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OXIDATION IN WINE: DOES EXPERTISE INFLUENCE THE PERCEPTION?

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ABSTRACT

Wines can develop off-odours that depreciate their quality. Among them, oxidation is one of the most prevalent. The main objective of this work was to study the perception of wine oxidation through the categorization of oxidized wines perceived as not-faulty/faulty depending on the expertise of participants. For this purpose, one white wine and one red wine were spiked with three volatile oxidation compounds (acetaldehyde, phenylacetaldehyde and methional) in order to recreate twelve levels of oxidation in a controlled way. Samples were submitted to orthonasal tasting for being categorized by wine experts and novices and coupled to a free description task. Results demonstrated that experts were significantly more consensual to categorize oxidized wines than novices. However, the difference between the two groups was not of great magnitude. To find an explanation, *a posteriori* individual data treatment was carried out. This analysis highlighted five particular behaviours as a function of the samples' oxidation level, irrespective of the level of expertise. Results also highlighted that for the experts, the frontier between the two categories (not-faulty/faulty) was significantly clearer for the white wine than for the red wine. This same tendency was also observed for the novices.

Keywords: wine oxidation; wine expertise; perception

1. INTRODUCTION

Wine quality is a complex and multidimensional concept (Jover, Montes, & Fuentes, 2004). Previous research has shown that perceived quality of wine is based on both extrinsic (brand, price, labelling, wine origin, variety, awards...) and intrinsic (organoleptic properties such as flavour, colour or mouthfeel) cues (Charters & Pettigrew, 2007; Jover et al., 2004; Veale & Quester, 2009). Among the intrinsic quality cues, the absence of negative odorants is of utmost importance.

Many wines identified as faulty in oenological contests have off-odours associated to deficient aging, in particular with oxidation (Ugliano et al., 2009). Oxidation is one of the most widespread wine faults found in nearly all the winegrowing regions in the world. Wine is in contact with atmospheric oxygen to a greater or lesser extent during operations occurring before, during, and after the fermentation process. This contact extends to bottle ageing as a result of the oxygen passing through the cork until its consumption (Karbowski et al., 2009). Then, if the management of the oxygen from the must to the glass is not well controlled, oxidation off-odours could appear. Many of the oxidation compounds with relevant aroma impact in wines are aldehydes. Different types of aldehydes can play an important role in wine. However, acetaldehyde (Wildenradt & Singleton, 1974), phenylacetaldehyde (Silva Ferreira, Hogg, & Guedes de Pinho, 2003) and methional (Escudero, Hernández-Orte, Cacho, & Ferreira, 2000) have a significant and negative sensory impact. Acetaldehyde is a major wine compound at levels of mg/L in oxidized wines and characterized by aromas of green apple and nuts. With respect to phenylacetaldehyde and methional, both compounds contribute with honey-like and boiled potato nuances respectively. Although these three compounds are always present in aged wines and can contribute to the expected wine tertiary aromas, at high concentrations, they may affect negatively the perception of wine quality. However, on the other hand, for some wines, high concentrations of oxidation compounds are

expected and positively evaluated (e.g. Xerez wines, “*vin jaune*”). Therefore, the evaluation of oxidation in wine is not straightforward, and can oscillate from positive to negative depending on the concentration in oxidation compounds, the context, and the expertise level of the participants.

On the other hand, identifying wine faults is an important activity for which wine experts are often trained for. Although wine experts and novices seem to be equal in terms of olfactory sensitivity (Bende & Nordin, 1997; Parr, White, & Heatherbell, 2004), they do not describe their perceptions of wines in the same way. Indeed, experts use more technical and precise terms than novices (Croijmans & Majid, 2016; Chollet & Valentin, 2000). Wine experts seem to have also better odour recognition and memorization abilities than novices (Hughson & Boakes, 2002). This superiority could be due to the level of wine knowledge and the way this knowledge is organized and activated in memory (Ballester, Patris, Symoneaux, & Valentin, 2008; Hughson & Boakes, 2002). Repeated exposure to wines seems to have also an effect on wine knowledge and mental representations (Honoré-Chedozeau, Lelièvre-Desmas, Ballester, Chollet, & Valentin, 2017)

Taken together, the previous studies suggest that experts, through repeated exposure, formal training and professional experience may have developed a common mental representation of wine faults, allowing them to recognize and describe these off-odours in a more consensual way. In agreement with this hypothesis, Tempère et al. (2016) reported that wine faults are often better discriminated by wine experts in comparison with novices. However, another study conducted by Tempère et al. (2014) showed a lack of consensus among wine experts about red wines spiked with ethyl phenols. On the novice side, Schumaker et al. (2017) showed that perception of *Brettanomyces* character in wine was influenced by the level of wine knowledge of novices. Those studies suggest that the difference between wine experts’ and novices’ ability to detect and identify wine faults is far from being clear cut.

To our knowledge, there is so far no research that had explored the perception of wine oxidation regarding to the expertise level. Then, the specific goal of this work was to explore the perception of oxidation off-odours in red and white wines as a function of the level of expertise of the participants. Based on the literature, we expected that experts would have a clearer mental representation of wine oxidation than novices and so to identify oxidation odours as a wine fault at lower concentrations than novices and in a more consensual way.

2. MATERIAL AND METHODS

2.1. Reactives

Ethanol used as solvent for preparing solutions of aldehydes was from Panreac (Barcelona, Spain). Acetaldehyde, phenylacetaldehyde and methional (Food grade $\geq 99\%$) were purchased from Sigma-Adrich (Gillingham, England).

2.2. Wines

One red and one white wine were used as base wines. These two wines were selected among four commercial red wines made from Grenache/Syrah and four commercial white wines made from Chardonnay for their absence of oxidative notes. The selection was made based on a pre-test during which 16 participants (second year students of Viticulture and Oenology from the University of Burgundy) described orthonasally the main aromas of the wines. The chemical characterization of the two base wines was made by means of OenoFossTM wine analyser (Foss Iberia, S.A. Barcelona, Spain). Alcoholic degree, volatile acidity, malic acid, reducing sugars, free and total SO₂ and pH were in the common range for reds and white wines. Information and basic compositional oenological parameters of the selected wines are shown in **Table 1**.

The two base wines were spiked with increasing concentrations of a mixture of acetaldehyde, phenylacetaldehyde and methional in order to create a twelve-samples oxidation gradient (**Table 2**). These three aldehydes are very labile compounds, which can interact mainly with

SO₂ but also with other wine compounds. For this reason, wines were spiked 30 minutes before the sensory sessions. The ratio chosen for these three compounds was within the natural proportions of occurrence in commercial wines (Bueno, Carrascón, & Ferreira, 2016). Detailed compositional data of samples are provided in **Table 2**.

2.3. Participants

Twenty nine (13 men and 16 women) experts were recruited according to the criteria proposed in previous works (Bende & Nordin, 1997; Parr et al., 2004). All experts were from the Beaujolais region. Their age ranged from 26 to 75 years old (average=48.7).

Thirty-two novices (10 women and 22 men) were recruited by means of a questionnaire including questions about wine-tasting experience and drinking habits. The criteria used to select wine novices were: not being under the legal drinking age of 18, drinking wine at least once per month, not having professional wine experience and not having followed formal training in wine-tasting or wine production. Novices age ranged from 32 to 77 years old (average=49.6). The number of novices and experts selected in this study is in line with the number of participants in most study investigating expertise effects (Ballester et al., 2008; Giboreau, Navarro, Faye, & Dumortier, 2001; Hoek, van Boekel, Voordouw, & Luning, 2011; Honoré-Chedozeau et al., 2017; Lelièvre, Chollet, Abdi, & Valentin, 2009; Parr, Valentin, Green, & Dacremont, 2010).

No information about the specific aim of the study was provided to the participants. They were only informed about the fact that they would be participating in a “wine study”. They were not paid for their participation in the study.

