The Effect of Bentonite Agents on the Aroma Composition of Sauvignon Blanc Wines

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Summary

Bentonite fining is commonly used by the wine industry as a clarifying technique to remove proteins that are a potential source of haze in wines. Large amounts of added bentonite can decrease the sensory properties of wines. The aim of this research was to study the influence of the standard wine clarification process by two different types of bentonite fining agents on the basic chemical composition and aromatic profile of Sauvignon Blanc by gas chromatography-mass spectrometry (GC-MS). The general characteristic of Sauvignon Blanc wines showed no differences among treated wines independently of the type (sodium bentonite Bentogran® and sodium-activated bentonite Majorbenton C®) and the dose of bentonite. The results showed that type of bentonite regardless of the dose applied, affected the monoterpenes concentration.

Key words

bentonite, wine, Sauvignon Blanc, aroma compounds

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Introduction

The international trade of wine is increasing globally and global wine consumption has been stable since 2009 estimated at 246 million hectoliters (OIV, 2019). As the demand for premium wines keeps increasing, the wine on the market, especially white wine, must meet certain conditions of which clarity is very important. Clarification and stabilization are a set of procedures of preparing wine for bottling and shipping for the market, with the aim of preventing the turbidity and precipitates of certain wine compounds. Hazy wine and the presence of precipitates are most commonly caused by three factors: microbial instability, tartrate instability, and protein heat instability (Van Sluyter et al. 2015). Clarifying wine is an essential step after the first racking. Bentonite fining is commonly used by the wine industry as a clarifying agent to remove proteins that are a potential source of haze in wines. It is mainly composed of at least 75 % of montmorillonite (Jaeckels et al. 2017). Montmorillonite has a multilayer structure of aluminum hydro silicate ($Al_2O_3 \times SiO_2 \times H_2O$) forming platelets. Different cations such as Ca^{2+}, Na^{+}, or K^{+} are complexed in the interlayer distance during swelling and the adsorbing behavior. A positively charged wine protein interacts electrostatically with bentonite because of its net negative charge at wine pH, which produces flocculation (Hsu and Heatherbell, 1987). It also removes other charged species or aggregates beside proteins. As a result, large amounts of added bentonite can decrease the sensory properties of wines, reducing important aroma and flavor components (Vincenzi et al. 2015, Voilley et al. 1990). The effects of bentonite usage in white wines in recent studies are shown in Table 1. In the case of aromatic white wines, like Sauvignon Blanc, protein stability and pronounced aromas are two even requirements. When low adsorbent amounts are enough to stabilize the wine, the concentration of the most aromatic substances is not significantly affected (Lambri et al. 2010). The adsorption intensity and capacity for the fermentative aromas mainly depend on bentonite characteristics (Lambri et al. 2016). As a consequence of the unselective fining process, sometimes even proteins or enzymes which are beneficial for wine, especially wine aroma, are removed. The removal of some fermentative aromas by bentonite is increased in the presence of wine proteins (Vincenzi et al. 2015) with direct evidence of main wine protein thaumatin-like protein VVTL1 binding to ethyl esters (Gaspero et al. 2017). Jaeckels et al. (2015) investigated the efficiency of different bentonites regarding the removal of proteins from must and provided an explanation for adsorbance of a specific wine protein, namely β-glucosidase in two German white wines (Pinot Gris and Riesling, vintage of 2010). Only a few aromatic compounds can be lost directly (by adsorption of aromas to bentonite) and most of them indirectly, via deproteinization (Lambri et al. 2013). Volatile aroma compounds affected by treatments with bentonite are terpenes, thiols, C-13 norisoprenoids, C-6 alcohols, ethyl esters and acetates (Moio et al. 2004, Armada and Falque, 2007, Baiano et al. 2012, Vincenzi et al. 2015, Vela et al. 2017). The synergistic effect of proteins and bentonite in removing β-ionone and γ-decalactone was studied in a model solution in the absence of alcohol (Lubbers et al. 1996) and in a model solution in the absence and presence of total and purified wine proteins (Vincenzi et al. 2015). Regarding discrepancies in the results of various studies, it is not possible to conclude when is the most appropriate time for bentonite addition during the vinification period to minimize the loss of aromatic compounds. Some authors agree that must clarification improves the sensory characteristic in white wines (Armada and Falque, 2007), while others observe the contrary (Puig-Deu et al.1999, Vela et al. 2017). According to Lambri et al. (2012), lower removal of free terpenols was observed in samples from double treatment with bentonite (on must and wine) in comparison to the addition of bentonite only after alcoholic fermentation. Several studies were focused on the fining of finished wines (Puig-Deu et al.1999, Sanborn et al. 2010, Lambri et al. 2010). In a study by Sanborn et al. (2010), bentonite significantly reduced linalool levels in Gewürztraminer, while sensory differences were not significant. Potential to reduce the dose of bentonite required and improve wine quality was hinted by recent findings of fining during the fermentation, especially in the middle or near the end (Lira et al. 2015, Horvat et al. 2019).

