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THE EFFECT OF UV-C IRRADIATION ON GRAPE JUICE TURBIDITY, SENSORIC PROPERTIES AND MICROBIAL COUNT

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ABSTRACT
In this work, we investigated the effect of UV-C radiation (254 nm) on turbidity, microbial count and sensoric properties of the grape juices treated or not treated with sulphur dioxide. The UV-C radiation is considered to be germicidal against microorganisms. This technology is routinely used to treat drinking water. Application of this method for the purpose of treating the wine was tested in few studies. These studies have shown a positive effect on the inactivation of microorganisms, but they not dealt in detail with the sensory properties of grape juice after the treatment. The main idea of using this method appears to eliminate the sulphur dioxide from wine making technology. There are people who have a genuine allergy to sulfites, and these allergies are often linked with asthma. These people have an rapid onset of symptoms when drinking liquids like wine treated with sulphur dioxide. In our work we have found that the application of this method of treating the grape juice is problematic. Intensity of UV-C radiation increases the turbidity of grape juices. This effect was observed in all grape juices with or without addition of sulphur dioxide and also in clarified or not clarified grape juices. We found that UV-C radiation negatively affect the sensory properties of grape juices. This effect was more pronounced in grape juices treated with SO_2. The smell and taste were significantly negatively changed. Exposure of grape juice treated with sulphur dioxide to UV-C radiation can probably lead to arising the sulphur compounds, which affects the smell and taste of grape juices. Also, it is very likely that the negative change in taste and smell may affect the quality of produced wines. For this purpose, we do not recommend to use UV-C treatment for the grape juice treatment. It will be interesting to conduct a detailed analysis of the grape juices composition before and after UV-C radiation treatment.

Keywords: grape wine; UV-C; irradiation; treatment; grape juic turbidity

INTRODUCTION
The aim of this work was to investigate the effect of the UV-C radiation on grape juice turbidity, sensoric properties and microbial count.

Ultraviolet C (UV-C) irradiation is one of the emerging techniques for the inactivation of microorganisms in liquid food products, and it holds considerable promise also for treatment of wine. This application can be of particular interest to reduce or even eliminate the use of sulphur dioxide as a preservative in winemaking, given its potential health risks **(Rizzotti et al., 2011)**.

Ultraviolet radiation involves the use of radiation from the electromagnetic spectrum from 100 to 400 nm and is categorized as UV-A (320 – 400 nm), UV-B (280 – 320 nm) and UV-C (200 – 280 nm) **(Guerrero-Beltrán and Barbosa-Cánovas, 2004)**.

UV-C radiation is considered to be germicidal against microorganisms such as bacteria, viruses, protozoa, yeasts, moulds and algae, where the highest germicidal effect is obtained between 250 and 270 nm **(Bintsis, Litopoulou-Tzanetaki, and Robinson, 2000)**.

Microbial inactivation caused by UV-C (254 nm) radiation is based on the rearrangement of the microorganism's nucleic acid which directly interferes with the ability of microorganisms to reproduce **(Bintsis et al., 2000; Thompson, 2003; Tran and Farid, 2004; Gabriel and Nakano, 2009)**.

The UV-C rays damage the structure of DNA, rendering microorganisms incapable of reproduction. Each type of microorganism requires a specific dose for destruction. In general, bacteria die at doses greater than 20 mj/cm^2, while molds can tolerate up to 300 mj/cm^2. Germicidal ultraviolet lamps gradually loose power with use. In order to stabilize the quantity of rays emitted in terms of time-surface units, the input power is increased as a function of the length of time in use (around a total of 10,000 hours) **(Delfini and Formica, 2001)**.

Cleaning and disinfection are important operations in food processing because of the significant contributions to product hygiene and food safety. The UV-C treatment is a physical method, which can be applied for this purpose **(Otto et al., 2011)**.

Ultraviolet rays fall perpendicular to the surface being irradiated but can not pass through any type of material, including glass. The surfaces to be treated must be smooth to avoid casting shadows in which microorganisms could be protected. In oenology UVC irradiation could be used to keep the mouth of bottles clean during transport from the sterilizer to the bottling line, and to the corker. UV irradiation could provide partial sanitation of metallic capsules of corks, as well the air around the bottler and corker **(Delfini and Formica, 2001)**.

UV-C radiation has offered a wide spectrum of effective inactivation of wine-associated microorganisms such as *Brettanomyces*, *Saccharomyces*, *Acetobacter*, *Lactobacillus*, *Pediococcus* and *Oenococcus* and therefore may hold promise as an alternative technology to inactivate spoilage microorganisms at different stages of vinification in conjunction with reduced SO_2 levels. From practical point of view, further studies pertaining to the long and short term effect of UV-C radiation on the sensorial and chemical properties of wine are imperative **(Fredericks, du Toit and Krügel, 2011)**.

The application of the UV-C treatment to different grape juice and wine samples in five diverse wineries assured the desired decrease of viable microorganisms **(Lorenzini et al., 2010)**.

Microbial reduction is in correlation with the UV-C dosage (J L^{-1}): higher microbial reductions were obtained with exposure to higher UV-C dosages (J L^{-1}). As a result, the highest microbial reduction was obtained after 3672 J L^{-1} **(Fredericks, du Toit and Krügel, 2011)**.

