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Sensory characterisation of Bordeaux red wines produced without added sulfites

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ABSTRACT

Aim: The evolution of consumer expectations has led to the development of new production methods using low inputs. From an oenological point of view, these methods include the production of wines without any SO_2 being added throughout the process. These wines are becoming very popular among consumers, but the absence of SO_2 during winemaking increases the risk of stability problems. Such wines have been poorly explored in the literature and there is thus a real need for them to be characterised. This study was developed to evaluate whether Bordeaux quality wines produced without added SO_2 have their own typicality, and it provides an insight into current wine production.

Methods and results: From a batch of fifty-two commercial Bordeaux red wines produced without adding SO_2 and twenty red wines made according to the usual winemaking methods, a selection tasting was performed to eliminate wines with at least one defect further to a sensory space evaluation. In a second phase, the napping test was applied to defect-free wines to evaluate the sensory specificities of wines produced without SO_2 addition. The wines without SO_2 addition presented a much higher frequency of defects than those with SO_2 (70 % vs 15 % respectively). Defects described in wines without added SO_2 were: "Oxidation" (47 %), "Volatile phenols" (31 %), "Mousy off-flavor" (10 %), "Reduction" (8 %) and "Vegetable" (4 %). Since the study focused on quality wines with or without SO_2 addition, it was difficult for the tasters to discriminate between them according to their overall technical pathway.

Conclusion: This approach has revealed that despite the large number of "non-added SO_2" wines with defects, upon blind tasting, expert tasters highlighted some "non-added SO_2" wines without defects. Nevertheless, at equivalent quality levels within the same geographic region, and in non-targeted sensory tests, wines with and without SO_2 addition were considered to be quite similar.

Significance of the study: This study was a first sensory step toward the objective characterisation of "non-added SO_2" wines, enabling further work to highlight markers of quality in wines without SO_2 addition and to develop the production of "non-added SO_2" wines without defects. Nevertheless, at this stage, our results show that the absence of sulfites during the whole winemaking process, including bottling, increases the risk of the development of defects.

KEYWORDS

wines without sulfites, wine defects, sensory analysis, napping, range task

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INTRODUCTION

Since the development of the "Dutch match" in the 18th century, sulfur dioxide (SO_2) has been widely used in the wine industry (Ribéreau-Gayon *et al.*, 2017), although in the literature the first report of SO_2 being used for food preservation dates back to 1664, when sulfur was burned in cider containers (Roberts and McWeeny, 1972). Historically, however, it is thought to have been used by the Romans and Egyptians for sanitising wine vessels. SO_2 is generally added throughout the winemaking process for its various properties. This additive is an anti-oxidant (Danilewicz, 2011; Usseglio-Tomasset, 1992) also used in the food industry (Mareschi *et al.*, 1992), and also has specific properties acting against the tyrosinase and laccase from *Botrytis cinerea* (Dubernet and Ribéreau-Gayon, 1973), the two oxidases that may be present in grapes. It also combines various antimicrobial properties affecting, among others, yeasts as well as lactic acid bacteria (Carr *et al.*, 1976; Solberg, 1991; Zuehlke and Edwards, 2013).

SO_2 levels have been legally regulated from country to country since the beginning of the 20th century. In the European Community, Commission Regulation (EC) No 934/2019 formalises the limits laid down by the International Organization of Vine and Wine (OIV). Currently, maximum levels are 150 mg/L for red wine, 120 mg/L for organic red wine and 70 mg/L for certain biodynamic certifications. For wines produced without the addition of sulfites, the limit for total SO_2 was laid down as 10 mg/L. During alcoholic fermentation, *Saccharomyces cerevisiae* is able to produce sulfites from sulfate reduction (Donalies and Stahl, 2002; Heinzel and Trüper, 1978, Wells and Osborne, 2012, Wells and Osborne, 2016), but generally not much more than a dozen milligrams per litre. Therefore, sulfur dioxide levels in wines are mostly of exogenous origin.

SO_2 levels are regulated according to toxicity, with the acceptable daily intake (ADI) of sulfite for humans being 0.7 mg/kg of body weight according to the World Health Organization (WHO) (FAO, 2009). Moreover, this additive can entail health risks for particularly sensitive consumers (Vally and Thompson, 2001). The first study on such SO_2 health risks dates back to the 1970s with the observation of the irritant capacities of SO_2, as well as anaphylaxis and skin problems with ingestion (Kochen, 1973; Lester, 1995; Prenner and Stevens, 1976).

Professionals are clearly striving to reduce inputs during the winemaking process and a recent study showed that the average concentration of total SO_2 in red wines was close to 75 mg/L (Peterson *et al.*, 2000), far below the permissible level. Some winemakers are even producing wines without, or with very low, added sulfites, which are becoming increasingly popular among consumers. Many studies on consumer willingness to pay and on the perception of "non-added sulfites" wines show that consumers prefer wine if it bears a "non-added sulfites" label (Amato *et al.*, 2017; Costanigro *et al.*, 2014; D'Amico *et al.*, 2016). Recently it was shown that consumers had a higher tolerance to off-flavors in wines presented as being closer to natural concepts (Romano *et al.*, 2020). This clearly underlines why an objective characterisation of these trendy "new" wines is essential.

