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1 **Color of Wine: development of reference grids/templates for sensory**  
2 **analysis with trained assessors**

3 **Reference grids for sensory assessment of wine color**

4  
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14  
15 **Abstract:** Color of wine gives information on many aspects of the product, and it is one of the  
16 main parameters defining wine quality. Consequently, color is an important attribute described in  
17 the Designations of Origin (PDO)'s technical specifications. In this paper color reference grids  
18 for color sensory evaluation of white, rosé and red wines (linked to a specific methodology and  
19 controlled illumination) are developed, presented and validated. The color intensity and color hue  
20 parameters of 2,353 wines of different types have been analyzed using these reference grids  
21 during the period 2021-2023. Considering the results obtained, the usefulness of having a double  
22 color measurement (color intensity and color hue) is questioned and discussed.

23  
24 **Practical applications:** The developed reference grids have a direct practical application in the  
25 sensory assessment of wine color since they could be used as a first step towards a standardization  
26 of a common methodology for sensory color evaluation. The proposed reference grids can be  
27 applied when training a panel of evaluators to ensure that the given scores are objective and

28 comparable. In addition, these color grids are a suitable tool for the official control of wines with  
29 PDO as well as for the characterization of varietal wines according to their color. It can also be  
30 used by winemakers to monitor different winemaking processes or to assess wine evolution/aging.  
31 The method described in this work for color assessment of wine is currently being applied in  
32 different Spanish wines having a PDO where color parameters (both intensity and hue) are  
33 included in the scope of a laboratory accredited according to ISO 17025.

34

35 **Keywords:** color hue, color intensity, PDOs, validation, control quality

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## 42 **1. Introduction**

43 Food appearance and especially its color is normally the first aspect human beings perceive as the  
44 visual driven species that we are. In fact, color is an important source of information about the  
45 product and its quality (ripeness degree in fruits and vegetables, oxidations processes, freshness,  
46 etc.). In the same vein, the color of wine gives information on many aspects of the product such  
47 as aging (evolution) or elaboration process (e.g., length of skin contact, oak cooperage exposure  
48 or grape maturity) (Jackson, 2017), and also provides relevant information about some defects  
49 (Fairchild, 2023; Fan et al., 2023). So, color is one of the main parameters of the wine quality and  
50 has an important influence on the overall acceptability of the product by consumers (Hensel et al.  
51 2023; Fan et al. 2023). Consequently, practically all wines covered by collective quality schemes,  
52 (Protected Designations of Origin (PDO) and Protected Geographical Indication (PGI)),  
53 incorporate visual attributes and specifically color, as a quality element of the wines (OJEU, 2013;  
54 2019). For this reason, color is an important sensory parameter to be controlled and described in  
55 the technical specifications of PDO / PGI wines (EC, 2023).

56

57 The visual evaluation of the color and appearance of wine, normally consists of observing the  
58 product in an uncolored transparent glass. During this evaluation, the position of the glass, the  
59 shape of the glass, the illumination and direction of the light it receives and the influence of the  
60 color of the background are important factors to control (Pridmore et al. 2005; Martin et al., 2007;  
61 Hernandez et al. 2009; Jackson, 2017; Fairchild, 2018). Most authors agree that observation  
62 conditions, such as illumination and the geometric shape of the container in which the sample is  
63 evaluated, can have a noticeable effect on color evaluation (Fan et al., 2023). Some other authors  
64 (Hernandez et al. 2009; Pridmore et al. 2005) even emphasize the importance of tilting the glass  
65 for visual assessment, specifically at 45° to the horizontal plane. According to Jackson (2017),  
66 this procedure allows the correct evaluation of hue (shade or tint) and depth (intensity) which are  
67 the most significant features of a wine's color. Fairchild (2018) conclude that standardization of  
68 lighting type, level, spectral characteristics, and geometry are needed for careful and consistent  
69 sensory evaluation of wine color. However, according to Jackson (2017), there is no need to assess

70 wine color under north-reflected light, because the brain can adjust very well to the varying  
71 spectral quality of lightest sources. As this author sustains “*a sheet of white paper looks the same*  
72 *color under sunlight or incandescent light*”.