Ultraviolet treatment is performed at low temperatures and is classified as a non-thermal disinfection method **(Tran and Farid, 2004)**.

The penetration effect of UV-C radiation depends on the type of liquid, its UV-C absorptivity, soluble solids and suspended matter in the liquid. The greater the amount of soluble solids, the lower the intensity of penetration of the UV-C light in the liquid **(Guerrero-Beltrán & Barbosa-Cánovas, 2005)**.

The UV-C treatment did not to alter the color and chemical parameters of grape juice and wine, even in the case of prolonged treatments **(Lorenzini et al., 2010)**.

The advantages associated with UV-C radiation used as a non-thermal method is that no known toxic or significant nontoxic byproducts are formed during the treatment, certain organic contaminants can be removed, no off taste or odor is formed when treating water, and the treatment requires very little energy when compared to thermal pasteurization processes. Fruit juice that undergo thermal pasteurization or sterilization tend to change color and lose some of its aromas and vitamins during the process of heating **(Choi and Nielsen, 2005)**.

The usage of UV-C treatment needs aware staff and requires clean equipments and facilities to keep must and wine stable during storage in barrels and in bottles. Indeed, after the treatment, the samples could be newly contaminated by spoilage microorganisms in poorly sanitized containers. The promising results reported here demonstrated that physical methods, such as UV-C, an incoming technology already commercially available, could exert a highly positive impact in the winemaking industry by eliminating or reducing the use of SO_2 in the near future **(Lorenzini et al., 2010)**.

Unluturk and Atilgan (2015) were investigated the effects of UV-C irradiation on the inactivation of *Escherichia coli* and on the shelf life of freshly squeezed turbid white grape juice. UV exposure was not found to alter pH, total soluble solid, and titratable acidity of juice. There was a significant effect on turbidity, absorbance coefficient, color, and ascorbic acid content. The microbial shelf life was doubled after UV-C treatment, whereas the quality of juice was adversely affected similarly observed in the control samples.

Scientific hypothesis

The UV-C treatment has an effect on the turbidity, sensory properties and total viable count of grape juice.

MATERIAL AND METHODOLOGY

Grape juice samples

Grape juices (*Chardonnay*) samples were taken from Chateau Malanta Vinery Company (Slovakia). The juices were taken 24 and 96 hours after sedimentation. The sterile 5 L glass bottles were used for sampling.

Sample A: Grape juice taken after 24 hours of sedimentation without addition of SO_2,
Sample B: Grape juice taken after 24 hours of sedimentation with adidion of 32 mg L^{-1} SO_2,
Sample C: Grape juice taken after 96 hours of sedimentation without addition of SO_2,
Sample D: Grape juice taken after 96 hours of sedimentation with addition of 32 mg L^{-1} SO_2.

Instruments and equipment

The UV-C reactor that consisted of a 1 L glass graduated measuring cylinder, at which the 45 cm UV-C lamp 254 nm, VanGraven 40 W (light output, 15 Watt/m of lamp) was vertically located. The UV-C lamp has been anchored to a long rod and was fixed in the center of the measuring cylinder. The lamp was shielded by quartz so the grape juice would not be in direct contact with the lamp. The reactor was placed on a magnetic stirrer.

Grape juice UV-C treatment

1 L of grape juices sample was treated: 0, 1, 10, 20 and 30 minutes with UV-C light.

Microbiological analyisis

Pour plate technique was applied on PCA to enumerate total aerobic count, then plates were incubated at 35 °C for 48 h.

UV-C Dose and energy used for treratment

UV-C Dose was calculated following these formulas.

The surface area of the whole lamp (A) and the surface area of the working part of the lamp (B) were calculated according to the same formula:

$$\text{Surface A and B } (m^2) = 2\, r\, \pi\, d$$

Where:
r – is radius of the lamp (m),
d – is length of the lamp (m).

Percentage of the surface of the lamp immersed in grape juice (working part of the lamp):

$$C\ (\%) = (B / A)\ 100$$

Where:
A – is surface area of the whole lamp (m^2),
B – is surface area of working part of the lamp (m^2),
C – is the percentage of the surface of working part of the lamp from the whole surface area (%)

Intensity (I) of the radiation:

$$I\ (W) = (D / 100) \times C$$

Where:
D – is the total UV-C output of the lamp (W) (according to the manufacturer 15 Watt),
C – is the percentage of the surface of working part of the lamp from the whole surface area (%).

UV-C dose was calculated according this formula:

$$\text{UV-C Dose } (J\ L^{-1}) = I / V\ t$$

Where:
I – is the intensity of the radiation (Watt),
V – is the volume of the grape juice in reactor (L),
t – is the time of the treatment (s).

Data used for calculation:
π: 3.14
r : 0.0125 m
d : 0,58 m (length of the whole lamp)
d : 0,185 m (length of the working part of the lamp)
A: 0.04553 m^2
B: 0.01452 m^2
C: 31,8965%
D:15 W
I: 4.7845 W
V: 0.42 L
t: 60 s, 120 s, 600 s, 1200 s, 1800 s.

Calculated UV-C doses: 1 min (683 J L^{-1}), 2 min (1366 J L^{-1}), 10 min (68349 J L^{-1}), 20 min (13670 J L^{-1})

Turbidity measurement

The intensity of turbidity was measured with spectrophotometer Neogen 4700 (Advanced Instruments, USA.