The aim of this study was to evaluate whether wines made without SO_2 addition are linked to each other by similar organoleptic descriptors, forming what is known as typicality. Our approach focused on quality wines, with the first definition of quality being purity (i.e., the absence of defects), which is used for foodstuffs in general (ISO 9000, 1994). For this purpose, a two-step study was performed. First, from a large set of "without sulfites" commercial wines, some wines were selected according to their effective SO_2 level and the absence of defects. Next, a sensory characterisation of selected wines without added sulfites was carried out.

MATERIAL AND METHODS

1. Wines

The following wines were bought on the market: i) fifty-two red wines described by their producers or retailers as containing less than 30 mg/L of SO_2 (hereafter referred to as "without sulfites" or "without SO_2"), which were produced in the Bordeaux area or in south-west France from Bordeaux varietals (mainly Merlot and Cabernet-Sauvignon, monovarietals or blends, aged in oak barrels or not), and ii) twenty wines of the same type (same varieties, geographic origins, prices and woody characters), but produced with added SO_2, from the 2015 and 2016 vintages. The 52 wines without added SO_2" represented the exhaustive

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TABLE 1. Wines studied - with and without added sulfites.

Sample origin	Wines without added SO_2		Wines with added SO_2	
	2015	2016	2015	2016
Bordeaux	3	4	1	3
Bordeaux supérieur	3	3	1	2
Bourg-Côtes-de-Bordeaux	0	2	1	0
Castillon-Côtes-de-Bordeaux	3	6	4	1
Côtes de Bergerac	2	3	0	1
Côtes de Duras	1	2	0	0
Franc-Côtes-de-Bordeaux	1	0	0	0
Haut-Médoc	0	0	0	1
Languedoc-Roussillon	1	0	0	0
Moulis-en-Médoc	0	1	0	0
Périgord (IGP)	1	1	0	0
Pessac-Léognan	1	0	0	0
Saint-Emilion	5	1	4	0
Vin de France (Wines without regional GI)	5	3	1	0
Total	26	26	12	8

consumer offer for such wines available in the Bordeaux region in early 2018. The origins of the wines are shown in Table 1.

2. SO_2 measurement

Free and total SO_2 were quantified using the OIV-recommended Franz-Paul method (Organisation Internationale de la Vigne et du Vin, 1990; Paul, 1958). For free SO_2, 50 mL of wine was poured into a 250 mL round-bottom flask together with 15 mL of orthophosphoric acid. In a bubble trap, 2 mL of hydrogen peroxide was added, as well as a few drops of Tashiro colorant. This solution was neutralised with sodium hydroxide at 0.01 M. The sample was subjected to a nitrogen flow for 15 minutes. The content of the bubble trap was assayed with 0.01 M sodium hydroxide. For total SO_2, the same protocol was followed, except that the wine was heated with a flame directly on the bottom of the flask.

3. Sensory analysis

3.1. General conditions

The sensory tests were conducted in a dedicated tasting room (ISO 8589: 2010). Samples were evaluated at controlled room temperature (20 °C), in individual booths, using covered, standard black ISO glasses containing about 50 mL of liquid, coded with random three-digit numbers as described by Martin and de Revel (1999).

3.2. Panels

All panelists were volunteers selected for their availability, level of training and interest. They were all research laboratory staff from the Oenology research laboratory of the Institute of vine and wine sciences, Bordeaux University (Unité de recherche Œnologie, Institut des sciences de la vigne et du vin, Université de Bordeaux) with homogeneous high sensory expertise.

Panel 1 comprised 8 experts on defect research in wine (4 men, 4 women, 31.2 ± 8.5 years old). Panel 2 was composed of 10 expert panelists (3 men, 7 women, 30.7 ± 5.3 years old). Panel 3 was a set of 23 panelists (7 men, 16 women, 33.5 ± 11.7 years old).

3.3. Sensory tests

In order to select wines without defects, Panel 1 evaluated all 72 wines selected for the study. Six to 10 wines were presented per session in standard black ISO glasses coded with random three-digit numbers, each panelist being given a different randomised tasting order with a Latin square arrangement. Each session included wines of the same type (i.e., with or without SO_2) and the panelists were not informed of what they were evaluating. First, the panelists

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had to answer the closed question, "Does this wine have a defect?". They were told to reply with a "yes" if they perceived a sensory character associated with a defect concept. If they identified one or more defects in this way, they had to describe it/them.

A free sorting task (Parr *et al.*, 2010) was assigned to Panel 2. Simultaneously and per vintage, they tasted wines with and without SO_2 that had been significantly considered as free of defects according to the X^2 test applied to Panel 1 results. This was carried out in one session with eleven 2015 wines and another with thirteen 2016 wines. In each session, the wines were simultaneously submitted to the panelists, each in a different randomised tasting order with a Latin square arrangement. In the first part of the session, the panelists had to group wines into clusters according to their similarity as perceived by the taster, with a minimum of two clusters and at least two wines per cluster. In the second part, they had to describe the clusters by freely giving a few descriptors to explain the differences between the groups.