Sauvignon Blanc is one of the most popular and famous aromatic cultivars in the world today. In Croatia, it is most widespread in the continental viticultural regions. This cultivar is highly valued for its distinctive aroma, described as green (vegetal, grassy, green pepper, herbaceous) and tropical (grapefruit and passion fruit) (Coetzee and du Toit, 2012). Sauvignon Blanc wines are high in proteins and they can exhibit protein haze if not clarified before bottling (Vela et al. 2017). Besides only one scientific article with bentonite experiments on Malvazija istarska wine (Horvat et al. 2019), there is a deficiency of results in Croatian winemaking conditions. The aim of this research was to study the influence of the standard wine clarification and stabilization process by two different types of bentonite fining agents on the basic chemical composition and aromatic profile of Sauvignon Blanc wines from wine-growing hill Zelina situated in viticultural region Croatian Uplands.

Materials and Methods

Winemaking and Bentonite Treatments

Harvesting and processing of commercial Sauvignon Blanc grapes occurred in September 2016 in the vineyard and wine cellar of the family farm at wine-growing hill Zelina, region Croatian Uplands. According to climate parameters the year 2016 was extremely warm with average rain falls. Fully ripe and healthy grapes were hand-picked in the early morning hours and transferred to the winery. The average yield per vine was 2.5 kg. The grapes were immediately destemmed, crushed, mashed, and pressed using a closed-type pneumatic press of 500 L capacity. Sugars (86°Oe) in the must were measured using hand refractometer (Atago, Saitama, Japan) and pH value (3.1) using pH meter (Mettler Toledo, Philippines). Titratable acidity in the must (7.2 g L^{-1}) was measured by titration with standard solution 0.1 M NaOH (OIV 2015). The must was inoculated with commercial *Saccharomyces cerevisiae* yeast Lalvin R2™ (Lallemand, Canada). The yeast was rehydrated according to the manufacturers´ instruction with the addition of starter Go-Ferm™ (Lallemand, Canada). Yeast supplements (25 g hL^{-1} of Fermaid E, Lallemand) were added on the 2nd and 7th days of fermentation. The fermentation was conducted at 15 ± 2°C, for 10 days (reducing sugars < 2 g L^{-1}). Once the fermentation was over, the free sulfur dioxide levels were adjusted to 25-30 mg L^{-1} by the addition of 5%-sulfurous acid Sumpovin (Inovet, Croatia).

Table 1. Recent studies of bentonite effect on wine aroma and corresponding references

Findings	Type of bentonite	Reference
Fining during fermentation of Malvazija istarska- reduction of bentonite dose with significant positive sensory effect	Granular activated sodium bentonite	Horvat et al. (2019)
Fining during fermentation of Sauvignon blanc- low effect on aroma compounds	La Elcha Minera Industrial, Argentine Siha Active Bentonite, EATON, Germany	Salazar et al. (2017)
Treatment of Sauvignon blanc must- negative impact on varietal thiols	Bentogran, AEB, Italy	Vela et al. (2017)
Treatment of model Moscato wine- decreasing of ethyl esters, loss of aroma	Nucleobent, EVER, Italy	Vincenzi et al. (2015)
Fining during fermentation of Albariño- reduced total dose of bentonite and maintained varietal sensory characteristics	Microcol Alpha, Laffort, France	Lira et al. (2015)
Double treatment of Chambave Muscat must and wine- lower loss of free terpenols	Top Gran DC, Dal Cin Gildo, Italy	Lambri et al. (2012)
Treatment of Chardonnay wine- losses in some aromatic compounds; low doses (20 g/hL) without significant effect on aroma	Superbenton DC, Top Gran DC, Dal Cin Gildo, Italy and experimental clay	Lambri et al. (2010)

After 2 months the wines were subjected to clarification with two different types of clarifying agents, sodium bentonite Bentogran® (named B) and sodium-activated bentonite Majorbenton C® (named MC) (both AEB, Italy). The bentonite slurries were prepared in deionized water at a concentration of 10% (w/w). After rehydration, the gels were stirred. Different doses of bentonite agents were applied to 10 L of heat-unstable wine according to manufacturer's recommendations due to the adsorption power. The treatments were: control (without fining agent), B (applied doses: 50 g hL^{-1} (B1), 125 g hL^{-1} (B2), 200 g hL^{-1} (B3)) and MC (applied doses: 100 g hL^{-1} (MC1), 200 g hL^{-1} (MC2), 300 g hL^{-1} (MC3)), made in duplicate. After the treatments, wines were kept for 14 days at 16 to 18°C, then they were racked and filtered with a cellulose plate's filter. Samples were frozen at -20°C until analyzed. The wines for the sensory analysis were bottled and left for 2- month aging.

Chemicals and Reagents

Methanol and dichloromethane were obtained from J.T. Baker (Derventer, Netherlands). All other chemicals including standards of aroma were obtained from Sigma-Aldrich (Steinheim, Germany) in the highest commercially available grade of purity.

Standard Physicochemical Analysis

Standard physicochemical parameters of wine were determined in duplicate by using methods proposed by O.I.V. (2015).

Heat Stability Test

Wine samples (20 mL) were filtered through a PTFE 0.45 µm syringe filter and heated at 80°C for 2 h in a water bath. The sample was then incubated at 4°C for another 2 h and then left to reach room temperature. The amount of haze produced was measured by a nephelometry (Hanna Instruments HI 83749, Padova, Italy). A sample was considered to be protein stable when the difference between a heated sample and an unheated control did not exceed 2 NTU (nephelometry turbidity units) (Pockok and Rankine, 1973).