2.4. Procedure

Participants were served the twelve samples. They were asked to smell the samples and to categorize them as faulty or not faulty. To clarify what we meant by faulty we asked them to imagine a scenario in which they had to decide whether they would serve a wine to their

friends (i.e. a wine that has no fault) or not (i.e. a faulty wine). They received the following instructions:

“Imagine you have a dinner with friends. You want to serve them a glass of wine, you open the bottle and you smell the wine. Then you have to decide if you can serve it to your friends. You have to smell the following wines (without tasting them) and answer the next question: If you were in the previous situation, would you serve the wine to your friends?”

You have to take into consideration that the twelve wines are Chardonnays from vintage 2015/ Côtes-du-Rhône from vintage 2016 (Grenache/Syrah) with a price under 7 euros.”

They indicated their response choosing one of the two categories proposed by ticking “yes, I would serve” or “no, I would not serve” in the answering sheet. They could also add free comments to describe the samples if they wished.

2.5. Experimental conditions

Each participant participated in two sessions the same day, one session for the white wines and the other for the red wines. Each session lasted about 20 min. Half of the participants smelled the set of red wines first and the other half assessed the set of white wines first. Twenty-millilitre wine samples were presented in trays of twelve samples according to a predefined order from minor to major concentration of oxidation compounds. This order of presentation of samples was chosen to avoid priming effect that could occur with a balanced design.

2.6. Data treatment

Firstly, a global analysis by expertise was carried out. Then, an *a posteriori* individual analysis was performed to better understand participants’ behaviour in the categorization task

2.6.1. Global analysis

Experts and novices were considered as independent groups. Logistic regression and student t-tests were carried out for the categorization data (serving the wine/not serving the wine) and frequency analysis for the free comments data.

Logistic regression, for both experts and novices and for both types of wines, was done with the binary data as dependant variable (0 = I would serve the wine; 1= I would not serve the wine) and the common logarithm of the ratio of the concentration of oxidation compounds as independent variable. The proportion among the three compounds was always the same along the scale of concentration of oxidation. The increasing factor between oxidation levels was 1.35. Thus, the common logarithm was applied to 1.00 corresponding to the level 1 of oxidation, and to 1.35, 1.82, 2.46, 3.32, 4.48, 6.05, 8.17, 11.03, 14.89, 20.11, and 27.14 from the level 2 until the 12 of the oxidation mixture respectively.

Student t-tests were carried out for comparing the slopes of the logistic regressions.

The free comments were transcribed including spelling mistakes. Words referring to the intensity level were removed. Then, three wine researchers lemmatized the words and grouped the words with similar meaning into odour categories. Once, the three wine researchers had individually categorized the words; the consensus was evaluated by checking whether their classifications were in agreement (Lawrence et al., 2013). Only those terms cited by a minimum of 15% of the experts and novices were considered in the subsequent statistical analyses. The frequency of occurrence of the final terms was computed for each wine and each participant group giving rise to four contingency tables. Separate Correspondence Analyses (CA) were performed on the four contingency tables.

In parallel, free comments were classified according to their valence (negative and positive/neutral). A logistic regression was performed with the resulting binary data as dependant variable (0 = positive/neutral terms; 1= negative terms) and the common logarithm of the ratio of the concentration of oxidation compounds as independent variable.

2.6.2. A posteriori individual analysis

Individual graphs representing the categorization data of each participant as a function of oxidation for each wine (red and white) were printed. Then, three wine researchers classified the printouts based on what, in their opinion, were similar behaviours. The three classifications were then compared to reach a consensual behavioural classification. The frequency of occurrence of response behaviours was then computed for both groups of participants. A Chi-square test was performed to evaluate the effect of expertise on the categorization behaviour distribution. A logistic regression was also carried out to model the different categorization behaviours.

3. RESULTS AND DISCUSSION

3.1. Global results

3.1.1. Measuring consensus and boundary between categories in the perception of oxidized wines

Fig. 1a shows three different hypothetical models of the consensus among participants in the categorization of wines. The slope reflects the degree of consensus of the participants at passing from the not-faulty category (I serve the wine to my friends) to the faulty one (I do not serve the wine to my friends) at the same average of oxidation level (level 6 in **Fig. 1a**). High consensus level would typically be given by a curve, in which, from a certain level of oxidation almost all participants would pass from one category to the other due to the presence of the oxidation off-odour. Indeed, since having a clear-cut and strong shift from not-faulty to faulty categories implies consensus at categorizing wines at the same level of the oxidation gradient, we can consider that the higher the slope the more consensual the participants. The increase in disagreement among participants would be translated by a decrease in the value of the slope represented by medium and low consensus model curves. This disagreement would reflect a wider range of oxidation levels in which participants move from one category to the other.

In **Fig. 1b**, three different hypothetical models of participants' sensitivity to move from one category to the other are presented (all of them showing similar consensus). Sensitivity to change of category could be defined as the boundary (level of oxidation) at which exists more than 50% of probability ($p(0.5)$) that an oxidized sample was perceived as faulty. In the high sensitivity curve $p(0.5)$ corresponds to the level 3 of oxidation. This means that from level 3 there is more than 50% of probability that a sample was considered as faulty. The decrease in the sensitivity would be given by $p(0.5)$ from low to high oxidation levels as for the medium ($p(0.5)$ at level 6) and low sensitivity ($p(0.5)$ at level 9) model curves.

A logistic regression (**Fig. 2**) was carried out with the categorization data of experts and novices for each of the wines as explained in section 2.5. For the white (**Fig. 2a** and **Table 3**) and red wine (**Fig. 2b** and **Table 3**) slopes for experts were significantly higher than for novices ($p < 0.05$). In contrast, values of sensitivity to move from one category to the other were nearly similar for experts ($p(0.5)_{\text{white}} = 0.65$; $p(0.5)_{\text{red}} = 0.53$) and novices ($p(0.5)_{\text{white}} = 0.63$; $p(0.5)_{\text{red}} = 0.52$) regardless of the wine matrix.

3.1.2. Analysis of free comments

Another approach to understand participant consensus and boundary between categories towards oxidized wines is to analyse their free comments. CA on the frequencies of citation of each term for each sample was carried out for each group of participants and type of wine (**Fig. 3**).

For the white matrix, the first dimension of CA corresponding to the experts (**Fig. 3a**) and novices (**Fig. 3b**) explained 42% and 29 % of the total variance and for both groups it was significantly correlated to the level of oxidation (experts: $r = 0.91$, $p < 0.001$; novices: $r = 0.90$, $p < 0.001$). Experts used 107 oxidation related terms for describing the samples whereas novices used just 14. Nevertheless, novices used negative terms for describing the samples.

The first dimension corresponding to CA of red matrix explained 42% and 33% of the total variance for experts (**Fig. 3c**) and novices (**Fig. 3d**). Again, the first dimension showed a significant correlation with the oxidation gradient for experts ($r = 0.94$, $p < 0.001$) and novices ($r = 0.88$, $p < 0.001$). The variance explained by the first dimension in the experts' CA for the red matrix was lower compared to the white matrix meaning that experts used less oxidation related terms for this matrix (74 oxidation related terms). This phenomenon was also observed for novices, but in this case, they just used hedonic negative terms. Novices passed from using 44 negative hedonic terms for describing whites to 31 for reds, which was, as for experts, 30% lower.

Finally, a hedonic categorization of terms in negative and positive/neutral was carried out (see section 2.5.). Logistics regression with the categorized terms (Fig. 4) corresponded to the same patterns that those of the regressions on the not-faulty/faulty categories towards oxidized wines observed in Fig. 2. It was observed that the higher level of oxidation the more negative terms used. Slopes obtained were 1.45 and 1.24 for the white, 0.47 and 0.43 for the red for experts and novices, respectively. The comparison of the slopes did not show significant differences between experts and novices, neither in the white samples nor in the red ones.

3.1.3. Comparison of experts' and novices' within-group consensus and verbalization

The logit regression for experts yielded a steeper slope than for novices, which suggests that experts were more consensual in their responses towards oxidation. However, both groups were similar in terms of average oxidation level to change of category. If we compare the curves from Fig. 2 with those of the models (Fig. 1), it can be noted that none of the four curves from Fig. 2 resembled to the high consensus model curve, neither for experts nor for novices. This showed a global lack of agreement in the responses of the participants, regardless their expertise level. This result suggests that, despite the significant difference in the consensus, the difference between experts and novices was not important.