Panel 3 was asked to conduct a napping test (Pagès, 2003) on all the wines (with and without added sulfites) for which a consensus had been reached in Panel 1 regarding the absence of defects, as well as on 5 wines with and without added sulfites, selected like the others. Thus, 13 wines from the 2015 vintage and 17 from the 2016 vintage were studied. For each vintage two sessions were conducted: one for orthonasal perception, and the other for overall mouth perception (including retronasal, gustative and trigeminal perceptions). In each session, the wines were simultaneously submitted to the panelists, each of them in a different randomised tasting order with a Latin square arrangement. All the panelists tasted all the wines and placed their wineglasses on an A1 paper tablecloth (59.4 cm × 84.1 cm) according to their own criteria. The instructions given to them were to evaluate the similarities (or dissimilarities) between wines. They had to position all wines on the paper tablecloth, whereby two wines being positioned close to each other meant they were similar, while two wines positioned far from each other indicated their differences according to perception. Data were digitalised, measuring, for each product and each panelist, X-co-ordinates and Y-co-ordinates from the point of origin (bottom left corner). At the end of the test, the panelists had to freely generate three descriptors for each wine or group of wines.

3.4. Data analysis

All data were analysed using RStudio (Boston, 2015). The results of the selection tasting to assess the defects were analysed via the X^2 test, which was applied to the panelists who perceived at least one defect in the wines. Defect descriptions were analysed through citation and sharing frequencies. For the range task test, the results were analysed by multidimensional scaling (MDS) from a contingency table that showed how often two wines were associated within the same cluster. Napping results were analysed by Multiple Factor Analysis (MFA) in line with Pagès (2003), as well as by hierarchical clustering with K-means methods. For MFA, each panelist represented an independent variable with the X-co-ordinates and Y-co-ordinates for all wines. Concerning the description of groups for the sorting task and description of wines for the napping test, the results were analysed by correspondence factor analysis (CFA). Word clouds were also generated using RStudio (Boston, 2015), with font size representing citation frequency.

RESULTS AND DISCUSSION

1. Wine selection

With a focus on evaluating the typicality of quality wines produced without added sulfites, this study started by selecting the wines with which it was possible to continue.

Free and total SO_2 were quantified for all wines, with and without added sulfites. Among the 52 wines indicated as being without sulfites, 43 had a total SO_2 concentration below 10 mg/L, 5 between 10 and 30 mg/L and 4 with a higher total SO_2 level. The current regulations allow bottles to be labelled "without added sulfites" when wines have a maximum SO_2 level of 10 mg/L, with the obligation to specify "contains sulfites" on wines containing more than 10 mg/L (R. EU 2019/33). However, 20 mg/L is considered by some winemakers to be a low value for total SO_2 produced during alcoholic fermentation performed with indigenous *Saccharomyces cerevisiae.*. Indeed, in some cases yeasts can produce up to 30 mg/L SO_2 during alcoholic fermentation (Donalies and Stahl, 2002), which is why 48 wines with higher total SO_2 levels were kept as candidates for

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TABLE 2. Frequency of wines with at least one defect according to use of sulfites and vintage.

	2015		2016	
	Wine with SO_2	Wine without SO_2	Wine with SO_2	Wine without SO_2
Number of wines with defect	03-déc	20/26	0/8	18/26
Percentage of wines with defect	25%	77%	0%	69%

	2015	2016	Total
Oxidation	37.5 %	33.3 %	35.4 %
Volatile phenols	20.8 %	16.6 %	18.7 %
Mousy off-flavor	12.5 %	0%	6.2 %
Reduction	4.1 %	8.3 %	6.2 %
Vegetable/Herbaceous	0%	8.3 %	4.1 %
Total	74.9 %	66.5 %	70.6 %



Figure 1. Citation frequencies and word cloud of descriptors of defects in wines without added sulfites, with agreement above 60 %.

research into a specific sensory space. Therefore, the four wines with more than 30 mg/L were not considered for tasting in the range task and napping test, but were included in the selection tasting. Total SO_2 average concentrations were 4.6 mg/L ± 4.7 mg/L (mean ± SD) for the 48 wines without added sulfites and 67.7 mg/L ± 21.8 mg/L (mean ± SD) for the 20 wines classically produced with sulfites. The maximal value of total SO_2 observed for a "without added sulfites" wine was 51.8 mg/L of total SO_2, and this level was present in more than 8 wines produced with sulfites.

All 72 wines (with and without added SO_2) - were tasted by Panel 1 to evaluate the occurrence of defects, with a wine being considered to have a defect when the frequency of defect detection by panelists was significant according to the X^2 test. The results are shown in Table 2.

Overall, the defect frequency was 15 % for wines produced using SO_2 and 73 % in wines without added SO_2. The defect frequencies for wines without added sulfites were very similar between the 2015 and 2016 vintages (77 % and 69 % respectively), suggesting that aging wine for an additional year in bottles without SO_2 does not affect the development of defects, which were, in any case, very often already present.

The four wines without added SO_2, but with more than 30 mg/L total SO_2, were all described by the panelists as having defects.