Analysis of Volatile Aroma Compounds

Sample Preparation for GC/MS Analysis

Aroma compounds were extracted according to Lopez et al. (2002). A 4 mL dichloromethane, 4 mL methanol and 4 mL aqueous ethanol solution (13.5%, v/v) was used to pre-condition cartridges containing 200 mg LiChrolut EN sorbent. Fifty milliliters of wine were passed through the SPE cartridge and dried in vacuum. The analytes were recovered by elution with 800 µL of dichloromethane. Ten microliters of internal standard (50 mg L^{-1}, 2- octanol) were added over the eluted sample.

GC/MS Analysis

The prepared extract was injected with the Agilent 6890 gas chromatograph and the 5973 mass selective detector, equipped with the Agilent 6890 autosampler. The GC column was ZB-WAX from Phenomenex, Torrance, USA, 60 m × 0.32 mm i.d., with 0.50 µm film thickness. The carrier gas was helium, 5.5 grade at a constant flow rate of 1 mL min^{-1}. The injection volume was 2 µL in splitless mode. The injector temperature was 250°C. The column temperature program was as follows: initial hold for 5 min at 40 °C, followed by a 2°C min^{-1} to 240°C, and then kept for 20 min. The temperature of the transfer line was 230°C. The temperatures of the ion source and quadrupole were 230°C and 150°C, respectively. The mass spectrometer was operated in electron ionization mode at 70 eV with selected ion monitoring (SIM). The identification was carried out by comparing retention times and mass spectra with those of pure standards and NIST05 library mass spectra.

Sensory Analysis

The Sauvignon Blanc wines were sensory evaluated 2 months after being treated with different doses of bentonites. A panel of six wine evaluators (3 males and 3 females) performed the evaluation and the results of their average evaluations are presented in Fig. 2. The evaluators used a 5-point structured scale to rate 13 sensory parameters. The evaluation was performed on 3 samples of Sauvignon Blanc wines treated with MC agent and 3 samples treated with B agent, both in comparison to control wine.

Statistical Analysis

The values of basic and aromatic wine composition presented in the paper were average (± standard deviation) of two independent samples (replicates). The one-way analysis of variance (ANOVA) was used to determine the significant difference in the parameters (significant at 5% level) and principal components analysis (PCA) was applied to the data. Statistical analyses were performed by means of SAS 9.4 (SAS Institute, Cary NC).

Results and Discussion

General Characteristic of Wines

In this research, the effect of bentonite fining agents on chemical composition and aroma profile of Sauvignon Blanc wines (vintage 2016) was studied. Table 2 summarizes the mean values of basic parameters of control wine and wines treated with different doses of granulated sodium and sodium-activated bentonite agents (B and MC). The results show that, despite some minor differences in the basic composition, all wines in the experiment were similar from a practical point of view. There were no differences among treated wines independently of the type and dose of bentonite. The only significant differences noticed were between control and treated wines regarding the sugar-free extract, total acidity and pH value. Similar results on white wines were also reported by other authors (Lira et al. 2014, 2015, Vela et al. 2017).

Protein Instability Test

After the completion of alcoholic fermentation and treatment with bentonite, protein instability tests were carried out to determine the efficiency of the bentonite fining treatments. Table 3 shows the initial turbidity of control wine and turbidity in treated wines. As can be seen, an increase in the amount of both bentonite agents added to the wines decreased the turbidity. In both cases, the middle dose of bentonite (B2 and MC2) was proper for protein stability (ΔNTU < 2). Different doses of both bentonites made significant differences in some basic chemical parameters only between treated wines and control (Table 2).

Aroma Profile

Sixteen different volatile, varietal compounds were determined in Sauvignon blanc wines. The influence of different types and doses of bentonites on the content of aroma compounds has been studied by many authors with different results (Table 1). As it can be seen from Table 4, higher concentrations of aroma compounds were not found always in the control wines, which is not completely in correlation with other authors, but can be explained by gradual liberation of volatile aglycons through hydrolysis of glycosides, oxidation or other conversions (Horvat et al. 2019). The monoterpenes are a diverse class of natural products that contribute to the important floral and citrus character of wine (Park et al. 1991). In untreated control wine, four individual monoterpenes had a lower concentration in comparison to wines with bentonite addition that can be related to enzymatic hydrolysis of their bound precursors and other transformation during the aging period (Horvat et al. 2019). The most abundant monoterpenes were citronellol and nerol, but only citronellol (citrus) and geranic acid (green) exceeded its odor threshold. Generally, wines treated with bentonite B had the highest values of monoterpenes and there was significant decreasing of total monoterpenes in MC2 and MC3 wines due to the lowest concentration of linalool, citronellol, nerol and geranic acid, which is in accordance with Sanborn et al. (2010) and Lambri et al. (2010). It can be concluded that the type of bentonite regardless of the dose applied affected the monoterpenes concentration. According to Armada and Falque (2007), in Albariňo wine with added 60 g hL^{-1} of bentonite a loss of 13% of total terpenes was observed, while in Falanghina wine treated with 80 g hL^{-1} of bentonite (but also with potassium caseinate, gelatin, silica gel, and charcoal), losses of totally free and bound terpenols were found, corresponding to 23% in must and 31–36% in wine (Moio et al. 2004). Norisoprenoids, such as the C13-norisoprenoids α-ionone, β-ionone, or β-damascenone, are substances that originate from carotenoid degradation. These compounds contribute to wine aroma and are reminiscent of violet, raspberry, and floral flavor attributes and can significantly impact wine aroma due to their low odor thresholds. The most affected compounds by bentonite B were α-ionone, as the most abundant compound and then β-damascenone by bentonite MC. Similar results for β-damascenone and β-ionone that was stabile were observed by Vincenzi et al. (2015) and Vela et al. (2017).