The main difference coming from the analysis of free comments concerns the way the two groups described the samples; experts used technical and accurate oxidation-related terms while novices relied on negative hedonic terms to describe the same samples. The difference would thus not be a perceptual difference but a lexical difference. This result is consistent with previous research (Croijmans & Majid, 2016; Chollet & Valentin, 2000).

3.2. Individual results

3.2.1. Definition of different behaviours towards oxidation

To understand the small difference in terms of consensus between experts and novices we looked at individual categorization behaviour. After classification (see section 2.5.), five different behaviours (**Fig. 5**) emerged from the individual data:

Behaviour A: “clear categorization”: participants classified the samples as not-faulty up to a certain concentration of oxidation compounds and then they moved suddenly to the faulty category. This indicates that from a certain concentration (which may be different from one participant to another) the fault was clearly identified. **Fig. 5a.**

Behaviour B: “almost clear categorization”: The participants categorized as not-faulty the samples for the lowest concentrations and vice versa for the highest concentrations. They had a period of hesitation for the intermediate concentrations, illustrated by a successive change of category. This period of hesitation suggests a less clear mental representation of oxidation than for behaviour A. **Fig. 5b.**

Behaviour C: “clear categorization after hesitation”: As for the previous behaviour, a period of hesitation was observed, but it appeared only for the lowest concentrations. On the other hand, from a certain concentration, the oxidation seemed to be clearly perceived and the samples were clearly classified in the faulty category. **Fig. 5c.**

Behaviour D: “Oxidation fan”: As for profile C, the participants initially hesitated and then, from a certain concentration (which may be different from one participant to another), the samples were classified as not faulty. This suggests a positive representation of oxidation. **Fig. 5d.**

Behaviour E: “Undecision”: The participants seemed to answer randomly; this was exemplified by a successive change between the not-faulty/faulty categories. **Fig. 5e.**

Nine individual response graphs (white wine: one novice and three experts; red wine: two novices and three experts) did not follow any of the precedent patterns of behaviours. They were deleted from further analyses.

Fig. 6 represents the logistic regressions done with the categories chosen by participants (experts and novices together) belonging to each pattern of behaviours for the white matrix (similar results for the red wine; data not shown). Participants from behaviour A presented the highest consensus towards oxidation (slope = 5.6). Although these participants did not show any period of hesitation the fact that they changed from not-faulty to faulty categorization at different levels of oxidation was reflected by a more gradual slope than the steep slope of the hypothetical high consensus model curve showed in **Fig. 1a**. The curve obtained for the behaviour B had a lower slope (slope = 4.6) compared to behaviour A (slope = 5.6), but higher than C (slope = 1.5). Behaviour B was characterized by a hesitation period that did not appear in behaviour A. This period of hesitation was more important in participants from behaviour C than those of behaviour B, which was translated in the difference between the two slopes. The logistic regression done with the categorization data of participants with behaviour E, characterized by a successive change between the two categories, was close to zero (slope = 0.6), although a tendency to consider the highest oxidation levels as faulty was observed. For behaviour D, the negative value of the slope (slope = -1.9) was indicative that these participants categorized the most oxidized wines as not-faulty, contrary to the participants of behaviours A, B and C.

The distribution of the number of experts and novices for each type of behaviour for the white and for the red is shown in **Table 4**. The distribution in the different categorization behaviour was independent of the expertise (chi-square = 3.54; $p=0.47$) and each type of behaviour can be found in both experts and novices, with the exception of behaviour D for white wine, where no expert followed this behaviour.

3.2.2. Exploring the different behaviours towards oxidation

As previously mentioned, we expected higher consensus among experts. We also expected that once an expert categorized samples with a certain level of oxidation in the faulty category

he/she would do the same with higher oxidized samples. However, the five behaviours that emerged from the individual responses of experts and novices showed that it was not systematically the case. The distribution of the number of experts and novices for each one of the behaviours was quite similar, with the exception of behaviour D for the white wine. The categorization of highly oxidized samples in the not-faulty category, could be explained by the ambivalent character of oxidation. Oxidation differs from other off-odours in the fact that oxidation compounds can provide positive aromas if they are well-integrated (Gambutì, Rinaldi, Ugliano, & Moio, 2012; Ugliano, 2013).

Our results revealed a heterogeneity of behaviours in the categorization of oxidized wines, for both experts and novices, which was in agreement with the lack of consensus observed in the global results (see section 3.1.). The small, but significant, difference previously observed in the consensus considering experts and novices as independent groups could be due to several reasons. The first one can be the higher number of novices in the behaviour D with regard to the experts' number for both matrices. Another plausible reason could be just that experts following behaviours A, B and C were slightly more consensual than novices at choosing the oxidation level at which they clearly categorized samples in the faulty category.

Even though the consensus among experts was better than among novices, it remains rather low. The low consensus among experts may be due to the heterogeneity of their backgrounds as Tempère et al. (2014) have observed.

3.3. White matrix vs. red matrix

In the **Fig. 2** and **Table 3**, it can be seen that both groups of participants exhibited greater slopes for the white wine than for the red one. Experts showed significantly more consensus to categorize white than red samples (2.82 vs. 1.93, $p < 0.05$). This difference was not significant for novices although a tendency was observed. This result would reflect a higher consensus among experts for the white matrix. On the other hand, experts showed more

variability and hesitation in the categorization of red samples. This clearly suggests a different perception of oxidation for whites and reds. The reason behind this difference in the consensus could be that, with the exception of some styles of oxidized white wines like, Xerez wines or Jura wines (“*vin jaune*”), oxidation is mostly considered negative in whites. Thus, the experts’ mental representation about white wines would be associated to fresher wines than reds, meaning that at a certain level of oxidation, white wines would be more likely to be perceived as faulty. On the contrary, there are many red wines in the market with oxidation nuances that are considered positive. It is more common for red wines to stay in the bottle during years developing oxidation aromas that, if well integrated and expected, give to the wine complexity and increase their quality. This could explain why the frontier between not-faulty/faulty categories towards oxidation would be less clear-cut in the case of red wines. Another explanation for the difference in the experts’ consensus between both types of wine could also be due to a matrix effect. Interactions between molecules, synergies and other chemical and physiological phenomena would lead to a different perception of the three spiked compounds in the two matrices. Both explanations are not mutually exclusive.

4. Conclusion

Although a clear-cut difference between experts and novices towards the perception of oxidation as wine fault was expected, our results have demonstrated that differences between both groups were quite small. Experts as well as novices showed low consensus at categorizing oxidized wines. However, experts were slightly, but significantly more consensual than novices. On the other hand, no difference in the boundary between not-faulty/faulty categories was found between the two types of participants. Five different behaviours in the categorization of oxidation in wine emerged. Contrary to what previous studies on wine expertise suggest, the “wine expert” label hides a wide variability of experiences and hence, of sensory responses. Taking wine experts as an *a priori*

homogeneous group is a rather simplistic approach that should be completed by an individual analysis if the objective is to better understand participants' behaviour.

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Figure 1. Hypothetical logistic regression models in the categorization of oxidized wines as not-faulty/faulty. **(a)** Models of logistic regression for high (full lines), medium (broken lines) and low (dotted lines) consensus panel. **(b)** Models of logistic regression for high (full lines), medium (broken lines) and low (dotted lines) sensitivity to change of category panel.