The panelists also described the defects they perceived. Among the three wines produced using SO_2, two were described as having "volatile phenols" and the other by the term "reduction". Figure 1 shows a word cloud of the defect descriptors for wines without added sulfites, which were counted when used for one wine by more than 60 % tasters (arbitrarily considering defects with the same description for five out of eight tasters). These results show that defects in "wines without added SO_2" were mainly described as oxidation; for the two vintages combined, half the wines (47 %) were described as oxidized. The other half of the defects largely comprised microorganism defects, specifically volatile phenols (31 %) and mousy off-flavor (10 %). This demonstrates that the principal defect in wines "without added SO_2" was associated with oxidation events responsible for the rapid evolution of red wines (Bueno *et al.*, 2010). These results correspond to the two main activities of SO_2 in wine (antioxidant and antimicrobial) and to the two

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key elements to be monitored in winemaking without added sulfites.

As previously mentioned, according to ISO standards, the quality of a product depends on its ability to satisfy consumer demands (ISO 9000, 1994). This implies that quality increases with price. For wines without added SO_2, and in the wine industry in general, consumers expect there to be a correlation between quality and price (Nerlove, 1995). Therefore, in this study, correlations between the retail price and the occurrence of defects in the "non-added SO_2" wines were sought. When comparing the prices of such wines with or without defects, Figure 2 reveals no link between these parameters. Moreover, in this large selection of wines, the most expensive were produced without the addition of SO_2, and all of them showed defects. Factually, for wines without added SO_2, a higher price does not mean a higher quality.

2. Sorting task method

Using the previous approach, cross-referencing the absence of defects with the target total SO_2 level, we were able to select 15 wines from the 2015 vintage and 16 from 2016. Among these wines, all those produced without added SO_2 were considered for this evaluation and, in order to only focus on their real counterparts produced using SO_2, some wines with SO_2 were not taken into account. Thus, range tasks were performed on two sets of wines: 11 wines from 2015 (5with sulfites and 6 without) and 13 from 2016 (5 with sulfites and 8 without).

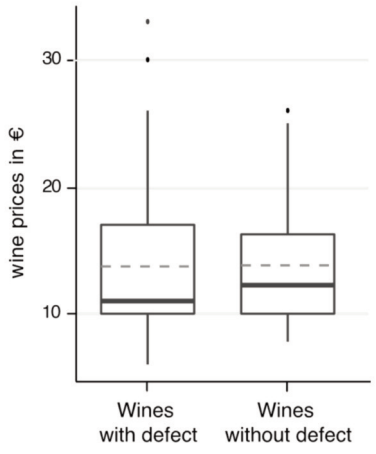


FIGURE 2. Boxplot illustrating price distribution of wines without added sulfites with and without defects
Mean represented by a dotted line.

A sorting task method, consisting in looking for similarities between products in order to highlight the existence of a specific sensory space, was applied to each of the 2015 and 2016 set of wines.

Figure 3 shows the results for the 2015 vintage, with range results and description results given separately. As shown in Figure 3A, such an approach does not differentiate between wines with and without SO_2; with this set of wines, the tasters did not discriminate between wines according to the presence or absence of added sulfites. Despite this, two groups seem to be represented by the MDS test on the second axis of the representation. Additionally, the descriptions of clusters were analysed to understand the absence of discrimination, depending on whether SO_2 was used during the whole winemaking process. Figure 3B reveals that the most-cited descriptors were associated with defects like volatile phenols and oxidation. Indeed, the two groups observed in the MDS results were found on the CFA repartition map: the first group was represented by the defect descriptors, "Mousy off-flavor", "Volatile phenols" and "Oxidation", and the second group comprising wines without added SO_2 (WS-6 and WS-5) and wines with added SO_2 (S-3, S-4 and S-5) was linked to the descriptors, "Woody", "Spicy" and "Floral". Similar to the wine selection stage, "Oxidation" was the dominant defect to be described, with a twenty percent citation frequency, and was the most commonly generated descriptor after "Fruity". "Volatile phenols" was the second most cited defect described. The CFA also revealed that six out of fourteen descriptors were associated with defects such as fungus odour, mousy off-flavor, oxidation, reduction, volatile phenols and acescence. The citation frequency of these defect descriptors accounts for 42 % of all panel answers. For the 2016 vintage, a range task was performed by the same panel and the results showed the same behavior as for 2015, with wines selected statistically as being free of defect, but whose clustering was influenced by defect perception ("Oxidation", "Vegetable" and "Volatile phenols"). These results highlight the limits of sensorial selection associated with the statistical test we used in the first step of this study. Indeed, some tasters in Panel 1 were also members of Panel 2; therefore, a defect perceived in one wine by a panelist during the selection tasting, which would not have been statistically rejected, could logically also be