Sensoric analysis

The grape juice smell and taste was analysed after the UV-C radiation treatment. We have used scale of the intensity of foreign smell (0 – odorless, 10 – strong odor) and scale of the intensity of foreign taste (0 – without foreign taste, 10 – strong foreign taste). The number of certified assessors was 7.

Reactor description

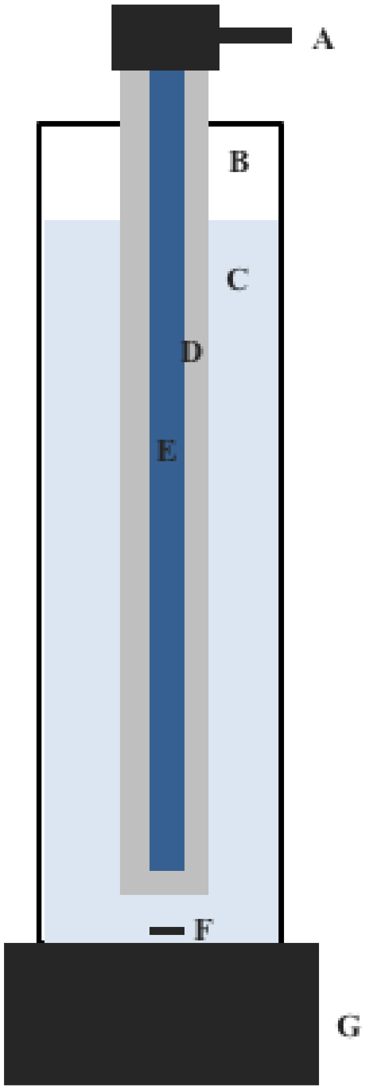

Figure 1 Description of the UV-C (254 nm) reactor used in this study.

Note:
A – Power supply
B – Measuring cylinder
C – Wine
D – Quartz sleave
E – UV-C lamp (15 W)
F – Magnet
G – Magnetic stirrer

Statistical analysis

We used the statistical program Tanagra 1.4 (Lumière University, Lyon, France) according to **Rakotomalala (2005)** for evaluation of turbidity results in relation to UV-C treatment time. The Shapiro-Wilks test was used to test the normality of data. Statistical analysis of turbidity results in relation to different UV-C treatment times was performed with one-way ANOVA for each grape juice (A, B, C and D). We were testing the null hyphotesis $H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4$ for main effect of factor A (grape juice turbidity) within four groups (0, 1, 10 and 20 min UV-C treatment). Consequently, we have used the paired Student's t-test for evaluation of differences among obtained results between groups. We have also used the same procedure for evaluation of the differences between grape juices (A – B and C – D). Differences between samples were considered as statistically significant at p <0.05. We have also performed the Principal Components Analysis (PCA) to reducing the original data and show position of grape juices according to the different UV-C treatment times.

The sensoric analysis data was analysed in statistical program Tanagra 1.4 (Lumière University, Lyon, France). Multiple comparison of samples was performed by nonparametric Friedman's test.

RESULTS AND DISCUSSION

The effect of the UV-C radiation treatment on the grape juice microbial counts is presented in the Table 1 and Figure 2. The effect of UV-C radiation treatment on the grape juice turbidity is presented in the Table 2 and Figure 3. The effect of UV-C radiation treatment on the grape juice sensory properties is presented in Table 3, Table 4, Figure 4 and Figure 5.

The effect of UV-C radiation (254 nm) was studied to reduce the microbial count in different grape juices with or without addition of SO_2. UV-C radiation is considered to be germicidal against microorganisms such as bacteria **(Bintsis, Litopoulou-Tzanetaki, and Robinson, 2000)**. We agree, the application of UV-C radiation reduced the microbial count in grape juices (Table 1). In grape juice A, an aplicaiton of 0.68 kJ L^{-1} UV-C reduced the log of microbial count from initial log 7.37 to log 4.53, dose 6.83 kJ L^{-1} to log 3.86 and dose 13.67 kJ L^{-1} to log 2.83. In grape juice B, an aplicaiton of 0.68 kJ L^{-1} UV-C reduced the log of microbial count from initial log 7.21 to log 3.93, dose 6.83 kJ L^{-1} to log 3.55 and dose 13.67 kJ L^{-1} to log 1.33. In grape juice C, an aplicaiton of 0.68 kJ L^{-1} UV-C reduced the log of microbial count from initial log 7.47 to log 6.53, dose 6.83 kJ L^{-1} to log 6.00 and dose 13.67 kJ L^{-1} to log 4.13. The reduction of log microbial counts with addition of SO_2 was more effective (Figure 2). The microbial counts in grape juice D was reduced to log 0, because this grape juice was sampled 96 hours after sedimentation and was effectively treated with SO_2.

Application of UV-C treatment in order to reduce microorganism counts in clarified grape juices in small demijohns, which are used by small producers is questionable according to our research. Some microbial counts can survive the treatment. The growth and spoiling capacity of the surviving microbes should be investigated in further research.

