*, *C. albicans*, and *S. boulardii* at the tested concentrations. Wine contains alcohol, acids, phenolic components, and other substances that can lead to increased stress-induced resistance in *L. monocytogenes* and *C. albicans* [32]. Probiotic cultures *L. plantarum* and *S. boulardii* are microorganisms that tolerate higher concentrations of alcohol, acids, and phenolic components contained in wine. Some strains of *L. plantarum* can be used as starter cultures in malolactic fermentation in winemaking, while *S. boulardii* can be used as a starter culture in wine production [33]. As shown in the research of Sabel *et al.* [34], all tested phenolic components either had no effect or had high MICs against some strains of *S. cerevisiae* and *L. plantarum*.

Control sample M1 had the best inhibitory effect on the tested microorganisms. However, samples B1, A1, C1, and A2 had the highest content of phenolic components, which are associated with the antimicrobial effect of plant extracts and wine, but in this research, they had different effects on the tested microorganisms. The mechanism of antibacterial activity of wine has not been fully elucidated. In experiments conducted by Boban *et al.* [35], it was determined that the antimicrobial activity of wine is manifested through the synergistic activity of phenolic components, the presence of organic acids, pH, and alcohol. In this research, a stronger antimicrobial effect cannot be associated with a higher content of phenolic components in all samples, because some samples with a lower phenolic content had a better antimicrobial effect. This supports the claim about

the synergistic effect of individual phenolic components, as well as phenolic and non-phenolic components of wines. Gram-positive bacteria are considered to be more sensitive to phenolic components than Gram-negative bacteria. However, in this study, *P. aeruginosa* had the lowest MIC and MBC values. *P. aeruginosa* is more sensitive to flavonoid components in wines than *S. aureus* and *E. coli*. On the other hand, *E. coli* is less sensitive than *S. aureus*. *B. cereus* also had low MICs in this study. By analyzing the antimicrobial activity of certain phenolic components in the pulp and peel extract of QF, it was determined that chlorogenic acid had the strongest antimicrobial activity against *S. aureus*, *E. coli*, and *P. aeruginosa*. Catechin had moderate activity against *S. aureus* and *P. aeruginosa* [3].

Mineral element composition

The most important reasons for determining mineral content in wines are their health impact, role in wine stability, possible toxicological risks, and food regulations. Some trace elements, such as Cu, Fe, Al, and Mn, can have a negative effect on the organoleptic properties or cause haze formation in wines. Several metals and metalloids, such as Cd, Pb, Sn, Hg, and As, are known to be potentially toxic. Therefore, awareness of human exposure to trace metals from beverages, such as wines and fruit wines, is very important. The results of mineral content determination in QF and QWs are shown in Table S1. The dominant minerals found in QF were K, Ca, and P, which are valuable for human health [3-5]. The dominant minerals in QWs were in the following order: $K > Ca \geq P > Na > Zn > Mg$. From the presented results, it can be concluded that samples M2-M4, macerated at 18 °C, had, in most cases, a much higher content of the analyzed minerals than control sample B1, but lower content than sample M1. On the other hand, samples A1, C1, and A2-A4 had lower mineral contents than the samples obtained at 18 °C. The obtained results are partially in agreement with the results of the study by Plotka-Wasyłka *et al.* [36], who determined the content of certain minerals in homemade QW. According to them, the contents of all metals in QW were considerably lower than the maximum concentrations allowed according to the OIV [10]. Shimizu *et al.* [37] examined the effects of various winemaking techniques on the concentration of 18 minerals in a total of 154 wine samples using grapes from different production areas. Among the various winemaking techniques, maceration with grape skin had the largest effect on mineral content, significantly changing the concentrations of 17 out of 18 elements.

Sensory evaluation

The results of the sensory evaluation (Figure 3) indicate clear differences among the analyzed QWs, particularly with respect to odor, taste, and typicity, which exerted the strongest influence on the overall sensory score. Color and clarity showed relatively small variations among the samples, indicating that the visual quality of the QWs was generally satisfactory and did not represent a limiting factor in sensory acceptance. Samples C1, M4, and A3 achieved the highest total sensory scores (18.6, 17.9, and 17.3,

respectively), mainly due to their higher odor and taste ratings. Odor scores ranged from 3 to 6, confirming the key role of aroma intensity and complexity in differentiating quince wines. Typicity scores varied considerably among the samples, reflecting differences in the expression of characteristic quince aroma and flavor attributes. Samples M4 and C1 exhibited the highest typicity values, indicating a more pronounced and recognizable quince sensory profile, which positively affected their overall acceptance. Taste scores showed the widest range among the evaluated attributes (5-9) and contributed most strongly to the total sensory score. QWs with higher taste ratings were perceived as more balanced and harmonious, which underlines the importance of technological control during fruit wine production in achieving desirable sensory balance. Clarity achieved the maximum score for all samples, showed no variability among the QWs, and therefore did not influence their sensory differentiation. Similarly, color scores showed only minor variation and did not strongly correlate with total sensory scores. Overall, the sensory evaluation highlights the dominant role of odor, taste, and typicity in shaping the perceived quality of QWs. The observed differences among samples may be attributed to variations in volatile aroma compounds derived from QF and fermentation processes, as well as to phenolic-related sensory effects, which are widely recognized as key contributors to wine aroma and flavor perception [38]. These findings confirm that comprehensive sensory analysis is a valuable tool for differentiating quince wines and for linking sensory perception with technological and compositional factors specific to fruit wine production.