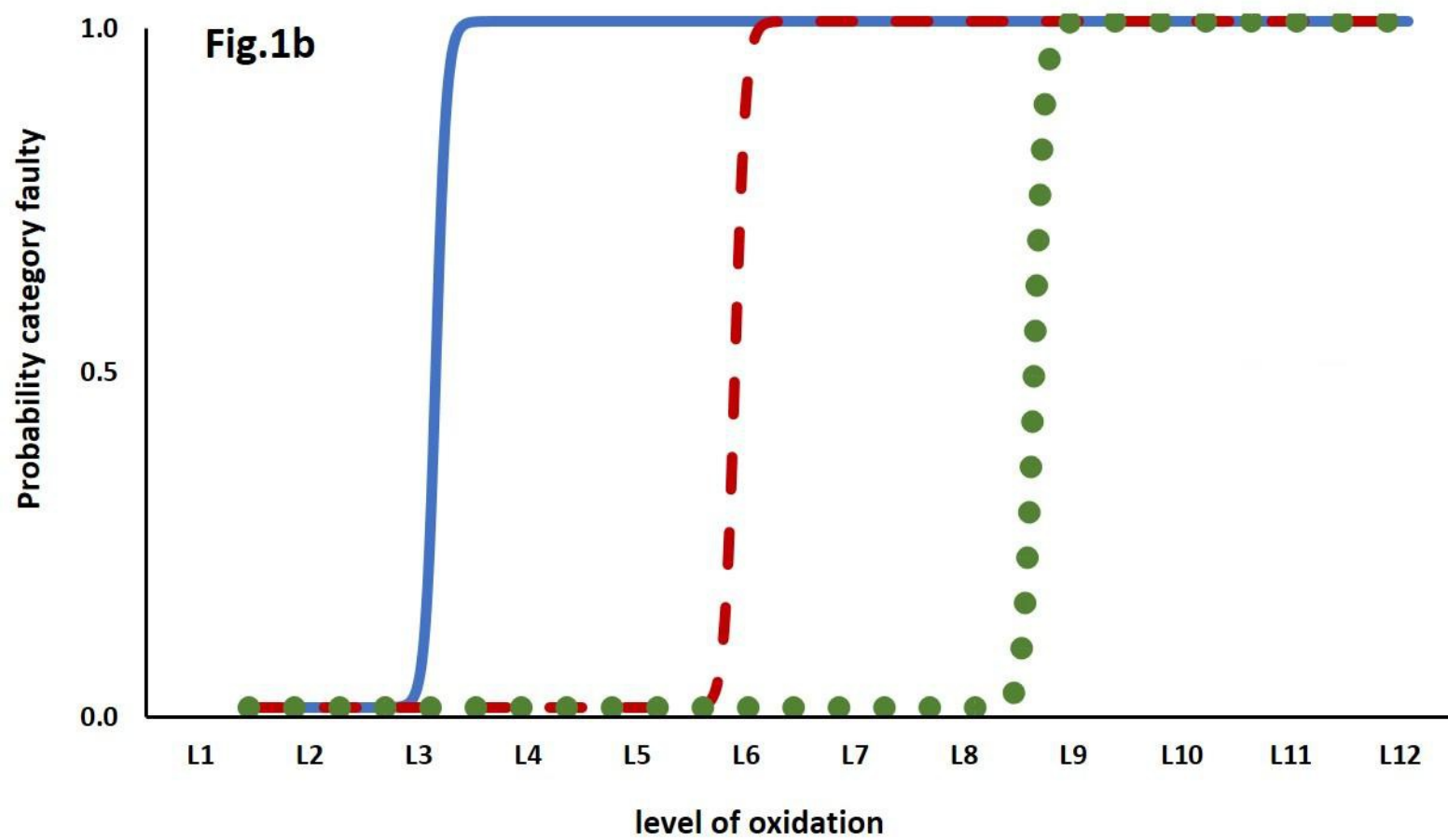
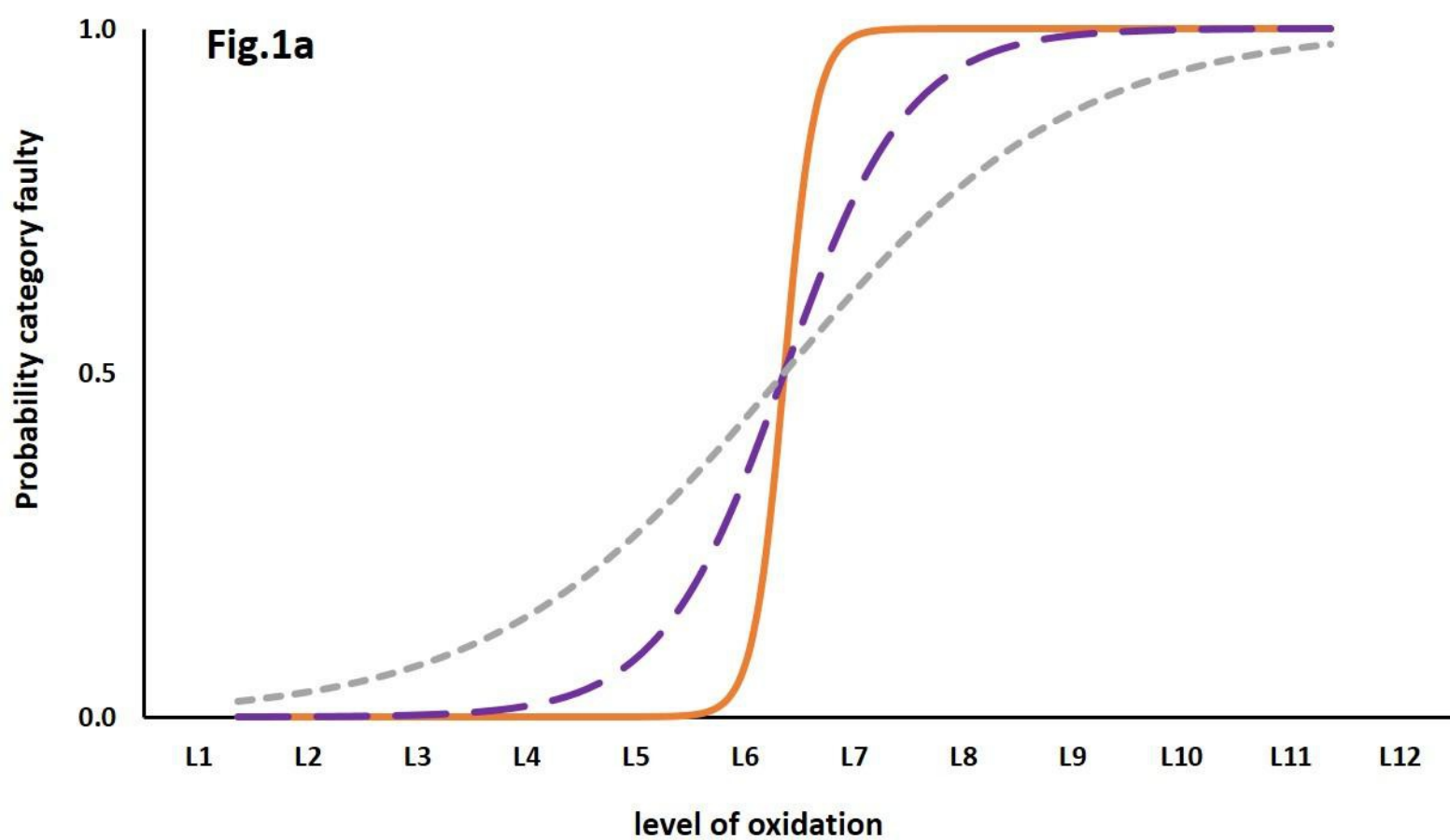
Figure 2. Logistic regression with the categorization data of wines. Probability of categorizing in faulty *versus* the common logarithm of the concentration of oxidation compounds for experts (triangles) and novices (squares). **(a)** white wine; **(b)** red wine.

Figure 3. Correspondence Analysis (CA) done with the categorization of the terms given for the description of wines. **(a)** white wine for experts; **(b)** white wine for novices; **(c)** red wine for experts; **(d)** red wine for novices.

Figure 4. Logistic regression with the negative categorized terms in function of the common logarithm of the ratio of the concentration of oxidation compounds for experts in white (full triangles), novices in white (full squares), experts in red (open triangles) and novices in red (open squares).

Figure 5. Illustration of the panellists' responses categorized in five behaviours. **(a)** behaviour A; **(b)** behaviour B; **(c)** behaviour C; **(d)** behaviour D; **(e)** behaviour E.