Lorenzini et al., (2010) found more effective method of treatment. These authors used reactor with 40 UV-C (254 nm) germicidal lamps in series, and exploits an advanced turbulent flow system to optimize the penetration of UV-C and improve microbial inactivation. In their study, grape juice and wine batches were circulated at a constant flow rate of 4000 L.h^{-1} by means of an eccentric screw pump and the dosage was 1000 J L^{-1}. Also, the fluid systems described in **(Fredericks, du Toit and Krügel, 2011)** was effective. **Rizzotti et al., 2015** was applied UV-C light treatment to ten different white and red wines during winemaking, for the first time at industrial scale, using a commercial turbulent flow system. The effect of 1.0 kJ L^{-1} dosage treatment on the viability of the natural microbial population, (total yeasts, lactic acid bacteria and acetic acid bacteria), was investigated. Data indicated that the UV-C irradiation was effective in reducing microbial counts for up to five log CFU mL^{-1}, depending on the wine.

The main aim of our study was to determine whether the UV-C radiation (254 nm) affects the sensory properties of grape juices.

According to **Fredericks, du Toit and Krügel (2011)** further studies pertaining to the long and short term effect of UV-C radiation on the sensorial and chemical properties of wine are imperative.

Lorenzini et al. (2010) were investigated the effect of UV-C treatment on chemical composition of grape juice and wine. Authors of this study found, UV-C treatment did not to alter the color and chemical parameters of grape juice and wine, even in the case of prolonged treatments. In contrast to our study, these authors didn't use the SO_2 for grape juice treatment. Authors reported, after UV-C irradiation no changes were observed for alcohol, reducing sugars, glycerine content, total acidity, pH and color in all the samples, including the red wines, which were subjected to higher UV-C dosage. These authors didn't study the sensory properties of treated grape juice.

In our study, we have used lower doses (0.68 kJ L^{-1} and 1.37 kJ L^{-1}) and higher doses (6.83 kJ L^{-1} and 13.67 kJ L^{-1}) to study the effect of UV-C treatment on the sensory properties of grape juice.

Unfortunatelly, we have found that UV-C treatment of grape juice has affected the sensory properties both in lower and higher doses.

The effect of UV-C radiation on grape juice turbidity is presented in Figure 3. We have observed incrase in turbidity in all UV-C treated grape juices with or without addition of SO_2. In average, an application of 0.68 kJ L^{-1} UV-C increased the turbidity 1.1 times, dose 6.83 kJ L^{-1} 1.2 times and dose 13.67 kJ L^{-1} 1.3 times.

The sensory properties, the smell (Table 3) and taste (Table 4) were changed immediately when grape juices were treated with SO_2. The sensory properties of grape juices sampled 24 and 96 hours after sedimentation without addition of SO_2 was changed slightly after 1 min of treatment (UV-C dose 0.68 kJ L^{-}1) and changed markedly (p-value <0.001) after 2 min of treatment (UV-C dose 1.37 kJ L^{-1}). We can describe the smell and taste after the treatment like baked and strongly simmilar to hydrogen sulphide. This smell and taste was very unpleasant and nasty.

The Principal Components Analysis of four grape juices with and without addition of sulphur dioxide according to the different UV-C treatment times is presented in Figure 6. This figure contains four groups of data that are separated by a distance, which indicates clearly that the UV-C radiation treatment affected the turbidity of grape juices. The turbidity of grape juices with and without addition of SO_2 was increased in relation to the length of UV-C treatment (p <0.05). This findig is in agreement with **Hartly (2008)**. All the wines absorb strongly upper end of the UV spectrum. Wavelengths of 375 and 440 nm have been identified as critical in promoting harmful reactions.

Table 1 The effect of UV-C radiation treatment (254 nm) on the grape juice microbial counts.

	A	**B**	**C**	**D**
UV-C light (254 nm) treatment (min) and Dose (kJ L^{-1})	**Grape juice sampled 24 hours after sedimentation without addition of SO_2**	**Grape juice sampled 24 hours after sedimentation with addition of SO_2**	**Grape juice sampled 96 hours after sedimentation without addition of SO_2**	**Grape juice sampled 96 hours after sedimentation with addition of SO_2**
	CFU mL^{-1}			
0 min	22×10^6	17×10^6	27×10^6	0
0 (kJ L^{-1})	252×10^5	152×10^5	321×10^5	0
1 min	58×10^3	9×10^3	32×10^5	0
0.68 (kJ L^{-1})	2×10^4	80×10^2	360×10^4	0
10 min	26×10^2	16×10^2	28×10^4	0
6.83 (kJ L^{-1})	219×10^1	103×10^1	190×10^3	0
20 min	9×10^2	2×10^1	14×10^3	0
13.67 (kJ L^{-1})	50×10^1	23×10^0	130×10^2	0

