INFLUENCE OF HIGH POWER ULTRASOUND, HIGH HYDROSTATIC PRESSURE AND NON-THERMAL PLASMA ON THE CHANGES IN SENSORY AND COLOR PROPERTIES OF WINE

Stela Križanović, Karla Kelšin, Anet Režek Jambrak, Tomislav Bosiljkov, Tomislava Vukušić, Ksenija Marković, Marina Tomašević, Karin Kovačević Ganić*

Faculty of Food Technology and Biotechnology, University of Zagreb, Zagreb, Croatia

** mtomasevic1@pbf.hr*

Introduction

Wine production represents a complex chemical and microbiological procedure where the use of sulfur dioxide in terms of antiseptic and antioxidant protection is most common practice. Despite its positive effects, this compound recently has been related to intolerance or even allergic reactions in some consumers [1], which has globally resulted in efforts for finding new, healthier and safe strategies in order to reduce or even replace the use of SO_2 as preservative. Herein, the use of novel, non-thermal technologies such as high power ultrasound (HPU), high hydrostatic pressure (HHP) and non-thermal plasma (NTP) are often emphasized, especially in terms of microbial stabilization of wines. Until now, HHP and HPU had been successfully applied in wine, as techniques for microbial inactivation [2-4], for increasing the extraction of phenolic and aroma compounds from grapes [2,5], as well as for accelerating the wine aging process [2,6,7]. Contrary to the described techniques, little is known about the effect of NTP on wine quality. Its application was only reported in our previous study where the effect of NTP on phenolic compounds and chromatic characteristics of white and red wines was examined [8]. But, recent studies involving fruit juices demonstrated that application of this technique improved extraction of phenolic compounds [9] and fruit juice pasteurization [10]. Despite the potential benefits of presented techniques regarding the microbial stabilization of wines, it is necessary to evaluate their impact on sensory properties, as one of the main parameters of wine quality. Hence, the aim of this paper was to evaluate the effect of these techniques on the sensory changes and chromatic characteristics of Cabernet Sauvignon wine.

Material and methods

Wines

The wines used in this study were young red wine Cabernet Sauvignon (*Vitis vinifera* L.), vintage 2016, obtained from winery Erdutski vinogradi (Erdut, Croatia). 24 hours prior to treatments, wine was inoculated with *Brettanomyces bruxellensis* yeast CBS 2499 (Westerdijk Fungal Biodiversity Institute, Utrecht, Netherlands) at approximately 6 log $CFUmL^{-1}$, incubated at 20 °C ± 2 °C and shaken prior to sampling. In order to avoid the yeast effect, an untreated wine with inoculated yeast represents the control sample.

High power ultrasound (HPU) treatments

200 mL of wine were placed in a round-bottom glass vessel (250 mL), which served as a treatment chamber. An ultrasonic processor (S 4000, Misonix Sonicators, Newtown, CT, USA), set at nominal power of 600 W and 20 kHz was used for HPU treatments. Diameters of probes

were 12.7 mm and 19.1 mm. Each probe was immersed in wine (2.5 cm) and placed at the center of treatment chamber. Ultrasonication was carried out at the amplitude of 100 % meaning 120 µm for 12.7 mm probe, and 60 µm for 19.1 mm probe. The samples were isothermally treated for 3, 6, 10 and 15 min at 25 °C, wherein the isothermal conditions were achieved by ice-water cooling of the treatment chamber. All treatments were carried out in triplicate.

High hydrostatic pressure (HHP) treatments

The HHP treatments were performed using a high hydrostatic pressure system FPG7100 (Stansted Fluid Power, Harlow, UK). The 100 mL of wine was poured into plastic bottle, vacuum sealed in bag and placed in the pressure chamber with maximum capacity of 2 L with propylene glycol as the compression fluid. The combination of following processing parameters: pressures (100 and 200 MPa) and pressure holding times (1, 3, 5, 15 and 25 min), were applied to assess the possible effects of the HHP treatment. All the treatments were carried out in triplicate and at room temperature (25 °C).