Sensory evaluation of fruit wines is very important, and Nguyen *et al.* [39] stated that, once basic visual quality is ensured, olfactory and gustatory attributes become the primary drivers of quality perception. Aroma is particularly important in fruit wines, where varietal fruit character and fermentation-derived volatiles strongly influence consumer acceptance [16]. A positive relationship between odor and taste scores in wine sensory evaluation suggests a pronounced interaction between aroma perception and flavor. In sensory studies, typicity is considered an important indicator of how well a product represents expected varietal or fruit-specific characteristics, particularly in comparative evaluations [16]. Lower typicity scores may suggest a less distinctive quince character or the dominance of fermentation-related notes over fruit-derived aromas. Rossi *et al.* [38] stated that wines with higher taste ratings are perceived as more balanced and harmonious, which is commonly associated with the appropriate integration of acidity, residual sugars, and phenolic-related sensory effects, as well as winemaking practices influencing mouthfeel and flavor perception. Although color may influence initial expectations, Nguyen *et al.* [39] stated that it is not a decisive factor in the final quality assessment when wines are evaluated by trained panels.

Conflicting results can be found in the scientific literature regarding the impact of maceration on the sensory properties of wines and fruit wines. According to Olejar *et al.* [26], the maceration process can modify the bitterness, astringency, color, and aroma of wines due to

the excessive extraction of phenolics. Bortolini *et al.* [7] observed in sensory analysis that cider fermented with apple pomace was more bitter compared to unmacerated cider, probably due to its phenolic composition. In their study, Castro *et al.* [22] concluded, after sensory evaluation, that ciders treated with apple pomace were perceived as less acidic and astringent, but more bitter than the unmacerated sample, with no significant differences in aroma intensity or taste acceptance. Radeka *et al.* [40] used six vinification treatments of the Malvazija istarska

(*Vitis vinifera* L.) variety: non-maceration control treatment (C), pre-fermentative two-day cryomaceration treatment at 8 °C (CRYO), seven-day maceration treatment at 16 °C (M7), 14-day maceration treatment at 16 °C (M14), and prolonged post-fermentative maceration treatments at 16 °C for 21 days (M21) and 42 days (M42), to investigate the differences between volatile aroma compounds when different maceration conditions are applied.

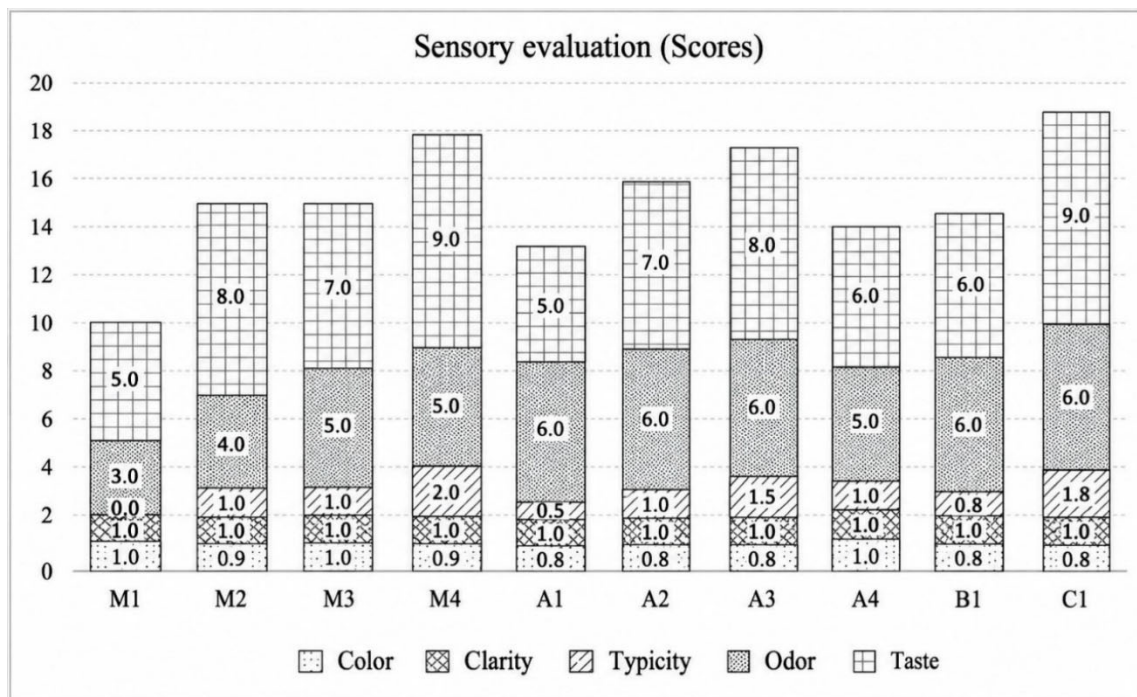


Figure 3. Graphical representation of the sensory analysis results.