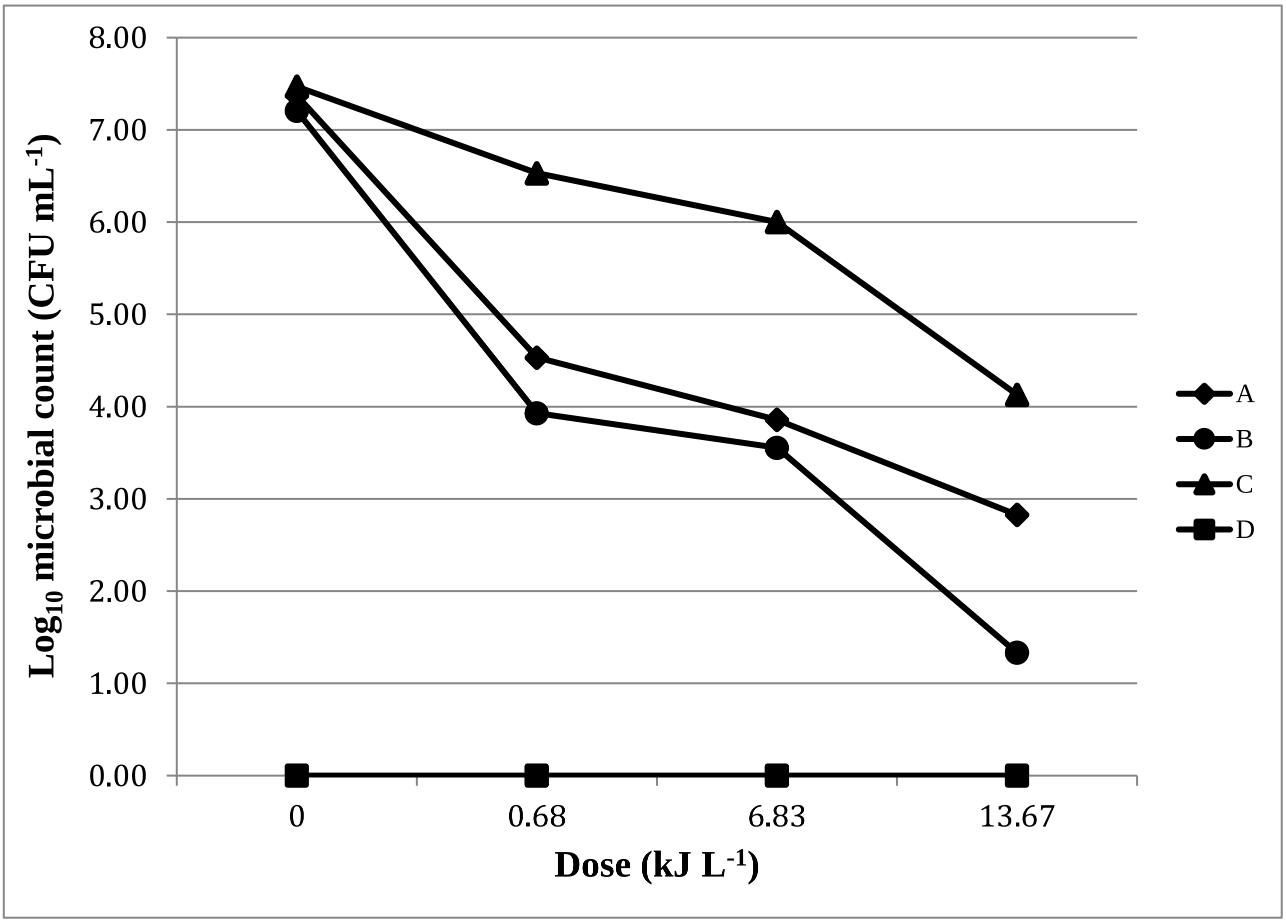

Figure 2 The effect of UV-C (254 nm) radiation treatment on the grape juice microbial counts.

Table 2 The effect of UV-C radiation (254 nm) treatment on the grape juice turbidity.

	A	**B**	**C**	**D**
UV-C light (254 nm) treatment (min) and Dose (kJ L^{-1})	**Grape juice sampled 24 hours after sedimentation without addition of SO_2**	**Grape juice sampled 24 hours after sedimentation with addition of SO_2**	**Grape juice sampled 96 hours after sedimentation without addition of SO_2**	**Grape juice sampled 96 hours after sedimentation with addition of SO_2**
	Average values of absorbance (405 nm)			
0 min 0 (kJ L^{-1})	0.541 cv = 3.5×10^{-6} sd = 0.002	0.589 cv = 2.1×10^{-6} sd = 0.001	1,623 cv = 4.0×10^{-6} sd = 0.002	0.375 cv = 6.0×10^{-7} sd = 0.001
1 min 0.68 (kJ L^{-1})	0.565 cv = 2.1×10^{-5} sd = 0.005	0.656 cv = 8.2×10^{-6} sd = 0.003	1.673 cv = 3.7×10^{-6} sd = 0.002	0.393 cv = 3.4×10^{-6} sd = 0.002
10 min 6.83 (kJ L^{-1})	0.654 cv = 1.9×10^{-6} sd = 0.001	0.749 cv = 3.5×10^{-6} sd = 0.002	1.808 cv = 5.8×10^{-6} sd = 0.002	0.415 cv = 2.0×10^{-6} sd = 0.001
20 min 13.67 (kJ L^{-1})	0.674 cv = 1.3×10^{-6} sd = 0.001	0.804 cv = 3.0×10^{-6} sd = 0.002	1.868 cv = 7.0×10^{-6} sd = 0.003	0.471 cv = 4.4×10^{-6} sd = 0.002

Note: each measurement (n = 30).