Table 2. Basic chemical composition of Sauvignon Blanc wines (control and bentonite treated wines, n=2)

	Control	B 1	B 2	B 3	MC 1	MC 2	MC 3
Alcohol (vol %)	12.4 ± 0.3	12.60 ± 0.4	12.70 ± 0.5	12.42 ± 0.4	12.60 ± 0.3	12.70 ± 0.3	12.51 ± 0.2
Residual sugar (g L^{-1})	1.8 ± 0.3	1.4 ± 0.2	1.4 ± 0.4	1.4 ± 0.2	1.4 ± 0.3	1.5 ± 0.4	1.5 ± 0.2
Total acidity (as g L^{-1} of tartaric acid)	6.6 ± 0.22[a]	6.3 ± 0.34[b]	6.3 ± 0.27[b]	6.3 ± 0.23[b]	6.0 ± 0.24[b]	6.15 ± 0.27[b]	6.0 ± 0.24[b]
Volatile acidity (as g L^{-1} of acetic acid)	0.3 ± 0.03	0.48 ± 0.01	0.53 ± 0.04	0.44 ± 0.05	0.44 ± 0.02	0.48 ± 0.03	0.48 ± 0.05
pH	3.31 ± 0.02[a]	3.20 ± 0.03[b]	3.22 ± 0.02[b]	3.20 ± 0.03[b]	3.21 ± 0.02[b]	3.20 ± 0.01[b]	3.21 ± 0.02[b]
Ash (g L^{-1})	1.78 ± 0.02	1.70 ± 0.01	1.75 ± 0.02	1.61 ± 0.02	1.63 ± 0.01	1.69 ± 0.02	1.71 ± 0.01
Free SO_2 (mg L^{-1})	22.0 ± 0.9	17.0 ± 0.7	21.0 ± 0.8	18.0 ± 0.6	18.0 ± 0.7	20.0 ± 0.9	18.0 ± 0.6

Note: Different letters indicate the mean is significantly different among samples at P < 0.05

Table 3. Differences in turbidity (ΔNTU) obtained in the heat test with different bentonite treatments of wines

	Control	B 1	B 2	B 3	MC 1	MC 2	MC 3
ΔNTU	29.3	3.8	1.0	0.2	4.2	0.9	0.3

Aldehydes and alcohols with 6 carbon atoms (C6) are volatile, odorous molecules that can contribute to the green, herbaceous aroma in wine (Mozzon et al. 2016). The overall effect on C6 and other compounds was significant. Compounds that significantly differ among treated and control wines were 2-hexenal, with the highest concentration in control (7.29 μg L^{-1}) and the lowest in the wine treated with the highest dose of Bentogran (0.21 μg L^{-1}), and hexan-1-ol with the lowest concentration in control wine that is in accordance to Vela et al. (2017), but not with Lambri et al (2010). This phenomenon can be partly explained by the strong binding of 2-hexenal to bentonite (Onsekizoglu et al. 2010). The results reported for furfural by other authors confirm the possibility of increasing after fining of wine like in the present study (Horvat et al. 2019). The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was performed with value of 0.77, which indicates that a factor analysis may be useful for data interpretation. Bartlett's test of sphericity was also performed and it showed significance level (less than 0.05). The PCA score plot (Fig. 1) showed more information about individual aroma compounds and some specific associations. As can be seen in Fig. 1 the F1 (34.32 %) showed almost clear separation of the treated wines (with negative values of F1) except for MC3, from the control (positive value F1). On the other hand, the F2 (32.37%) allowed separation of the wines treated with MC bentonite (positive values of F2) from the wines treated with bentonite B (negative values of F2). It can be seen that control wine is positively related to the β-damascenone and 2-hexen-1-ol, while MC1 and MC2 were more related to geraniol. Wines B1, B2 and B3 were almost uniform and associated with citronellol and nerol.