Non-thermal plasma (NTP) treatment

The plasma treatments were conducted in a 1000 mL glass vessel with a point to point electrode configuration in a so-called hybrid reactor with discharges in and above the liquid. Configuration and parameters of NTP were in detail described by Lukić et al [8]. 300 mL of wine was treated with plasma at the combination of following processing parameters: frequency at 60 and 120 Hz and treatment duration of 3, 5, 10, 20 and 30 min. All the treatments were carried out in triplicate.

Sensory analysis and chromatic characteristics

Immediately after the treatments, the sensory and spectrophotometric analyses were conducted. For sensory evaluation, the triangle tests were employed, where the treated sample was the one different and compared to other two samples that represent the control, untreated wine. Trained panel group of 14 judges were asked to smell the samples and to mark different one. Also, panelists were asked to state whether that change was positive or negative. Triangle tests were analyzed by Chi-square (χ^2) test [11] where the samples are statistically different ($p < 0.05$) in case of $\chi^2 > 3.84$.

The chromatic characteristics measurements were carried out using the CIELab space [12]. The spectra were registered directly on wine after removing *B. bruxellensis* cells from wine, using a 10 mm optical path glass cell and a Specord 50 Plus AnalytikJena spectrophotometer (Jena, Germany).

Results and Discussion

In order to determine the potential negative effect of applied techniques on the main quality characteristics of wine, sensory analysis and color measurements were conducted. Fig. 1 shows the results of the triangle tests conducted after each applied treatment. The marked line stands for statistical limit wherein the values higher than 3.84 represent significantly different samples. In other words, these samples were affected by applied treatments. Also, panelists were asked to state whether this difference was positive or negative. The obtained data are not shown since the answers were uniform and stating that observed changes were, in all cases, negative. Regarding the HPU treatment, it can be seen (Fig. 1a) that only one processing variation, namely treatment with 12.7 mm probe during 15 min, influenced negatively the sensory properties of treated wine. This results confirm the previously determined fact that the sonication probe diameter is one of the main processing factors which should be taken into consideration when planning the ultrasound processing. It is demonstrated that ultrasound waves are focused on the probe tip, where the smaller tip diameter effects a more localized but also ‘harsher’ mixing and further enhancing mechanical effects in treated samples [13]. Furthermore, Fig. 1b shows that the least hazard technique was HHP, since there were no statistical differences between control and treated wines which is in line with previous studies where it was demonstrated that HHP did not influenced sensory alterations of wine immediately after the treatment. But, differences were perceptible after 6 months of storage, and those wines were described as aged-wine like [6]. Contrary to the mentioned techniques, the application of NTP had detrimental effect on wine sensory properties, where only treatments at 3 min duration did not resulted in sensory degradation of samples (Fig. 1c). To our best knowledge, no studies investigated the influence of this technique on sensory properties of wine, there is only one study regarding the changes in phenolic composition and chromatic characteristics [8].