73

74 To reduce the variability in the measurement of wine color because of the chosen sensory  
75 procedure (light type, background, etc.), some researchers prefer to rely on instrumental  
76 measurements. There are several instrumental methods for the evaluation of color in wine, from  
77 the chromatic indices (Glories, 1984) to chromatic spaces such as the Munsell Color System or  
78 CIELab. This last approach, established by the *Commission Internationale de l’Eclairage* (CIE,  
79 1986), is the method recommended for determination of chromatic characteristics of wine (OIV,  
80 2022). All these instrumental procedures attempt to predict the human color perception. However,  
81 according to Hensel et al. (2023), even though CIELab performed better than other systems, not  
82 all CIELab coordinates align with the perceived color. Other approaches based on computer  
83 vision (Hutchings, 2002; Martin et al., 2007), also have some limitations since the human eye in  
84 connection with the brain can capture and integrate nuances that are not perceptible or difficult to  
85 measure by instrumental methods. In fact, sensory appreciation of color depends not only on an  
86 individual capture of radiation at a given wavelength, but also on how each individual perceives  
87 and interprets the impulses the eyes transmit (Lawless & Heymann, 2010; Jackson, 2017). Several  
88 studies have attempted to establish relationships between sensory and instrumental  
89 measurements. The results obtained show the existence of some discrepancies between both  
90 measurements (Martin et al., 2007), which vary depending on the area of the sample where the  
91 measurement was taken and the color of the wine (white, rosé or red) (Hernández et al., 2009;  
92 Sáenz Gamasa et al., 2009). Thus, although instrumental measurements can represent a good  
93 starting point to train and verify assessors, it should not be forgotten that the human eye and the  
94 interpretation that the brain can make of the perceived information allows to obtain a more  
95 complex and holistic measure of the color of the wine, which, real or not, is the one perceived and  
96 valued by the end user of the product.

97 In general, sensory evaluation requires well-trained assessors and the use of appropriate  
98 references for a reliable evaluation, which also applies for color assessment. The sensory  
99 measurement of color is often neglected by sensory specialists or even added as an afterthought  
100 (Lawless & Heymann, 2010). Curiously, there is no accepted terminology, nor a widely accepted  
101 standardized methodology for color evaluation in products such as wine (Hernández et al. 2009;  
102 Martin et al. 2007; Jackson, 2017). The most extended system for the characterization of wine  
103 color is based on non-standardized terms used in the wine sector (e.g., brick red, straw yellow,  
104 orangish rosé, ...), which are quite limited, ambiguous at best and in some cases are not color  
105 names (Jackson, 2017; Fairchild, 2023). From a more educative perspective, there are materials  
106 such as posters or charts on wine color (Pouzalgues, 2006; Cayla et al., 2010; Wine Folly, 2013;  
107 Bouchard Ainé et al., 2023) that can be easily accessed through the website. However, although  
108 this material may be useful for teaching purposes, it is not the most appropriate for descriptive  
109 sensory analysis as there is insufficient information available on how they were generated and  
110 their validity. In addition, and as Hutchings (2002) points out, normally reaching an agreement  
111 among panelists to design adequate scales and score the samples in a disciplined and  
112 homogeneous way is needed. Fairchild (2023) has recently presented a simple method that can be  
113 used as a reference for the sensory evaluation of wine. It is a color sorting system based on two  
114 dimensions: hue (from greenish yellow, through orange, red to purplish-red) and depth, which is  
115 the combined variation of lightness (value) and saturation (light, medium, deep). The result is a  
116 chart with 15 points established in Munsell coordinates and corresponding sRGB values. The  
117 described method is very promising and may be useful for untrained evaluators or hedonistic  
118 tastings, but it does not include the wide variety of color attributes described in most of the wine  
119 PDO specifications, nor does allow to distinguish between the characteristic colors of different  
120 wine typologies (for more information about the existing wine typologies included in different  
121 PDOs see Gomis-Bellmunt et al., 2022). Although, from the system proposed by this author it is  
122 possible to extrapolate colors not included in the 15 color points shown in his work, this  
123 extrapolation process can be complex for some evaluators and generate a greater variability in  
124 their responses.