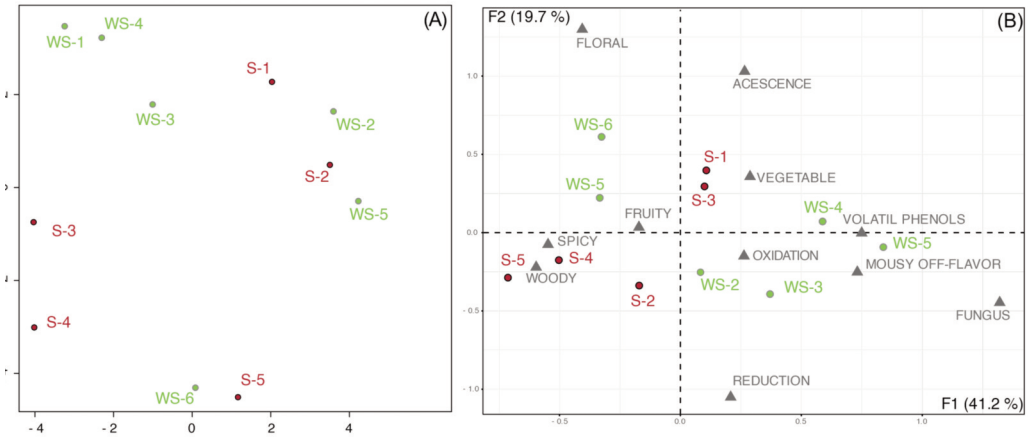


FIGURE 3. Representation of range task results (A) corresponding to MDS of grouping wines and (B) corresponding to CFA of descriptors associated with wines from the 2015 vintage. (n = 11). WS corresponds to "non-added SO_2" wines and S corresponds to wines with SO_2.

perceived by the same panelist in this sorting test. Moreover, Panel 2, with only 8 tasters, was too small to be representative of the overall sensibility of a population. This first approach was elaborated to evaluate the existence of a sensory space by panelists with similar backgrounds, which could, as observed by Picard *et al.* (2015), elicit more accurate discriminations than a less specific panel. For instance, wines which were described as containing defects by only one or two tasters in Panel 1 were statistically considered as free of defects. The results of the range task tasting highlight that this "statistical" wine selection was not restrictive enough, because it was possible for the wines statistically considered as being free of defects during the selection tasting to be described as having defects in the range task tasting. Furthermore, the presence of wines with defects clearly impacted the range task method, as the tasters had made defect clusters. Indeed, despite the potential hypersensibility of the panelists involved in the first step of the selection, and despite a high elimination of wines, some wines were described here as having defects; for most of these defects ("Oxidation", "Volatile phenols" and "Mousy off-flavor") a consensual description was given. These results highlight that the presence of defects is a limitation of a study dedicated to the sensory space of wines "without added SO_2".

3. Approaches to research the sensory space of "non-added SO_2" wines: napping test

A second approach to research the sensory space of "wines "without added SO_2" was tested via the napping sensory test.

The problems previously encountered linked to defect perception were taken into account and another wine selection methodology was used: a wine considered to have any defect by at least one taster in Panel 1was eliminated. This approach drastically reduced the number of selected samples, and additional wines from the same vintages were selected using the same process. Thus, two wines from the 2015 vintage were eliminated and replaced by two others, whereas three wines from the the 2016 vintage were rejected and replaced by four others.

The napping test was carried out by a bigger panel than for the range task, because the effect of the tasters' expertise could be modulated by the larger number of tasters (Pagès, 2003). This choice aimed to reduce the impact of individual tasters and to accentuate group phenomena. Four napping tests were performed on each of the two vintages: olfactory tests on one hand, and global mouth perceptions (including retronasal, gustative and trigeminal perceptions) on the other.

First of all, as intended, this global napping approach was not affected by defect perception: once the wines had been positioned on each sheet, any descriptor associated with the slightest defect was given by any panelist to describe them. Figure 4 shows the wine distribution maps by MFA. From this analysis we were able to produce four illustrations which represent between 30 and 35 % of total variability. Thus, the majority (around 70 %) of variabilities was not represented by this approach. However, Figures 4A and 4B, which show the results for the 2015 vintage, highlight

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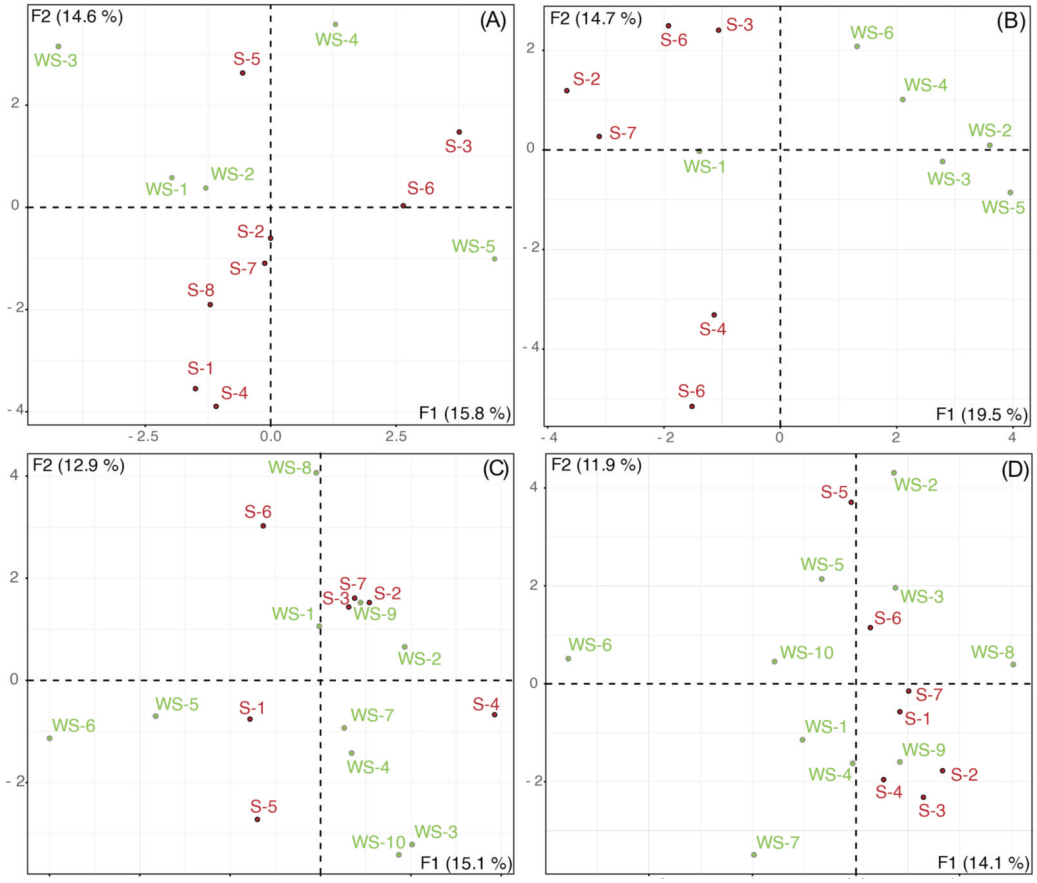