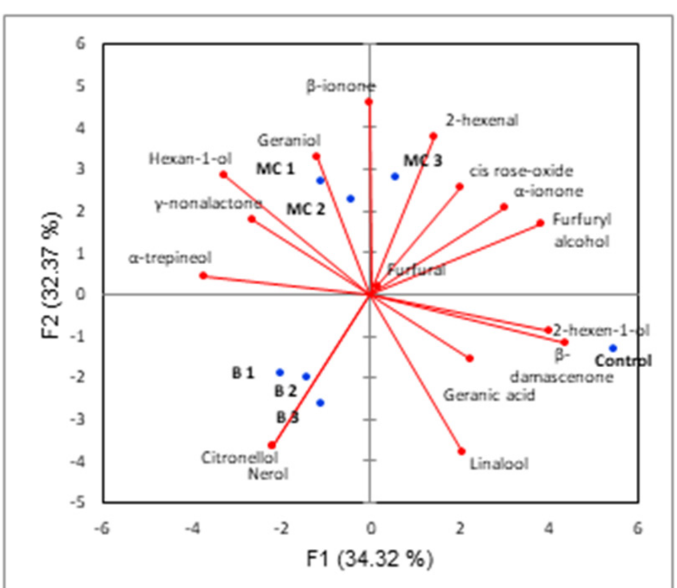
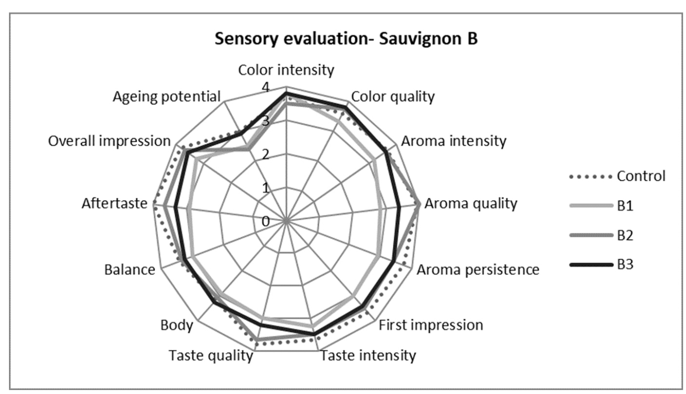


Figure 1. Principal component analysis of aromatic compounds in Sauvignon Blanc wines treated with two different bentonites

Sensory Evaluation

The results of the sensory evaluation indicated differences in the quality of Sauvignon wines treated with different bentonite agents. According to Fig. 2, it can be seen that wines treated with bentonite B had generally more intensive sensory parameters in comparison to agent MC. Wines treated with MC agents were more different from control wine regarding almost every sensory parameter. Results of sensory evaluation correspond to the differences between the amounts of aromatic compounds e.g. terpenes and some C-13 norisoprenoids (Table 4). The highest concentration of total terpenes possibly contributed positively to average sensory scores for aroma intensity and quality for B2 and B3 wines that is in accordance with findings of Horvat et al. (2019). The lowest score for aroma quality in MC1 wine corresponds with the significantly highest concentration of herbaceous C-6 compounds. The color intensity was best rated (visually) in both cases in wines with the highest concentrations of bentonite (B3 and MC3). Overall impression scores were the lowest for B1 and MC1 wines.

(a)



(b)

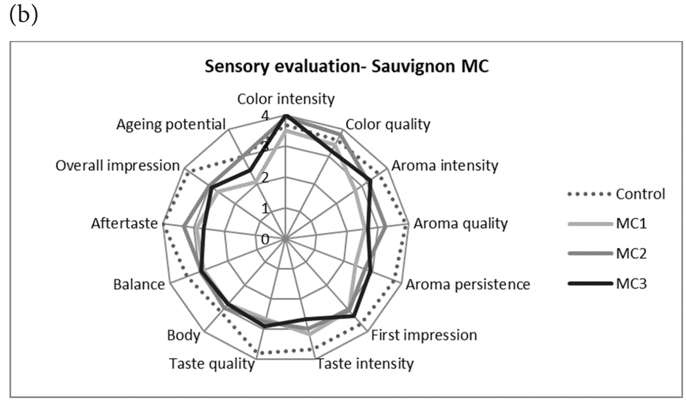


Figure 2. Sensory evaluation of Sauvignon Blanc wines treated with a) bentonite B (1, 2 and 3) and b) MC (1, 2 and 3) in comparison to control wine

Table 4. Mass concentrations and odor thresholds of aroma compounds in control and treated wines of Sauvignon Blanc (μg L^{-1})

Aroma compound (threshold)	**Odor descriptor**	**Control**				**B 1**			
cis-Rose oxide (0.5)	rose	0.41	±	0.02	a	0.21	±	0.05	c
Linalool (25)	floral	23.60	±	0.15	a	22.10	±	0.17	d
α-Terpineol (250)	lilac	6.37	±	0.11	e	6.90	±	0.08	c
Citronellol (100)	citrus	**174.81**	±	**1.23**	**d**	**183.88**	±	**1.65**	**b**
Nerol (500)	orange flowers, rose	173.21	±	1.05	d	182.19	±	1.11	b
Geraniol (20)	geranium, rose	0.32	±	0.09	e	0.59	±	0.05	d
Geranic acid (40)	green	**59.67**	±	**0.98**	**a**	**55.26**	±	**0.55**	**b**
Total monoterpenes		438.39	±	3.63		451.13	±	3.66	
β-damascenone (0.05)	sweet, fruity, stewed apple	**2.49**	±	**0.06**	**a**	**2.01**	±	**0.09**	**b**
α-ionone (2.6)	violets	**4.23**	±	**0.11**	a	0.76	±	0.05	e
β-ionone (0.09)	violet, raspberry	**1.46**	±	**0.05**	**d**	**1.44**	±	**0.05**	**de**
Total C-13 norisoprenoids		**8.18**	±	0.22		4.21	±	0.19	
2-hexen-1-ol (100)	green, herbaceous	3.45	±	0.10	a	2.04	±	0.08	e
2-hexenal (17)	green, herbaceous	7.29	±	0.13	d	2.74	±	0.08	f
Hexan-1-ol (1620)	fresh cut grass	856.21	±	1.32	g	1143.25	±	2.05	c
Total C-6- compounds		866.95	±	1.55		1148.03	±	2.21	
Furfural (14100)	sweet, woody, almond	1.00	±	0.08	c	1.18	±	0.04	b
Furfuryl alcohol (15000)	medicinal	1.55	±	0.09	a	1.01	±	0.03	e
γ-nonalactone (30)	coconut, peach	3.09	±	0.10	d	3.61	±	0.09	b
Other compounds		5.64	±	0.27		5.80	±	0.16	

Table 4. Continued.