Figure 6. Logistic regression for each one of behaviours (A, triangles; B, squares; C, circles; D, diamonds; E, crosses) found in white wine, considering experts and novices together, in function of the common logarithm of the concentration of oxidation compounds.



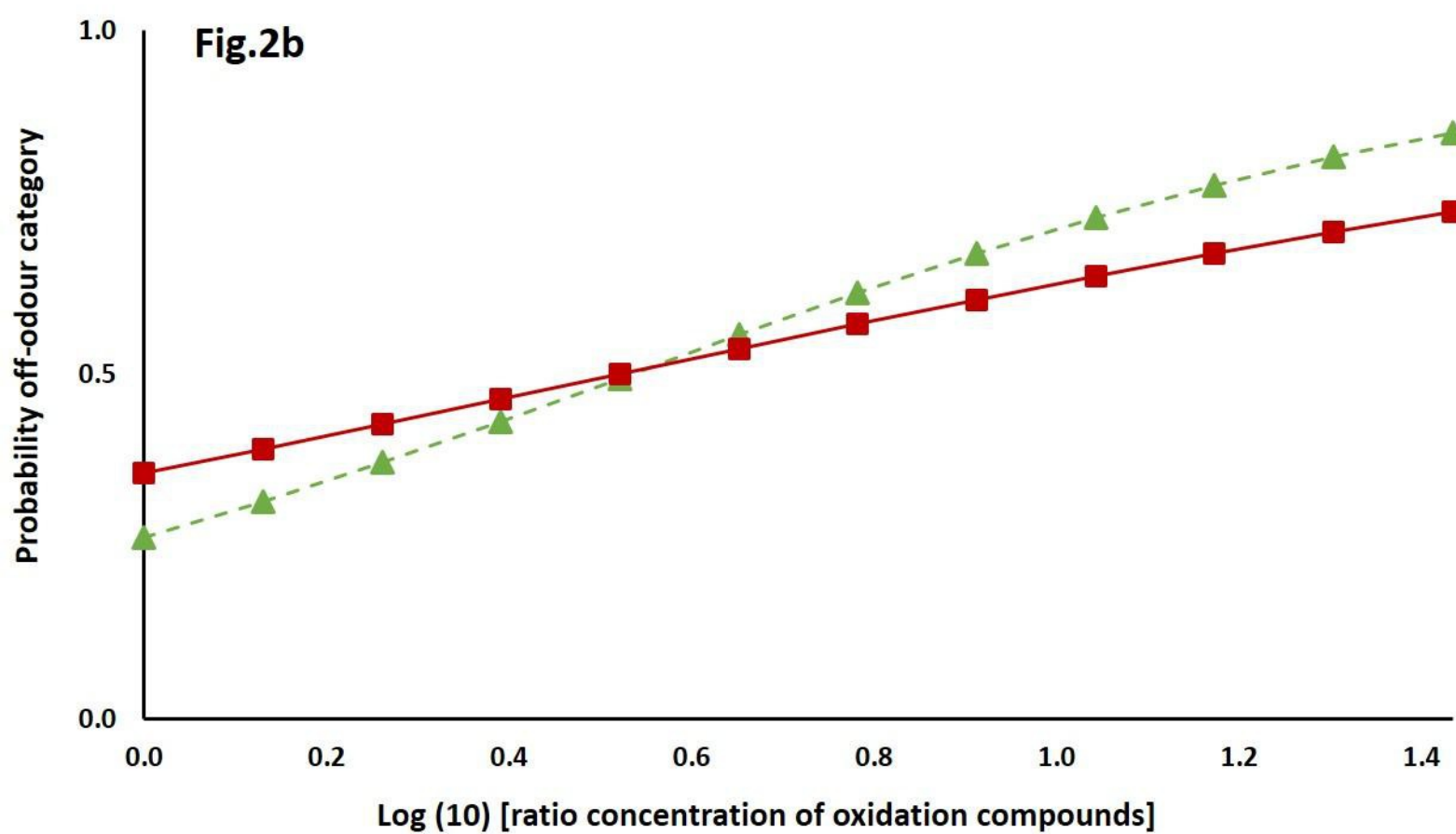
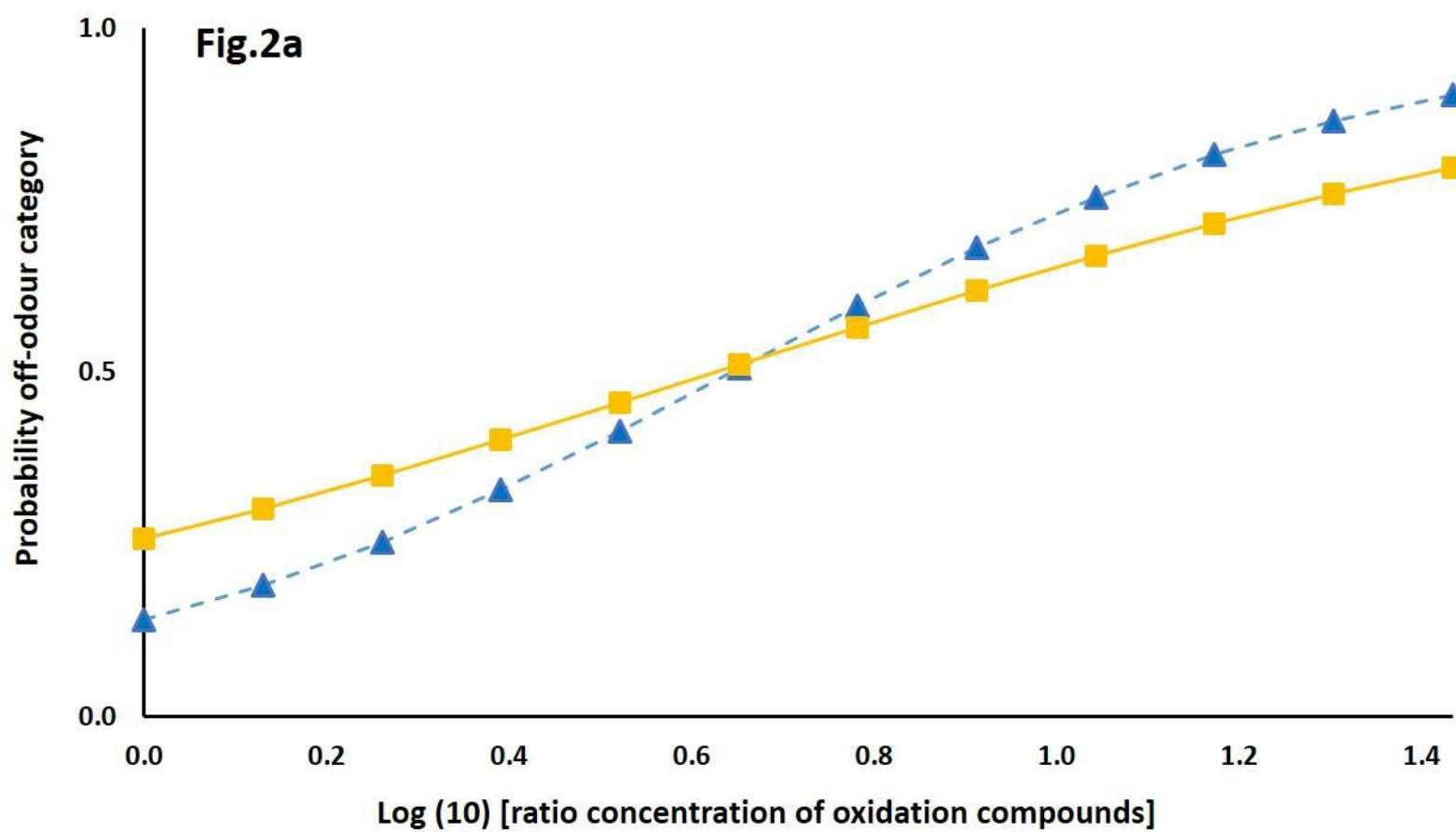
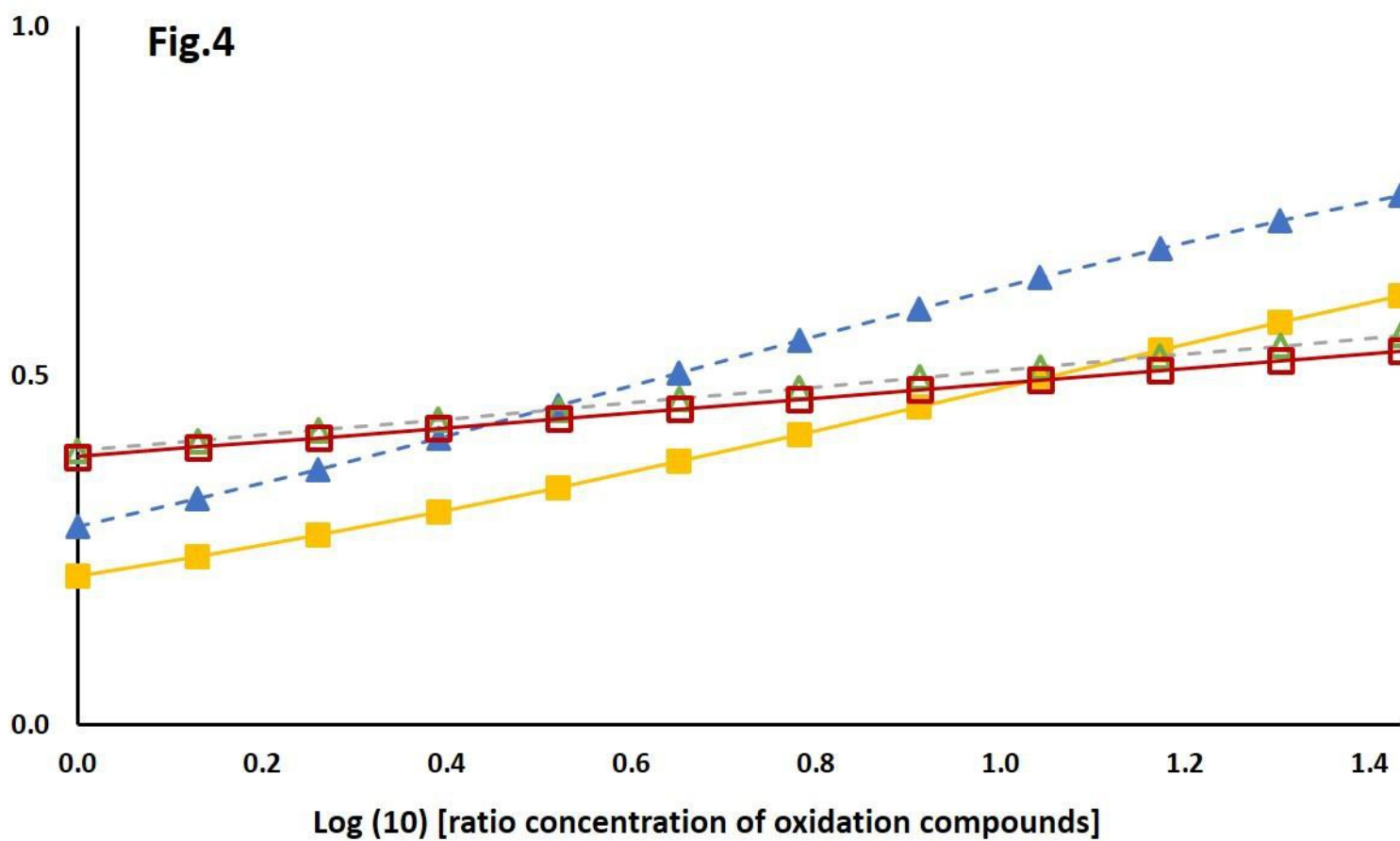