FIGURE 4. Representation of distribution map of wines with MFA treatment with napping results: (A) 2015 wines evaluated by direct olfaction, (B) 2015 wines evaluated by mouth evaluation, (C) 2016 wines evaluated by direct olfaction, and (D) 2016 wines evaluated by mouth evaluation.

that "non-added SO_2" wines were differentiated from wines with SO_2 when carrying out a mouth evaluation. More precisely, regarding this mouth evaluation result (Figure 4B), wines with and without added sulfites were differentiated on the first axis, because all the wines "without added SO_2" (except WS-1) were on the same side of Axis 1. This means that tasters could distinguish wines "without added SO_2" in a mouth evaluation more readily than via olfactory tasting. With regards the 2016 vintage (Figures 4C and 4D), the results are not so clear, and the panelists were unable to differentiate between wines according to SO_2 use.

Clustering the napping results with 50 % variability represented was also explored (Figure 5). For the 2015 vintage, Figures 5A and 5B highlight that tasters differentiated between wines with and without sulfites. In this illustration, the dotted lines represent the significance of the representation. For the 2016 vintage (Figures 5C and 5D), the judges could not differentiate between wines with and without sulfites via direct olfaction; however, they were able to highlight two clusters of wines "without added SO_2" and one cluster of wines with sulfites via mouth evaluation. This approach shows that it is possible to differentiate wines with and without added sulfites by tasting, specifically via a mouth evaluation. However, other parameters would seem to limit these results, as revealed by the 2016 vintage. Figure D strongly suggests that geographical origin within the Bordeaux wine area impacts differentiation. Indeed, wines "without added SO_2", WS-6, WS-7, WS-1, WS-4 and WS-10 are produced on the right bank of the Garonne river, and WS-5, WS-3, WS-2 and WS-8 on the left bank; it would therefore seem that, in this case, geographic typicality has more impact than the use of SO_2. For the 2015 vintage, all the wines