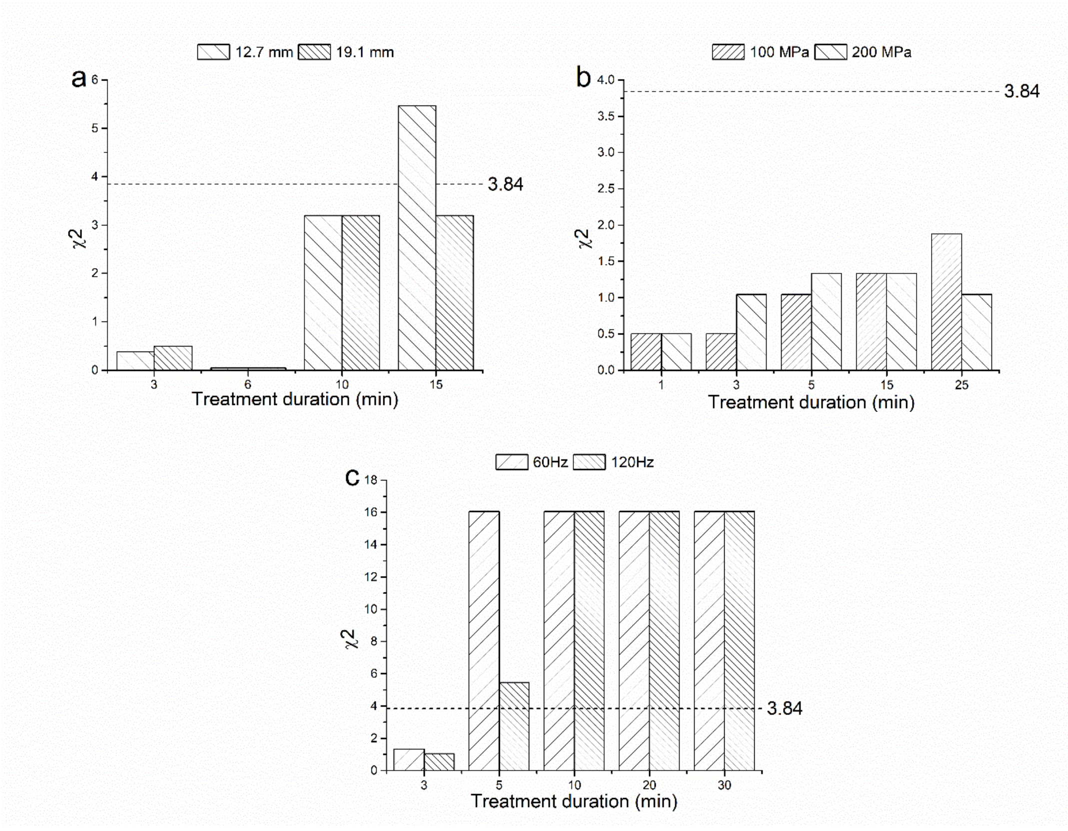

Fig. 1. χ^2 values obtained from sensory analysis of wines treated by: a) HPU, b) HHP and c) NTP

Color was expressed as CIE coordinates of L* (lightness), a* (redness/greenness) and b* (yellowness/blueness), as well as chroma (C*) and hue angle (H*) and the results are presented in Table 1. As can be seen, the HHP treatment influenced no changes in chromatic parameters, while HPU resulted only in slight decrease of L, a, b and C values, which is in correlation with our previous research where similar trend was observed after HPU treatment of Cabernet Sauvignon, Merlot and Plavac mali wines [14]. Furthermore, treatment with NTP resulted in slightly higher values of previously mentioned color parameters. This trend is contrary to the one previously established for Cabernet Sauvignon wines [8] where treated wines showed lower values of these parameters. Potentially, this could be due to the *Brettanomyces* yeast present in wine samples or their synergistic effect with applied treatment. Generally, increment of L, a, b and H values leads to more pronounced orange-red hue in the samples, which is characteristic of aged wine and according to previous studies, significant changes do not occur immediately after the treatment, but after a quite short storage period, as of 10 days for HPU treated wines [16], as well as 6 months for HHP samples [15]. But, little information can be found in literature about the effect of these techniques on red wine color and the general conclusion cannot be drawn without deeper insight in effect of these techniques, and especially of NTP, on overall wine quality.