Fig.4

Probability off-odour category



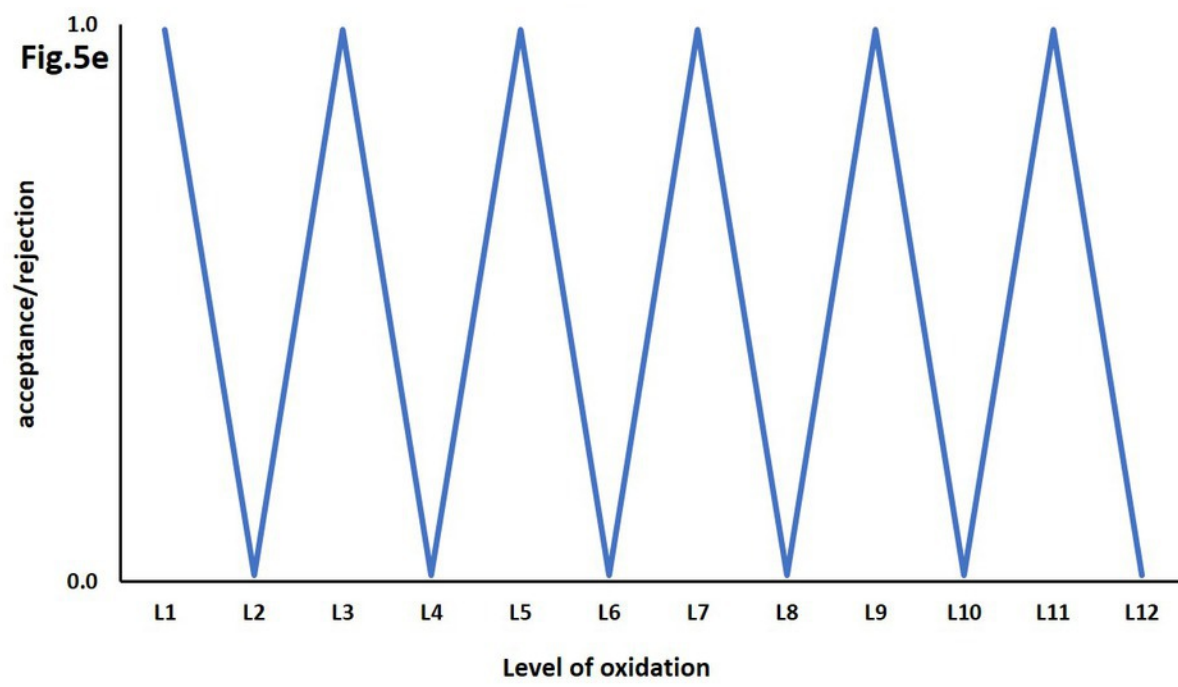
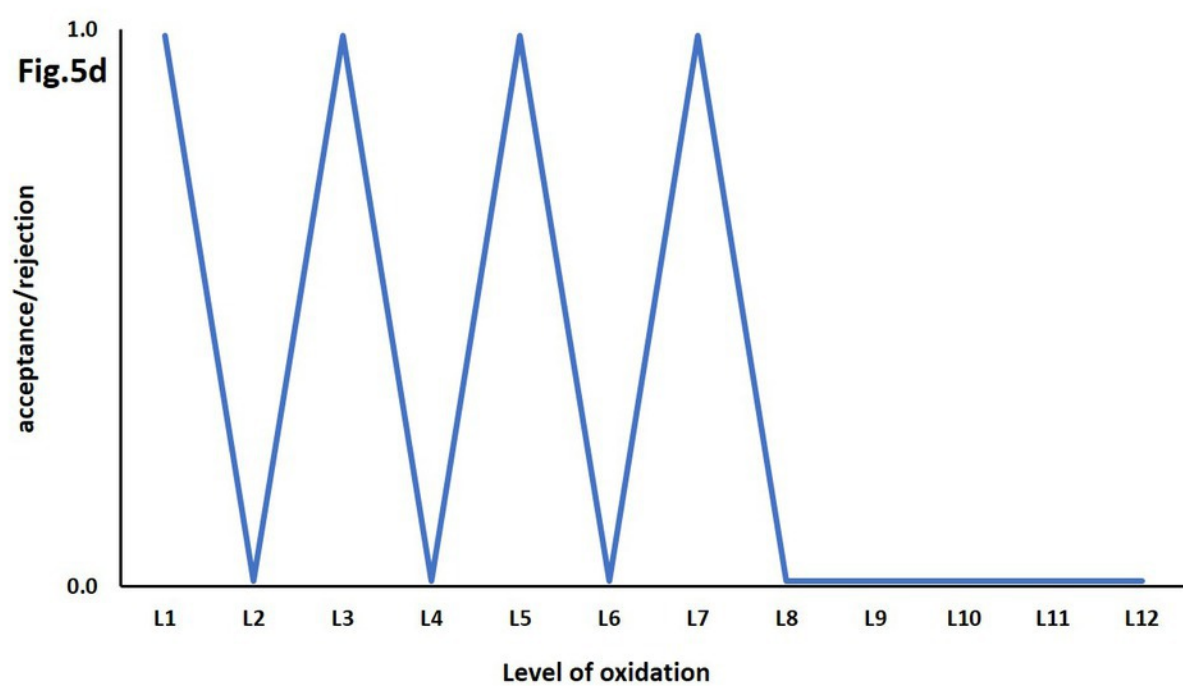
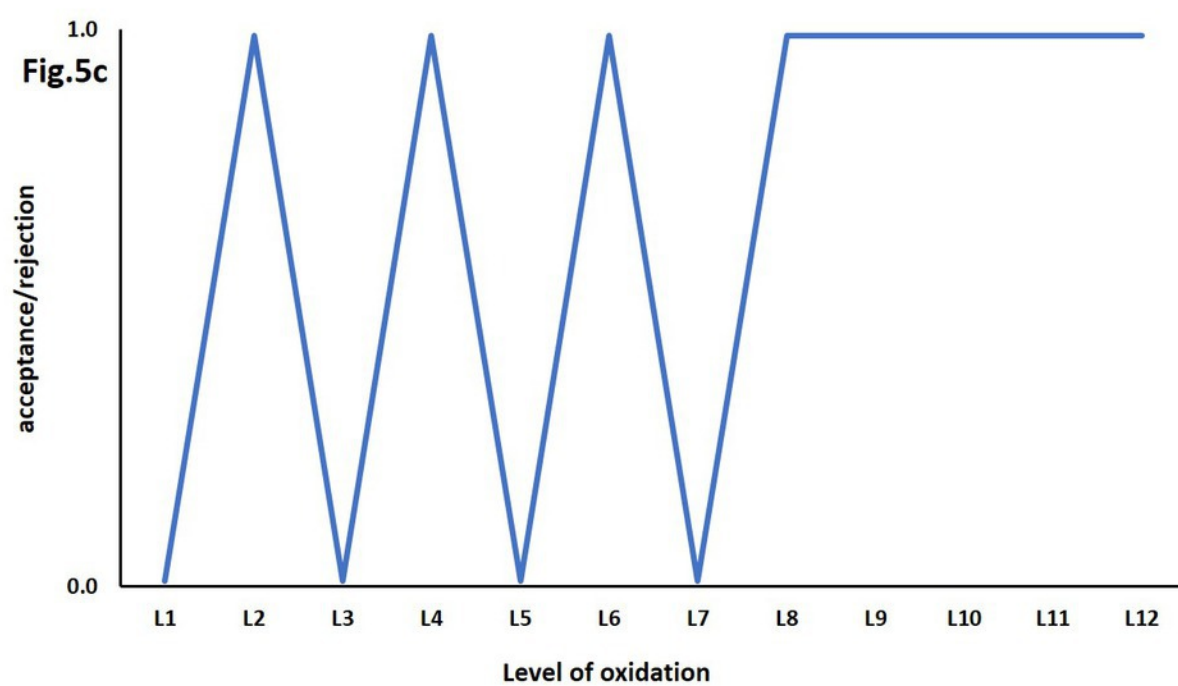