Table 4. Antimicrobial activity of quince wines (QWs).

Sample/microorganism	B1	M1	M2	M3	M4	A1	C1	A2	A3	A4
<i>E. coli</i>										
MIC (%)	20	20	20	20	30	>30	20	>30	>30	30
MBC (%)	>30	20	30	30	30	>30	>30	>30	>30	30
<i>P. aeruginosa</i>										
MIC (%)	10	10	10	10	10	10	10	10	10	10
MBC (%)	20	10	20	20	10	30	20	20	20	20
<i>B. cereus</i>										
MIC (%)	5	10	10	10	10	5	5	10	10	10
MBC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
<i>S. aureus</i>										
MIC (%)	20	10	20	20	20	30	30	30	30	20
MBC (%)	30	30	>30	>30	>30	30	30	30	30	>30
<i>L. monocytogenes</i>										
MIC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
MBC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
<i>C. albicans</i>										
MIC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
MFC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
<i>S. boulardii</i>										
MIC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
MFC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
<i>L. plantarum</i>										
MIC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30
MBC (%)	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30

Sensory analysis showed that wines obtained with longer maceration treatments (M14, M21, M42) were characterized by greater aroma complexity, varietal floral typicity, pronounced fruitiness, accentuated dried fruit notes, and moderate honey and herbal notes.

CONCLUSION

This study examined the possibility of using QP from the Leskovac cultivar and different maceration treatments on the physicochemical, biological, and sensory properties of QW. Maceration promoted a faster onset of fermentation, and the addition of QP led to the production of QWs with physicochemical characteristics similar to those of the control samples, except for large differences in methanol content, which was up to 10-fold higher. The addition of QP increased the antioxidant activity by up to 7-fold and reduced the antimicrobial characteristics of QW compared to the unmacerated samples. Overall, control samples B1 and C1 showed the best antioxidant and antimicrobial characteristics. Sample A2, macerated for 24 h at 10 °C, showed the best antioxidant and antimicrobial characteristics among the macerated samples, and better results were obtained for samples macerated at 10 °C. Samples C1 (control sample), M4 (macerated for 60 h at 18 °C), and A3 (macerated for 48 h at 10 °C) achieved the highest total sensory scores (18.6, 17.9, and 17.3, respectively), mainly due to their higher odor and taste ratings. Generally, bio-waste QP can be applied in QW production, but the obtained results indicate that maceration parameters must be thoroughly examined.

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NAUČNI RAD

UTICAJ DODATKA TROPA DUNJE NA KVALITET VINA OD DUNJE

Za proizvodnju vina od dunje (QW) se koristi sok od dunje (QJ), ali se proizvodnja može unaprediti, na primer primenom procesa maceracije uz dodatak tropa dunje (QP). Stoga je cilj ove studije bio da se istraži upotreba QP sorte Leskovac kao fermentacionog supstrata za proizvodnju QW. Kontrolni uzorci su pripremljeni sa 100% QJ, sa i bez dodatog šećera, dok su obrađeni uzorci pripremljeni dodavanjem različitih količina QP u QJ. Dodatak QP doveo je do proizvodnje QW sa sličnim fizičko-hemijskim karakteristikama kao i kod kontrolnih uzoraka, osim značajno većeg sadržaja metanola u skoro svim maceriranim QW. Kontrolni uzorci su pokazali mnogo bolja antioksidativna i antimikrobna svojstva u poređenju sa maceriranim QW. Najbolja antioksidativna svojstva ustanovljena su kod kontrolnih uzoraka B1 i C1, koji su fermentisani uz dodatak 10% šećera, dok je kontrolni uzorak M1 pokazao najbolje inhibitorno dejstvo na ispitivane mikroorganizme. Senzorna svojstva maceriranih uzoraka bila su, u pojedinim slučajevima, bolja u odnosu na nemacerirane uzorke. Uzorci C1, M4 i A3 ostvarili su najviše ukupne ocene senzornih svojstava (18,6; 17,9 i 17,3). Sveukupno, QP je pokazao potencijal za primenu u proizvodnji QW-a, ali je neophodno dodatno ispitati parametre maceracije..

Ključne reči: sorte dunje Leskovac, tretmani maceracije, vino od dunje, bioaktivna svojstva, senzorna analiza.