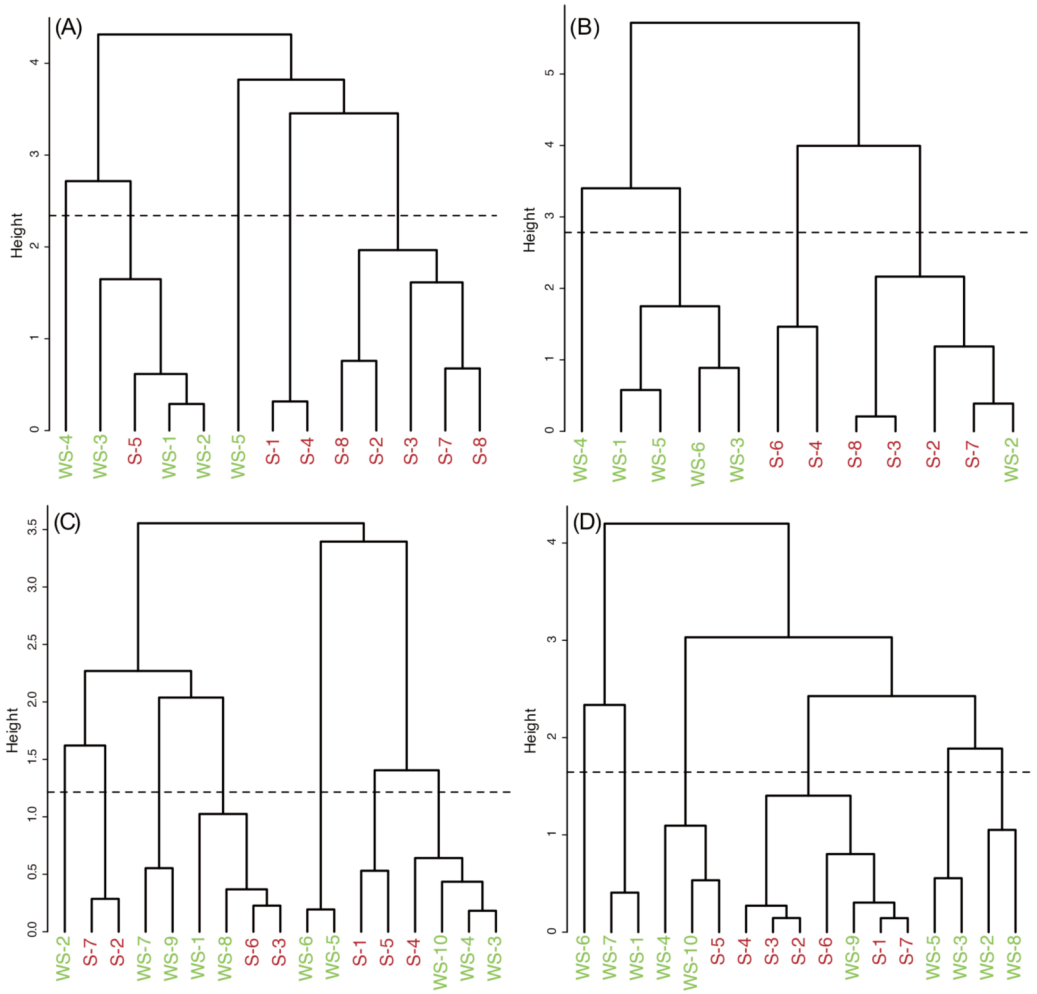


FIGURE 5. Representation of clustering of wines with MFA treatment with napping results (A) 2015 wines evaluated by direct olfaction, (B) 2015 wines evaluated by mouth evaluation, (C) 2016 wines evaluated by direct olfaction, (D) 2016 wines evaluated by mouth evaluation.
WS corresponds to "non-added SO_2" wines and S corresponds to wines with SO_2.

used came from the right bank, so without this additional source of variation the panel was more efficient in differentiating between wines with and without sulfites.

CONCLUSION

Comparing similar Bordeaux red wines produced with or without SO_2 in order to evaluate whether wines "without added SO_2" have their own typicality, this work was a first approach toward their sensory characterisation. Covering all wines without added SO_2 from the 2015 and 2016 vintages available to consumers on the Bordeaux market in mid-2018, it showed that defect frequencies for such wines were much higher than for wines produced using SO_2, and that most of them contained at least one defect. This finding raises questions about the concept of typicality among these wines, which represent an overall commercial offering. Despite this, a restrictive selection blind tasting method with expert judges evidenced some "non-added SO_2" wines without defects. Focusing on the wines without defects, tasters had difficulty in differentiating wines "without added SO_2" from those produced with. Nevertheless, certain tests performed via an overall mouth evaluation sometimes led to good discrimination, even though the panelists were unable to agree about why this was. In general, this initial study highlights the difficulties related to the production of quality wines without adding SO_2; however, it nonetheless shows that such production is possible, and it provides some initial answers about the existence of typicality in wines without added SO_2 when the wines with

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defects are discarded. Finally, this study could be repeated with producers of wines made without any added sulfites. Indeed, Gómez-Corona *et al.* (2017) observed differences in the categorisation and discrimination of craft versus industrial beers depending on the consumption habits of the taster. The repeated tasting of a type of wine may perhaps influence the ability of tasters to evaluate these wines.

REFERENCES

FAO (2009). Assessing chemical risks in food (JECFA). https://www.who.int/news-room/fact-sheets/detail/food-additives (2020)

Amato, M., Ballco, P., López-Galán, B., De Magistris, T., & Verneau, F. (2017). Exploring consumers' perception and willingness to pay for "non-added sulphite" wines through experimental auctions: A case study in Italy and Spain. *Wine Economics and Policy*, *6*(2), 146-154. doi: 10.1016/j.wep.2017.10.002

Bueno, M., Culleré, L., Cacho, J., & Ferreira, V. (2010). Chemical and sensory characterization of oxidative behavior in different wines. *Food Research International*, *43*(5), 1423-1428. doi: 10.1016/j.foodres.2010.04.003

Carr, J., Davies, P., & Sparks, A. (1976). The toxicity of sulphur dioxide towards certain lactic acid bacteria from fermented apple juice. *Journal of Applied Bacteriology*, *40*(2), 201-212. doi: 10.1111/j.1365-2672.1976.tb04166.x

Costanigro, M., Appleby, C., & Menke, S. (2014). The wine headache: Consumer perceptions of sulfites and willingness to pay for non-sulfited wines. *Food Quality and Preference*, *31*, 81-89. doi: 10.1016/j.foodqual.2013.08.002

D'Amico, M., Di Vita, G., & Monaco, L. (2016). Exploring environmental consciousness and consumer preferences for organic wines without sulfites. *Journal of Cleaner Production*, *120*, 64-71. doi: 10.1016/j.jclepro.2016.02.014

Danilewicz, J. (2011). Mechanism of autoxidation of polyphenols and participation of sulfite in wine: key role of iron. *American Journal of Enology and Viticulture*, *62*(3), 319-328. doi: 10.5344/ajev.2011.10105

Donalies, U., & Stahl, U. (2002). Increasing sulphite formation in *Saccharomyces cerevisiae* by overexpression of MET14 and SSU1. *Yeast*, *19*(6), 475-484. doi: 10.1002/yea.849

Dubernet, M., & Ribéreau-Gayon, P. (1973). Présence et signification dans les moûts et les vins de la tyrosinase du raisin. *OENO One*, *7*(4), 283-302. doi: 10.20870/oeno-one.1973.7.4.2089

Gómez-Corona, C., Valentin, D., Escalona-Buendía, H.B., & Chollet, S. (2017). The role of gender and product consumption in the mental representation of industrial and craft beers: An exploratory study with Mexican consumers. *Food Quality and Preference, 60*, 31–39. https://doi.org/10.1016/j.foodqual.2017.03.008

Heinzel, M., & Trüper, H. (1978). Sulfite formation by wine yeasts. *Archives of Microbiology, 118*(3), 243-247. doi: 10.1007/bf00429112

Kochen, J. (1973). Sulfur dioxide, a respiratory tract irritant, even if ingested. *Pediatrics,* 52:145–6.