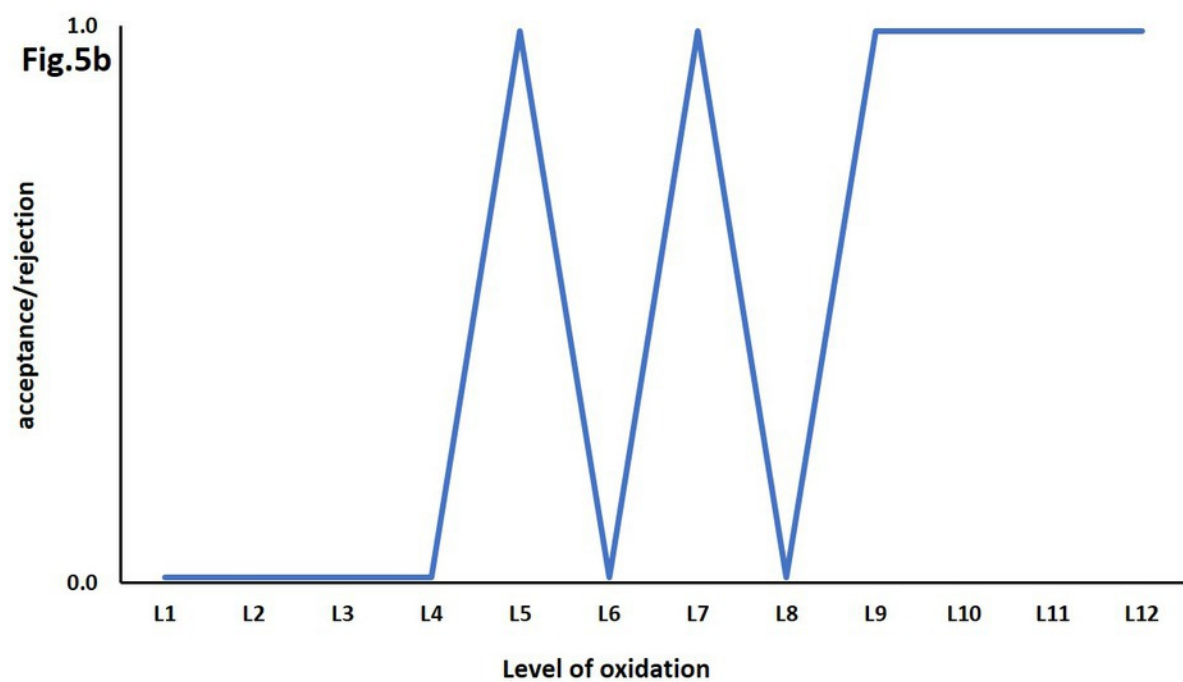
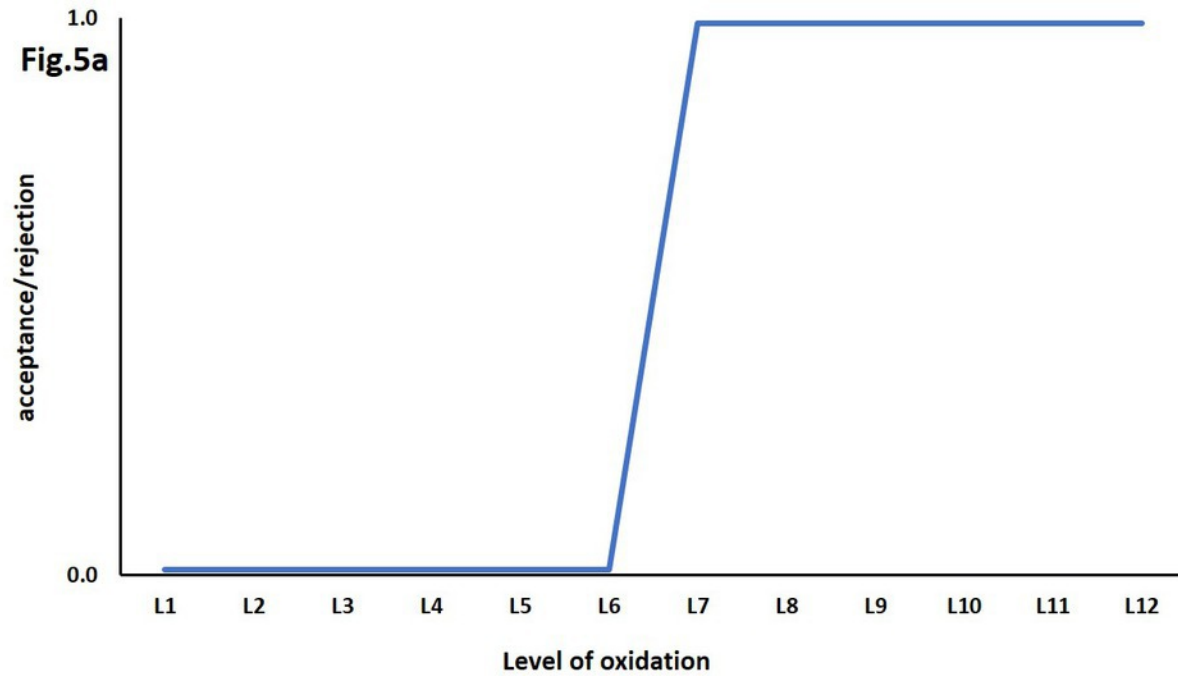
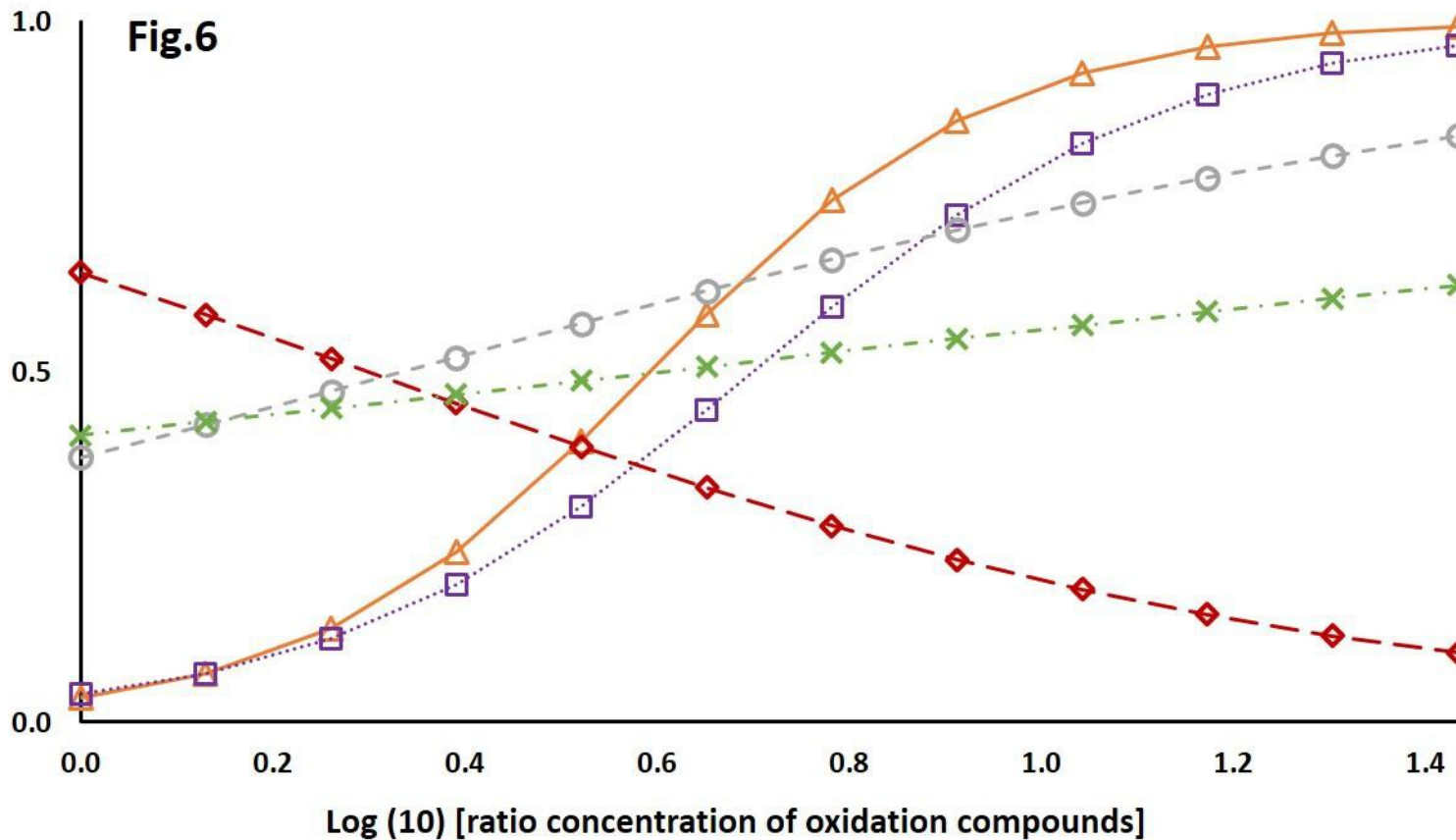