125 Even though previous studies have provided relevant insights into the practical aspects of sensory  
126 evaluation of wine color, to the best of our knowledge, no previous work has developed a  
127 scientific-validated references for the sensory color assessment of PDO wines. The existence of  
128 these references is a crucial tool for harmonization and official control of wine production. Thus,  
129 the objective of this work is to develop a descriptive methodology and their corresponding  
130 references to facilitate the objective and reproducible sensory evaluation of the wine color. A  
131 validation process of the proposed method and references is also carried out with real wines  
132 samples.

133

134

## 135 **2. Material and methods**

136

### 137 *2.1. Evaluators*

138

139 A panel of thirty evaluators was used to carry out the present work (12 women and 18 men, aged  
140 between 45 and 55 years). The evaluators were recruited from the wine sector, i.e. they were  
141 expert evaluators (according to the definition provided by ISO Standard 5492, (ISO 2008)). The  
142 entire procedure for selecting and training them is described in detail in a previous work (Gomis-  
143 Bellmunt et al., 2022).

144

### 145 *2.2. Color references development*

146

147 In order to develop the color references, the Pantone + Series color palette (GG5103) containing  
148 a total of 1,736 different colors (solid colors) were presented to the evaluators. The palette was  
149 made up of 248 color sheets with 7 slight variations of the same color. In the first step, evaluators  
150 had to choose which of these 248 sheets were applicable to the wine color. The selected sheets  
151 (n=99) at least by 24 evaluators (agreement between 80% of them) were then submitted to a  
152 second selection process. In this case, evaluators had to choose within each of the previously

153 selected color sheets the specific colors that could be found in wines. From the total of 693  
154 possible colors (n=99 selected sheets, containing 7 different colors each) 162 were finally selected  
155 (again those selected by at least 24 evaluators). The selection criteria in both cases was based on  
156 the personal experience of each evaluator. This process was carried out in tasting booths equipped  
157 with 6500 K daylight lighting according to ISO 8589 (ISO, 2010). After that, the Pantone  
158 reference codes located in the different sheets (hexadecimal color codes) of the selected colors,  
159 were downloaded via the website iColorpalette (<http://www.icolorpalette.com>) as a “png”  
160 extension file. All this color images were then allocated in a PowerPoint file (max. 40 images per  
161 slide) and each evaluator had to examine the file and select the most suitable colors for white  
162 wines, including liqueur wines made from white grape varieties, rosé wines and red wines. From  
163 this selection 51 colors were obtained for white wines, 119 for rosé wines and 37 for red wines  
164 (some colors were allocated in two wine types simultaneously, i.e. white-rosé, rosé-red). Finally,  
165 the process was repeated with the selected colors for each wine type and a second selection  
166 process was made asking again evaluators to select the most suitable colors for each type of wine,  
167 in this case the most frequently chosen colors were considered (Table 1 and 2). The final result  
168 was 19 colors for white wines, 90 for rosé wines and 24 for red wines. Each of these colors was  
169 translated to their respective RGB values (<http://www.icolorpalette.com>) for statistical analysis.  
170 Tables 1 and 2 shows the colors selected to build the wine reference palette and their  
171 corresponding Pantone ID and RGB values and includes the number of assessors who chose each  
172 color.

173

174 With the RGB values of the colors selected for each type of wine (white, rosé and red), a principal  
175 component analysis (PCA) was performed in order to project these colors in a two-dimensional  
176 space. In all three cases, the percentage of variance explained by these two dimensions was greater  
177 than 80% (Figures 1, 2 and 3). In order to elaborate the different grids, the colors farthest from  
178 the center in both dimensions per quadrant and well represented in the graph (squared cosines  
179 higher than 0.5 in at least one of the dimensions) were selected from each principal component  
180 analysis. From the RGB coordinates of these 4 points in each PCA, the RGB values of the

181 remaining points of the scale (7 on the abscissa axis and 7 on the ordinate axis) were interpolated.  
182 Subsequently, the grid was completed with additional interpolations between the different colors  
183 until a total of 81 different colors per type of wine was obtained.