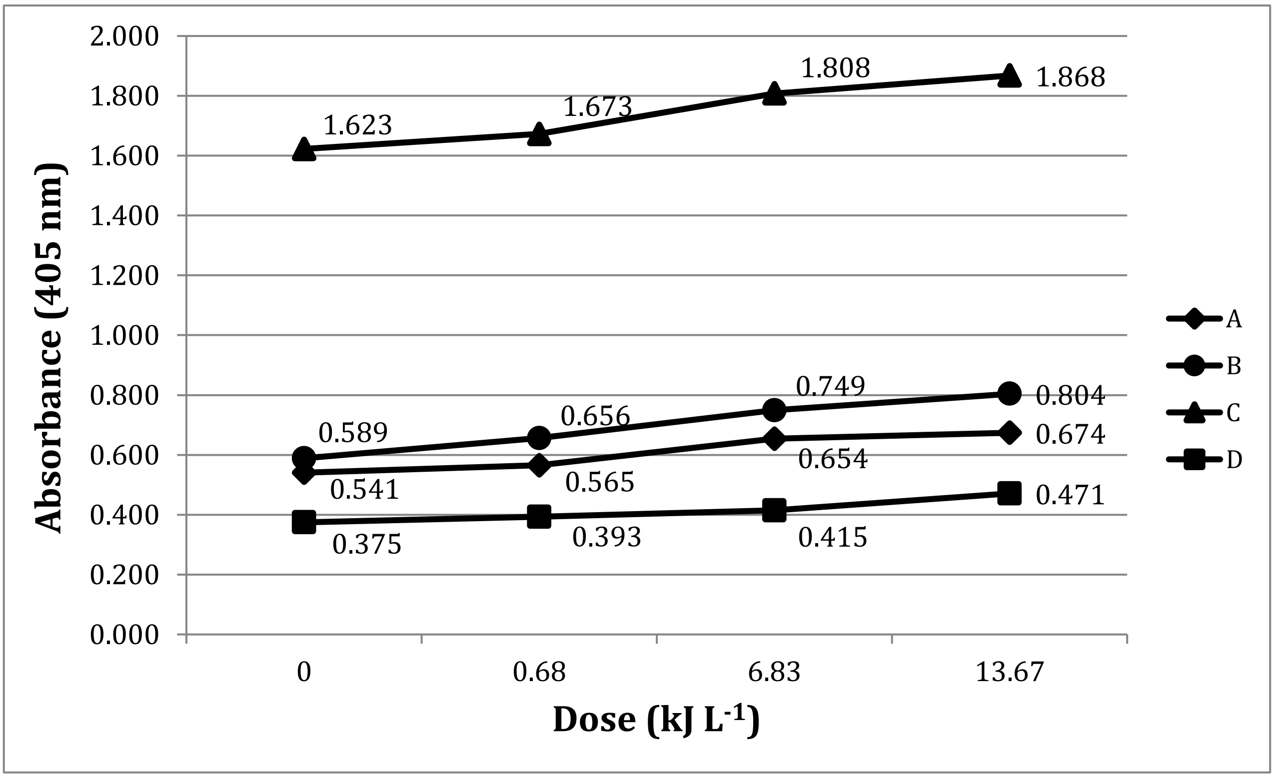

Figure 3 The effect of UV-C radiation (254 nm) on grape juice turbidity.

Table 3 The effect of UV-C radiation (254 nm) treatment on the grape juice smell.

	A	B	C	D
UV-C light (254 nm) treatment (min) and Dose (kJ L^{-1})	**Grape juice sampled 24 hours after sedimentation without addition of SO_2**	**Grape juice sampled 24 hours after sedimentation with addition of SO_2**	**Grape juice sampled 96 hours after sedimentation without addition of SO_2**	**Grape juice sampled 96 hours after sedimentation with addition of SO_2**
	Intensity of foreign smell in the grape juice (0 – 9)			
0 min 0 (kJ L^{-1})	0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0
1 min 0.68 (kJ L^{-1})	2, 3, 3, 2, 3, 2, 5	9, 9, 9, 9, 9, 9, 9	4, 3, 2, 2, 3, 3, 3	9, 9, 9, 9, 9, 9, 9
2 min 1.37 (kJ L^{-1})	8, 9, 7, 8, 8, 8, 7	9, 9, 9, 9, 9, 9, 9	9, 8, 8, 8, 7, 8, 9	9, 9, 9, 9, 9, 9, 9
10 min 6.83 (kJ L^{-1})	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9
20 min 13.67 (kJ L^{-1})	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9

Note: scale of the intensity of foreign smell (0 – odorless, 10 – strong odor). The number of certified assessors: 7.

Multiple comparison of samples by nonparametric Friedman‘s test revealed there is no significant difference in 0 mins, 10 mins and 20 mins treatments among samples A,B,C and D. In 1 minute and 2 minutes treatments are significant differences (***p*** **<0.001**). This hypothesis is supported by Figure 4 and Figure 5.