Aroma compound (threshold)	**Odor descriptor**	**B 2**				**B 3**			
cis-Rose oxide (0.5)	rose	0.30	±	0.03	b	0.41	±	0.05	a
Linalool (25)	floral	22.79	±	0.12	b	22.33	±	0.13	c
α-Terpineol (250)	lilac	7.00	±	0.09	b	6.93	±	0.07	c
Citronellol (100)	citrus	**190.77**	±	**1.35**	**a**	**190.56**	±	**1.33**	**a**
Nerol (500)	orange flowers, rose	189.03	±	1.26	a	188.82	±	1.14	a
Geraniol (20)	geranium, rose	0.51	±	0.04	de	0.47	±	0.05	de
Geranic acid (40)	green	**46.35**	±	**0.58**	**e**	**47.49**	±	**0.79**	**d**
Total monoterpenes		456.75	±	3.47		**457.01**	±	**3.56**	
β-damascenone (0.05)	sweet, fruity, stewed apple	**2.16**	±	**0.08**	**b**	**2.07**	±	**0.09**	**bc**
α-ionone (2.6)	violets	0.31	±	0.05	f	0.29	±	0.08	f
β-ionone (0.09)	violet, raspberry	**1.41**	±	**0.06**	**de**	**1.39**	±	**0.04**	**e**
Total C-13 norisoprenoids		3.88	±	0.19		3.75	±	0.21	
2-hexen-1-ol (100)	green, herbaceous	2.65	±	0.08	b	2.61	±	0.07	b
2-hexenal (17)	green, herbaceous	6.35	±	0.09	e	0.21	±	0.04	g
Hexan-1-ol (1620)	fresh cut grass	1126.87	±	2.11	e	949.49	±	1.52	f
Total C-6- compounds		1135.87	±	2.28		952.31	±	1.63	
Furfural (14100)	sweet, woody, almond	1.16	±	0.03	b	0.76	±	0.02	e
Furfuryl alcohol (15000)	medicinal	1.19	±	0.03	cd	1.11	±	0.05	d
γ-nonalactone (30)	coconut, peach	3.68	±	0.08	b	3.64	±	0.10	b
Other compounds		6.03	±	0.14		5.51	±	0.17	

Table 4. Continued.

Aroma compound (threshold)	Odor descriptor	MC 1	MC 2	MC 3
cis-Rose oxide (0.5)	rose	0.42 ± 0.04 a	0.41 ± 0.05 a	0.42 ± 0.03 a
Linalool (25)	floral	21.41 ± 0.16 e	21.23 ± 0.11 f	20.42 ± 0.15 g
α-Terpineol (250)	lilac	7.28 ± 0.10 a	6.88 ± 0.10 c	6.55 ± 0.09 d
Citronellol (100)	citrus	**180.33 ± 1.49 c**	**171.69 ± 1.21 e**	**166.92 ± 1.10 f**
Nerol (500)	orange flowers, rose	178.67 ± 1.12 c	170.11 ± 0.99 e	165.38 ± 1.02 f
Geraniol (20)	geranium, rose	4.59 ± 0.06 a	1.98 ± 0.03 b	0.90 ± 0.07 c
Geranic acid (40)	green	**53.07 ± 0.59 c**	**46.22 ± 0.47 e**	**42.70 ± 0.56 f**
Total monoterpenes		445.77 ± 3.56	418.52 ± 2.96	403.29 ± 3.02
β-damascenone (0.05)	sweet, fruity, stewed apple	**1.72 ± 0.05 d**	**1.78 ± 0.05 cd**	**1.82 ± 0.06 cd**
α-ionone (2.6)	violets	**3.94 ± 0.09 b**	1.93 ± 0.04 c	1.38 ± 0.08 d
β-ionone (0.09)	violet, raspberry	**1.63 ± 0.05 b**	**1.66 ± 0.05 a**	**1.59 ± 0.04 c**
Total C-13 norisoprenoids		**7.29** ± 0.19	5.37 ± 0.14	4.79 ± 0.18
2-hexen-1-ol (100)	green, herbaceous	2.60 ± 0.07 b	2.31 ± 0.08 d	2.48 ± 0.05 c
2-hexenal (17)	green, herbaceous	7.93 ± 0.10 c	8.15 ± 0.11 b	13.86 ± 0.10 a
Hexan-1-ol (1620)	fresh cut grass	1239.55 ± 1.99 a	1158.73 ± 1.97 b	1136.43 ± 1.84 d
Total C-6- compounds		**1250.08** ± 2.16	1169.19 ± 2.16	1152.77 ± 1.99
Furfural (14100)	sweet, woody, almond	0.79 ± 0.04 e	0.93 ± 0.04 d	1.31 ± 0.05 a
Furfuryl alcohol (15000)	medicinal	1.37 ± 0.03 b	1.25 ± 0.04 cd	1.27 ± 0.03 c
γ-nonalactone (30)	coconut, peach	4.68 ± 0.11 a	3.64 ± 0.09 b	3.37 ± 0.08 c
Other compounds		6.84 ± 0.18	5.82 ± 0.17	5.95 ± 0.16

Note: Different letters indicate mean is significantly different among samples at $P < 0.05$ by Duncan's test after a significant one-way ANOVA.