Fig.6

Probability off-odour category



Information and Compositional data	Wine	
	Red wine	White wine
Protected Designation of Origin (PDO)	Côtes du Rhône (France)	Val de Loire (France)
Vintage year	2016	2015
grape variety	Grenache/Syrah	Chardonnay
alcohol % (v/v)	12.58 ± 0.03	11.78 ± 0.13
pH	3.55 ± 0.01	3.35 ± 0.01
Free SO ₂	22.4 ± 0.07	41.6 ± 0.09
Total SO ₂	43.2 ± 2.7	99.2 ± 3.1
Volatile acidity (g/L)	0.39 ± 0.035	0.25 ± 0.030
Malic acid (g/L)	nd	2.25 ± 0.040
Glucose+Fructose (g/L)	0.56 ± 0.010	3.47 ± 0.48

Table 1. Mean results with standard error of some basic compositional parameters of base wines, also including origin, age and varietal composition. nd, not detected.

Levels of oxidation	Compound		
	Acetaldehyde (mg/L)	Phenylacetaldehyde (µg/L)	Methional (µg/L)
L1	1.8	7.4	3.7
L2	2.5	9.9	5.0
L3	3.4	13.4	6.7
L4	4.5	18.1	9.1
L5	6.1	24.5	12.2
L6	8.3	33.0	16.5
L7	11.2	44.6	22.3
L8	15.1	60.2	30.1
L9	20.3	81.3	40.6
L10	27.4	109.7	54.9
L11	37.0	148.1	74.1
L12	50.0	200.0	100.0
Odor threshold	0.5	1.0	0.5

Table 2. Concentration of acetaldehyde (mg/L), phenylacetaldehyde (µg/L) and methional (µg/L) for each one of the oxidation levels (Ln). Odor threshold for acetaldehyde (Guth, 1997), phenylacetaldehyde (Culleré, Cacho, & Ferreira, 2007) and methional (Escudero, Hernández-Orte, Cacho, & Ferreira, 2000).

Matrix	Level of expertise	Slope			Intercept		
		value	Pr(Khi ²)	SE	value	Pr (Khi ²)	SE
White	Novices	1.69	<0.001	0.26	-1.06	<0.001	0.21
	Experts	2.82	<0.001	0.32	-1.81	<0.001	0.25
Red	Novices	1.13	<0.001	0.24	-0.59	<0.01	0.20
	Experts	1.93	<0.001	0.28	-1.03	<0.001	0.22

Table 3. Slope and intercept with their probability of Khi² (Pr (Khi²)) and standard error (SE) for the logistic regression of categorization data for both experts and novices and red and white wine.

Matrix	Level of expertise	Behaviours towards oxidation in wine				
		A	B	C	D	E
White	Novices	7	10	5	4	5
	Experts	7	7	7	0	5
Red	Novices	6	5	10	7	2
	Experts	6	4	11	4	1

Table 4. Distribution of the number of novices and experts in each type of behaviour for white and red wine.