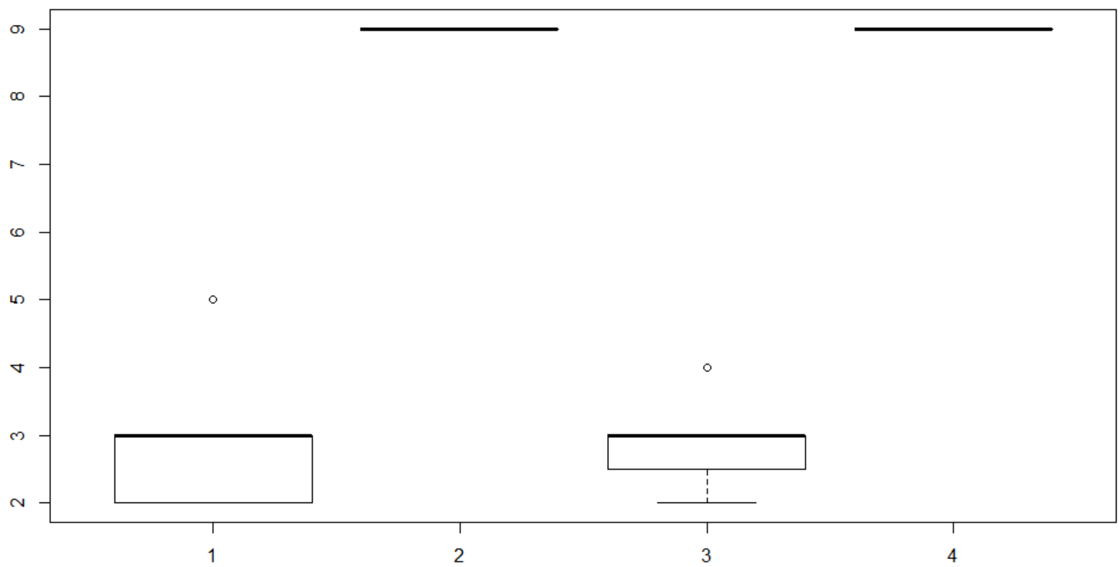

Figure 4. Boxplot of sensory smell values of samples UV-C radiated by (254 nm) 1 minute treatment.

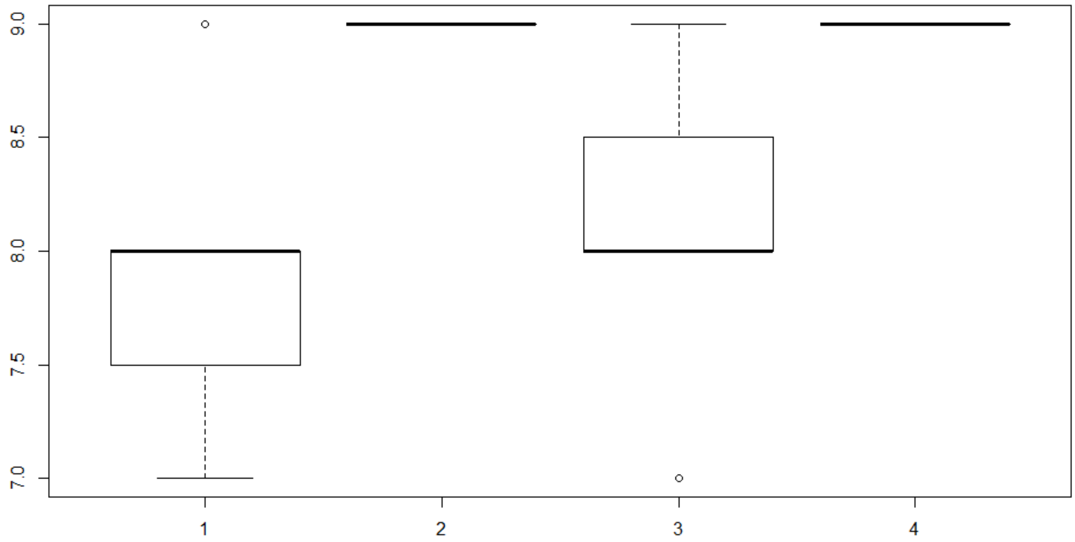

Figure 5. Boxplot of sensory smell values of samples UV-C radiated by (254 nm) 2 minutes treatment.

Table 4 The effect of UV-C radiation (254 nm) treatment on the grape juice taste.

	A	**B**	**C**	**D**
UV-C light (254 nm) treatment (min) and Dose (kJ L^{-1})	**Grape juice sampled 24 hours after sedimentation without addition of SO_2**	**Grape juice sampled 24 hours after sedimentation with addition of SO_2**	**Grape juice sampled 96 hours after sedimentation without addition of SO_2**	**Grape juice sampled 96 hours after sedimentation with addition of SO_2**
	Intensity of foreign smell in the grape juice (0 – 9)			
0 min 0 (kJ L^{-1})	0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0
1 min 0.68 (kJ L^{-1})	2, 3, 3, 2, 3, 2, 3	9, 9, 9, 9, 9, 9, 9	2, 2, 2, 3, 4, 3, 5	9, 9, 9, 9, 9, 9, 9
2 min 1.37 (kJ L^{-1})	7, 8, 8, 8, 7, 8, 8	9, 9, 9, 9, 9, 9, 9	8, 8, 7, 8, 7, 8, 9	9, 9, 9, 9, 9, 9, 9
10 min 6.83 (kJ L^{-1})	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9
20 min 13.67 (kJ L^{-1})	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9	9, 9, 9, 9, 9, 9, 9

Note: scale of the intensity of foreign taste (0 – without foreign taste, 10 – strong foreign taste). The number of certified assessors: 7.

Multiple comparison of samples by nonparametric Friedman's test for taste attributes revealed there is no significant difference in 0 mins, 10 mins and 20 mins treatments among samples A,B,C and D. In 1 minute and 2 minutes treatments is significant difference (p <0.001). Visualization of effect is similar to Figure 4 and Figure 5.