Lester, M. (1995). Sulfite sensitivity: significance in human health. *Journal of The American College of Nutrition*, *14*(3), 229-232. doi: 10.1080/07315724.1995.10718500

Mareschi, J., François-Collange, M., & Suschetet, M. (1992). Estimation of sulphite in food in France. *Food Additives and Contaminants*, 9(5), 541-549. doi: 10.1080/02652039209374108

Martin, N., & de Revel, G. (1999). Sensory evaluation: scientific bases and oenological application. *Journal International des Sciences de la vigne et du vin, special issue 33*, 81–94.

Nerlove, M. (1995). Hedonic price functions and the measurement of preferences: The case of Swedish wine consumers. *European Economic Review*, 39(9), 1697–1716. https://doi.org/10.1016/0014-2921(95)00013-5

Organisation Internationale de la Vigne et du Vin (1990). *Compendium of International Methodes of Analysis of Wines and Musts.*

Pagès, J. (2003). Recueil direct de distances sensorielles : application à l'évaluation de dix vins blancs du Val-de-Loire. *Sciences des Aliments*, *23*(5-6), 679-688. doi: 10.3166/sda.23.679-688

Parr, W., Valentin, D., Green, J., & Dacremont, C. (2010). Evaluation of French and New Zealand Sauvignon wines by experienced French wine assessors. *Food Quality and Preference*, *21*(1), 56-64. doi: 10.1016/j.foodqual.2009.08.002

Paul, F. (1958). *Klosterneuburg*, *Rebe u. Wein, ser. A*, *821*.

Peterson, G.F., Kirrane, M., Hill, N., and Agapito, A. (2000). A comprehensive survey of the technical brief total sulfur dioxide concentrations of American wines. *Am J Enol Vitic*. 51, 189–191.

Prenner, B.M., & Stevens J.J. (1976). Anaphylaxis after ingestion of sodium bisulfite. *Ann Allergy*, 37:180–2.

Picard, M., Tempère, S., de Revel, G., & Marchand, S. (2015). A sensory study of the ageing bouquet of red Bordeaux wines: A three-step approach for exploring a complex olfactory

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concept. *Food Quality and Preference,* 42, 110–122. https://doi.org/10.1016/ j.foodqual.2015.01.014

Ribéreau-Gayon, P., Dubourdieu, D., Donèche, B., & Lonvaud, A. (2017). Traité d'œnologie - Tome 1 - *7e éd. - Microbiologie du vin. Vinifications: Microbiologie du vin. Vinifications (Traité d'œnologie (1))* (French Edition). Paris, France : DUNOD.

Roberts, A., & McWeeny, D. (1972). The uses of sulphur dioxide in the food industry: a review. *International Journal of Food Science & Technology*, 7(3), 221-238. doi: 10.1111/j.1365-2621.1972.tb01658.x

Romano, M., Chandra, M., Harutunyan, M., Savian, T., Villegas, C., Minim, V., & Malfeito-Ferreira, M. (2020). Off-flavours and unpleasantness are cues for the recognition and valorization of organic wines by experienced tasters. *Foods*, *9*(1), 105. doi: 10.3390/foods9010105

Solberg, M. (1991). Mechanisms of action of food preservation procedures. *Trends In Food Science & Technology*, *2*, 155. doi: 10.1016/0924-2244(91) 90663-4

Usseglio-Tomasset, L. (1992). Properties and use of sulphur dioxide. *Food Additives and Contaminants*, 9(5), 399-404. doi: 10.1080/026520392093 74090

Vally, H., & Thompson, P., (2001). Role of sulfite additives in wine induced asthma: single dose and cumulative dose studies. *Thorax*, *56*(10), 763-769. doi: 10.1136/thorax.56.10.763

Wells, A., & Osborne, J. (2016). Production of SO_2 Binding compounds and SO_2 by *Saccharomyces* during alcoholic fermentation and the ompact on malolactic Fermentation. *South African Journal of Enology and Viticulture*, *32*(2). doi: 10.21548/32-2-1387

Wells, A., & Osborne, J. (2012). Impact of acetaldehyde- and pyruvic acid-bound sulphur dioxide on wine lactic acid bacteria. *Letters In Applied Microbiology*, *54*(3), 187-194. doi: 10.1111/j.1472-765x.2011.03193.x

Zuehlke, J.M., & Edwards, C.G. (2013). Impact of sulfur dioxide and temperature on culturability and viability of *Brettanomyces bruxellensis* in wine. *Journal of Food Protection*, *76*(12), 2024-2030. doi: 10.4315/0362-028x.jfp-13-243r

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