184

185 The grids were printed on a 200x200 mm square white matt coated paper (250 g/m<sup>2</sup>) with  
186 calibrated printers in quatricomia (Stein Copisteria, Girona, Spain). Color grids measured 170  
187 mm on each side and each colored square measured 18 mm on each side and the spacing between  
188 squares was 1 mm.

189

190

### 191 2.3. *Reference validation*

192

193 To validate the developed references (grids) and check their suitability for the sensory analysis of  
194 wines, three different verifications were carried out: (i) the panel was able to meet specified  
195 performance criteria when using the developed methodology and references, (ii) sensory data  
196 correlate with instrumental color measurements performed on the same wine samples, and (iii)  
197 the usefulness of the described methodology to characterize real samples belonging to the  
198 different PDOs and whether the 2,353 samples evaluated fall within the space defined by the  
199 different color grids.

200 Firstly, the performance of the panel was checked (appropriate use of the references by the  
201 evaluators). Thus, the overall panel performance was checked according to the recommendations  
202 of standard ISO 11132 (ISO, 2017a). This process involved thirty evaluators and was carried out  
203 in three stages: one for white wines, one for rosé wines and a third for red wines. The experimental  
204 design was based on eight different wines for every color grid. In each of these stages four sessions  
205 were held and in each session six wines were evaluated. In each session two of the wines were  
206 presented in duplicate (to calculate repeatability) while the other two samples were repeated in  
207 the following session (to calculate reproducibility). At the end, each wine was evaluated three  
208 times. The parameters calculated were repeatability, reproducibility, homogeneity, and

209 discriminant capacity. Measures of the performance of the panel as a whole was analyzed by  
210 means of two- and three-way ANOVAs (samples, assessors, sessions) (ISO, 2017a). To calculate  
211 repeatability of the panel, for each attribute (color intensity x and y and color hue x and y), samples  
212 repeated in the same session were considered and the repeatability index ( $I_r$ ) was estimated as  
213 inversely related to the square root of the Mean Square of the Error (from the ANOVA table). To  
214 check for reproducibility of the panel, samples of the same wine at different sessions were used,  
215 and the reproducibility index ( $I_R$ ) was computed as inversely related to the square root of the Mean  
216 Square of the Error (from the ANOVA table). To check the homogeneity of the panel, the  
217 homogeneity index ( $I_H$ ) was calculated as inversely related to the square root of the Mean Square  
218 of the Interaction (from the ANOVA table). Finally, to check the discriminant capacity or ability  
219 to discriminate of the panel, two tests were carried out: a three-way ANOVA (samples, assessors,  
220 sessions) and a discriminant analysis (DA). This verification was performed at the beginning of  
221 the panel's operation, as it is a requirement of the ISO 17025 standard (ISO, 2017b) for which the  
222 sensory lab is accredited (Accreditation number 941/ LE 1830, 2019) by ENAC (National  
223 Accreditation Entity, Spain). The concepts of repeatability and reproducibility may vary  
224 depending on the source consulted. In this work, the definitions provided in ISO 11132:2017 have  
225 been used, which have been extended in the new version of the same standard (ISO 11132:2022)  
226 to include other options such as the assessment of reproducibility by comparison between panels.  
227 One of the best ways to validate the developed color grids, would have been by means of a  
228 proficiency test involving other sensory labs. However, since we did not have access to this type  
229 of test, the instrumental measurement of the color of the samples was chosen instead. This  
230 approach has some limitations as already mentioned previously in this paper, especially  
231 considering that sensory perception of the color is more complex than the simple light absorbance  
232 at certain wavelength. Although sensory and instrumental analyses of the wine color may capture  
233 different nuances, there should be some relationship between the two measurements. In our  
234 opinion, a certain degree of agreement between both measurements can be regarded as the  
235 minimum requirement the panel should comply with to validate it. Consequently, color of a total  
236 of 81 wines were analyzed both sensorial and instrumentally (28 white wines, 19 rosé wines and

237 34 red wines). These wines were chosen among commercial samples that are routinely analyzed  
238 in the sensory lab from the Catalan Institute of Vine and Wine (INCAVI) with the aim of covering  
239 a wide range of the involved PDOs wines and to have samples located in different places in the  
240 reference grids (different colors).  
241 Finally, to verify that the use of the grids was useful for the wine industry (PDOs involved in the  
242 present study), the color of a total of 2,353 wines of different types and PDOs (958 white wines,  
243 345 rosé wines, and 1,050 red wines) were assessed. These wines were real wines samples  
244 analyzed from 2021 to 2023 by the panel using the reference grids already described and the  
245 corresponding accredited method according to ISO 17025 (ISO, 2017b).