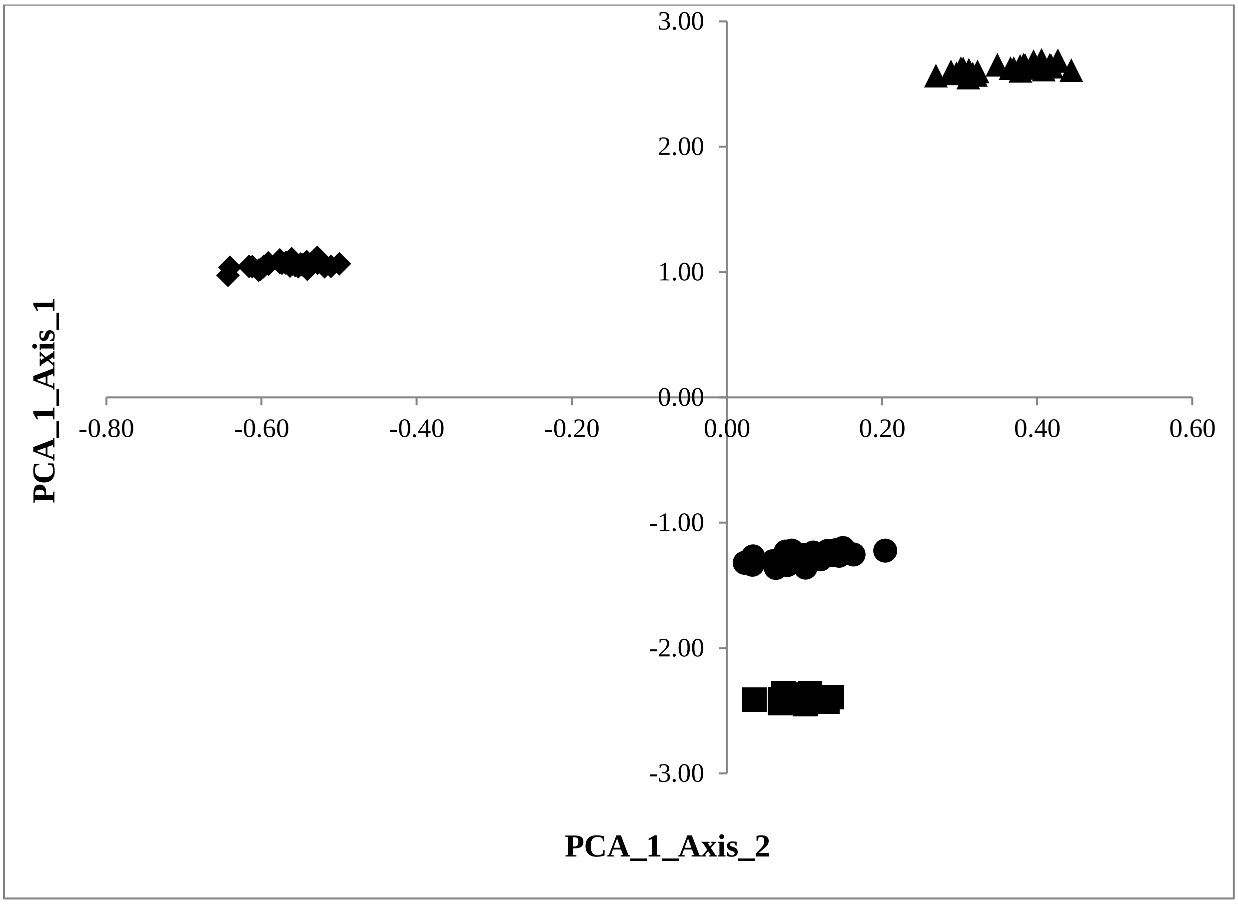

Figure 6 The PCA analysis of four grape juices with and without addition of sulphur dioxide according to the different UV-C treatment times. The PCA_1_Axis_1 and PCA_1_Axis_2 represents the turbidity data of four grape juices after 1 min (■), 2 min (●), 10 min (◆) and 20 min (▲) treatment with UV-C. The turbidity of grape juices with and without addition of sulphur dioxide was increased in relation to the length of UV-C treatment.

TExposure of wine to light results in what is known as light-struck flavours and aromas. These are produced by the initiation of chemical reactions in the wines, resulting in the formation of sulphurous compounds with an unpleasant smell and taste. The reactions can occur within minutes of exposure to light and a tiny amount of the sulphurous compounds can impart a noticeable (bad) taste and aroma to a wine.

The subject of further investigation may be the effect of fermentation on grape juices treated with UV-C radiation. It would be useful to found how the changed sensory properties of grape juice affect the final product.

CONCLUSION

The UV-C (254 nm) radiation increases the turbidity of grape juices (p <0.001). This effect was observed in all grape juices with or without addition of sulphur dioxide and also in clarified or not clarified grape juices.

We found UV-C radiation negatively affect the sensory properties of grape juices (p <0.001). This effect was more pronounced in grape juices treated with sulphur dioxide. The smell and taste were significantly negatively changed. Exposure of grape juice treated with sulphur dioxide to UV-C radiation can probably lead to arising the sulphur compounds, which affects the smell and taste of grape juices. Also, it is very likely that the negative change in taste and smell may negatively affect the quality of produced wines. For this reason, we do not recommend to use UV-C light for the grape juice treatment. It will be interesting to conduct a detail analysis of the grape juices composition before and after UV-C radiation treatment in next work.

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