Table 1. Chromatic characteristics of control and treated wines

Treatment variation	min	**L**	**a**	**b**	**C**	**H**
Control		22.73±0.12	52.53±0.14	35.81±0.16	63.57±0.20	0.60±0.00
HPU						
12.7 mm	3	21.29±0.17	51.68±0.17	34.03±0.23	60.49±0.26	0.58±0.00
12.7 mm	6	18.70±0.23	48.87±0.24	30.75±0.33	57.73±0.38	0.56±0.00
12.7 mm	10	22.39±0.10	52.04±0.12	35.94±0.14	63.24±0.18	0.59±0.01
12.7 mm	15	20.77±0.19	50.84±0.23	33.47±0.28	60.87±0.34	0.58±0.00
19.1 mm	3	22.41±0.50	52.67±0.46	35.42±0.55	63.47±0.68	0.59±0.00
19.1 mm	6	18.52±0.01	48.66±0.02	30.45±0.01	57.40±0.02	0.56±0.00
19.1 mm	10	18.15±0.12	47.88±0.16	29.78±0.19	56.39±0.24	0.56±0.00
19.1 mm	15	20.09±0.04	50.41±0.02	32.73±0.04	60.10±0.04	0.56±0.00
HHP						
100 MPa	1	22.37±0.77	52.22±1.18	35.28±1.31	63.11±1.61	0.59±0.02
100 MPa	3	22.64±0.73	52.45±1.11	35.67±1.23	62.01±0.10	0.60±0.02
100 MPa	5	22.90±0.72	52.69±1.10	36.11±1.23	63.10±0.80	0.59±0.01
100 MPa	15	22.60±0.50	52.40±0.75	35.62±0.86	61.95±0.03	0.60±0.01
100 MPa	25	22.30±0.47	52.12±0.73	35.16±0.81	62.25±0.49	0.59±0.01
200 MPa	1	22.46±0.06	52.09±0.06	35.38±0.10	62.97±0.10	0.60±0.00
200 MPa	3	22.09±0.28	51.66±0.34	34.87±0.40	62.33±0.50	0.59±0.00
200 MPa	5	22.67±0.18	52.36±0.21	35.70±0.25	63.37±0.31	0.60±0.00
200 MPa	15	23.13±0.12	52.96±0.18	36.36±0.17	64.24±0.25	0.60±0.00
200 MPa	25	22.52±0.88	51.67±0.45	35.51±1.28	63.13±1.67	0.60±0.01
NTP						
60 Hz	3	22.73±0.03	52.53±0.03	35.81±0.01	63.57±0.02	0.60±0.00
60 Hz	5	21.55±0.08	51.30±0.06	35.26±0.04	62.24±0.07	0.60±0.01
60 Hz	10	21.26±0.00	51.10±0.02	35.20±0.01	62.04±0.02	0.60±0.00
60 Hz	20	23.13±0.15	52.96±0.21	38.80±0.02	64.24±0.28	0.60±0.00
60 Hz	30	22.52±1.10	51.67±0.51	37.78±0.12	63.13±1.92	0.60±0.01
120 Hz	3	23.09±0.07	52.70±0.11	36.34±0.12	63.90±0.15	0.60±0.00
120 Hz	5	23.36±0.07	52.91±0.09	36.78±0.12	64.24±0.13	0.61±0.00
120 Hz	10	23.72±0.05	53.18±0.08	37.34±0.09	64.48±0.10	0.61±0.00
120 Hz	20	24.78±0.06	53.93±0.07	38.98±0.10	65.92±0.10	0.63±0.00
120 Hz	30	24.93±0.04	54.11±0.07	39.18±0.06	66.15±0.08	0.63±0.00

Data presented as average value of two analytical repetitions ± standard deviation. Abbreviations: L - lightness; a - redness/greenness; b - yellowness/blueness; C - chroma; H - hue angle

Conclusions

Based on obtained results, it can be concluded that HHP is the least invazive technique, while HPU slightly influnced changes in color parameters. The most pronounced changes, primarily negative sensory effect was determined after NTP treatment, where practically all applied treatment variations resulted in significant changes of wines. But, before making general conclusions, it is necessary to investigate the influence of these techniques on other quality parameters of wine, as well as their long-term effect.

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