* Odour perception thresholds and descriptors ($\mu g\ L^{-1}$) reported in the literature (Noguerol-Pato et al. 2013, Ferreira et al. 2000, Etievant 1991, Guth 1997, Nakamura et al. 1988)

Conclusion

The general characteristic of Sauvignon blanc wines showed no differences among treated wines independently of the type and the dose of bentonite. The type of bentonite regardless of the dose applied affected the concentrations of aroma compounds. The results showed that fining had an impact on the aroma profile of Sauvignon blanc, and also the type of bentonite can define the different aroma profiles and overall sensory properties. Characteristic Sauvignon blanc aroma compounds such as varietal thiols and pyrazines, which analysis is complex and challenging, should be analyzed and taken into account in future perspective.

References

Armada L., Falqué E. (2007). Repercussion of the Clarification Treatment Agents before the Alcoholic Fermentation on Volatile Composition of White Wines. Eur Food Res Technol. 225: 553-558. doi: doi.org/10.1007/s00217-006-0453-3

Baiano A., Terracone C., Longobardi F., Ventrella A., Agostiano A., Del Nobile M. A. (2012). Effects of Different Vinification Technologies on Physical and Chemical Characteristics of Sauvignon Blanc Wines. Food Chem. 135: 2694-2701. doi: 10.1016/j.foodchem.2012.07.075

Coetzee C., du Toit W. J. (2012). A Comprehensive Review on Sauvignon Blanc Aroma with a Focus on Certain Positive Volatile Thiols. Food Res Int. 45: 287-298. doi: 10.1016/j.foodres.2011.09.017

Di Gaspero M., Ruzza P., Hussain R., Vincenzi S., Biondi B., Gazzola D., Siligardi G., Curioni A. (2017). Spectroscopy Reveals that Ethyl Esters Interact with Proteins in Wine. Food Chem. 217: 373–378. doi: 10.1016/j.foodchem.2016.08.133

Etievant P. X. (1991). Wine. In Volatile Compounds of Food and Beverages. H Maarse (ed.), Dekker, New York, pp. 483-546

Ferreira V., López R., Cacho J. F. (2000). Quantitative Determination of the Odorants of Young Red Wines from Different Grape Varieties. J Sci Food Agric. 80: 1659–1667. doi: 10.1002/1097-0010(20000901)80:11%3C1659::AID-JSFA693%3E3.0.CO;2-6

Guth H. (1997). Quantitation and Sensory Studies of Character Impact Odorants of Different White Wine Varieties. J Agric Food Chem. 45: 3027-3032. doi: 10.1021/jf970280a

Horvat I., Radeka S., Plavša T., Lukić I. (2019). Bentonite Fining during Fermentation Reduces the Dosage Required and Exhibits Significant Side Effects on Phenols, Free and Bound Aromas and Sensory Quality of White Wine. Food Chem. 285: 305-315. doi: 10.1016/j.foodchem.2019.01.172

Hsu J. C., Heatherbell D. A. (1987). Heat-Unstable Proteins in Wine. I. Characterization and Removal by Bentonite Fining and Heat Treatment. Am J Enol Vitic. 38: 11-16

Jaeckels N., Tenzer S., Meier M., Will F., Dietrich H., Decker H., Fronk P. (2017). Influence of Bentonite Fining on Protein Composition in Wine. LWT-Food Sci and Technol. 75: 335-343. doi: 10.1016/j.lwt.2016.08.062

Jaeckels N., Tenzer S., Rosch A., Scholten G., Decker H., Fronk P. (2015). β Glucosidase Removal Due to Bentonite Fining during Wine Making. Eur Food Res Technol. 241: 253–262. doi: 10.1007/s00217-015-2451-9

Lambri M., Colangelo D., Dordoni R., Torchio F., De Faveri D. M. (2016). Innovations in the Use of Bentonite in Oenology: Interactions with Grape and Wine Proteins, Colloids, Polyphenols and Aroma Compounds, In: Morata, A., Loira, I. (eds) Grape and Wine Biotechnology. IntechOpen, pp. 381-400

Lambri M., Dordoni R, Silva S., De Faveri D. M. (2010). Effect of Bentonite Fining on Odor-Active Compounds in Two Different White Wine Styles. Am J Enol Vitic. 61: 225–233

Lambri M., Dorodoni R., Silva A., De Faveri D. M. (2012). Comparing the Impact of Bentonite Addition for Both Must Clarification and Wine Fining on the Chemical Profile of Wine from Chambave Muscat Grapes. Int J Food Sci Technol. 47: 1-12. doi: 10.1111/j.1365-2621.2011.02800.x

Lambri M., Dorodoni R., Silva A., De Faveri D. M. (2013). Odor-Active Compound Adsorption onto Bentonite in a Model White Wine Solution. Chem Eng Trans. 32: 1742-1746. doi: 10.3303/ACOS1311021

Lira E., Rodríguez-Bencomo J. J, Salazar F.N., Orriols I., Fornos D., López F. (2015). Impact of Bentonite Additions during Vinification on Protein Stability and Volatile Compounds of Albariño Wines. J Agr Food Chem. 63: 3004–3011. doi: 10.1021/acs.jafc.5b00993

Lira E., Salazar F. N., Rodriguez-Bencomo J. J., Vincenzi S., Curioni A., López F. (2014). Effect of Using Bentonite during Fermentation on Protein Stabilisation and Sensory Properties of White Wine. Int J Food Sci Technol. 49: 1070-1078. doi: 10.1111/ijfs.12402

Lopez R., Aznar M., Cacho J., Ferreira V. (2002). Determination of Minor and Trace Volatile Compounds in Wine by Solid-Phase Extraction and Gas Chromatography with Mass Spectrometric Detection. J Chromatogr A. 906: 167-177. doi: 10.1016/S0021-9673(02)00696-9

Lubbers S., Charpentier C., Feuillat M. (1996). Etude de la rétention de composés d'arôme par les bentonites en moût, vin et milieux modèles. Vitis 35: 59–62

Moio L., Ugliano M., Gambuti A., Genovese A., Piombino P. (2004). Influence of Clarification Treatment on Concentrations of Selected Free Varietal Aroma Compounds and Glycoconjugates in Falanghina (*Vitis vinifera* L.) Must and Wine. Am J Enol Vitic. 55: 7-12

Mozzon M., Savini S., Boselli E., Thorngate J. H. (2016). The Herbaceous Character of Wines. Ital J Food Sci. 28: 190-207. doi: 10.14674/1120-1770/ijfs.v304

Nakamura S., Crowell E. A., Ough C. S., Totsuka A. (1988). Quantitative Analysis of γ-Nonalactone in Wines and Its Threshold Determination. J Food Sci. 53: 1243-1244. doi: 10.1111/j.1365-2621.1988.tb13578.x

Noguerol-Pato R., González-Álvarez M., González-Barreiro C., Cancho-Grande B., Simal-Gándara J. (2013). Evolution of the Aromatic Profile in Garnacha Tintorera Grapes during Raisining and Comparison with That of the Naturally Sweet Wine Obtained. Food Chem. 139: 1052–1061. doi: 10.1016/j.foodchem.2012.12.048

OIV (2015). Compendium of International Methods of Wine and Must Analysis. vol 2. Paris: International Organisation of Vine and Wine (OIV)

OIV (2019). State of the Vitiviniculture World Market, State of the Sector in 2018

Onsekizoglu P., Baheci Savas K., Jale Acar M. (2010). Clarification and the Concentration of Apple Juice Using Membrane Processes: A Comparative Quality Assessment. J Membr Sci. 352: 160-165. doi: https://doi.org/10.1016/j.memsci.2010.02.004

Park S. K., Morrison J. C., Adams D. O., Noble A. C. (1991). Distribution of Free and Glycosidally Bound Monoterpenes in Skin and Mesocarp of Muscat of Alexandria Grapes during Development. J Agric Food Chem. 39: 514-518. doi: 10.1021/jf00003a017

Puig Deu M., Lopez-Tamames E., Buxaderas S. (1999). Quality of Base and Sparkling Wines as Influenced by the Type of Fining Agent Added Pre-Fermentation. Food Chem. 66: 35-42. doi: 10.1016/S0308-8146(98)00093-4

Pocock K. F., Rankine B. C. (1973). Heat Test for Detecting Protein Instability in Wine. Australian Wine. Brewing and Spirit Review 91 (5): 42-43

Salazar F. N., Maragon M., Labbe M., Lira E., Rodriguez-Bencomo J., Lopez F. (2017). Comparative Study of Sodium Bentonite and Sodium-Activated Bentonite Fining during White Wine Fermentation: Its Effect on Protein Content, Protein Stability, Lees Volume and Volatile Compounds. Eur Food Res Technol. 243: 2043-2054. doi: 10.1007/s00217-017-2917-z

Sanborn M., Edwards C. G., Ross C. F. (2010). Impact of Fining on Chemical and Sensory Properties of Washington State Chardonnay and Gewürztraminer Wines. Am J Enol Vitic. 61: 31 –41

Van Sluyter S. C., McRae J. M., Falconer R. J., Smith P. A., Bacic A., Waters E. J., Marangon M. (2015). Wine Protein Haze: Mechanisms of Formation and Advances in Prevention. J Agric Food Chem. 63: 4020-4030. doi: 10.1021/acs.jafc.5b00047

Vela E., Hernandez-Orte P., Castro E., Ferreira V., Lopez R. (2017). Effect of Bentonite Fining on Polyfunctional Mercaptans and Other Volatile Compounds in Sauvignon Blanc Wine. Am J Vitic and Enol. 68: 30-38. doi: 10.5344/ajev.2016.16052

Vincenzi S., Panighel A., Gazzola D., Flamini R., Curioni A. (2015). Study of Combined Effect of Proteins and Bentonite Fining on the Wine Aroma Loss. J Agric Food Chem. 63: 2314-2320. doi: 10.1021/jf505657h

Voilley A., Lamer C., Dubois P., Feuillat M. (1990). Influence of Macromolecules and Treatments on the Behavior of Aroma Compounds in a Model Wine. J Agric Food Chem. 38: 248-251. doi: 10.1021/jf00091a054

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