246

### 247 *2.3.1. Sensory analysis of the color*

248 For the visual evaluation of the color, transparent tasting glasses (Sensus model, Schott-Zwiesel,  
249 Germany, standardized according to the DIN standard 10960 (DIN, 1981)) with a double  
250 reference mark were used. The first mark at 50 ml indicates the volume of wine to be evaluated,  
251 and the second mark indicates the tilt point (45°) to which the evaluator should tilt the glass  
252 (Hernández et al., 2009; Sáenz Gamasa et al., 2009). The two markers were located at 90 degrees  
253 from each other so as not to overlap when assessing the sample (Figure 4a). Evaluators had to  
254 hold the tilted glass 30 cm placed below the light source in the direction of the front wall of the  
255 sensory booth (Hensel et al., 2023). In this position the wine surface formed an ovoid shape  
256 (Figure 4b) where two main zones can be distinguished and evaluated: the centroid of the ovoid  
257 (maximum wine depth) and the upper semicircle of the glass (minimum wine depth). The zone  
258 with the highest wine volume gives information about color intensity, which most authors define  
259 as depth. Evaluators assessed the sample visually by direct comparison with the developed  
260 reference grid using the coordinates defined in it. This color coordinate was named as Color  
261 Intensity (CI). In the same way, the zone with low wine volume was defined as rim zone, which  
262 gives information about wine hue and was identified as Color Hue (CH) (Etaio et al., 2008;  
263 Jackson, 2017).

264

265 All the evaluations were carried out in a standardized sensory booth (ISO, 2010) equipped with a  
266 lamp on the front wall with a controlled illumination type daylight of 8 watts, with a color  
267 temperature of 6500 K (Meicon, Madrid, Spain). The color rendering index (CRI) was 95 and  
268 samples were assessed on a white background.

269

### 270 2.3.2. *Instrumental measurements*

271 The spectrophotometric measurement of the samples was performed according to the official  
272 method established in the OIV Compendium of International Methods of Wine and Must Analysis  
273 (OIV, 2022). A Perkin Elmer spectrophotometer, model Lambda 25 UV/VIS Spectrometer, was  
274 used. The software used was UV WINLAB version 2.85.04 (Perkin Elmer, Inc.) together with the  
275 program COLVIN ver. 1.00.04.

276

277 According to the recommendation of the official method (OIV, 2022), the measurements for white  
278 and rosé wines were taken in a 10 mm glass cuvette, while for red wines a 1 mm cuvette was  
279 used. All wines were filtered with 45µm PTFE microporous membrane filter (Filter-Lab, Filtros  
280 Anoia, S.A., Barcelona, Spain) before being analyzed.

281

282 The instrumental parameters retained were the coordinates a\*(red-green color), b\* (yellow-blue  
283 color), L\* (lightness), C\* (chroma) and h\* (hue angle) of the CIELAB System. These parameters  
284 are normally well correlated with the sensory measurements (Hernandez et al. 2009; Sáenz  
285 Gamasa et al. 2009).

286

### 287 2.4. Statistical analysis

288 The analysis of the color data was carried out by means of a principal component analysis on the  
289 correlation matrix. To determine the relationship between sensory and instrumental  
290 measurements, a Pearson's simple correlation analysis was performed. To check the performance  
291 of the panel, two-way and three-way analysis of variance were carried out. Discriminant analysis

292 was also used to test for discriminant ability. All statistical analyses were completed using  
293 XLSTAT software, version 2020.1 (2020) (Addinsoft, Paris, France).

294

295

### 296 **3. Results**

297

298 The visual references developed were made up of three color grids or palettes, one for white  
299 wines, one for rosé wines and one for red wines, covering all types of wines, from young to aged,  
300 including the full range of sweet wine colors (Figures 5, 6 and 7). These grids were developed  
301 from the farthest points (colors) per quadrant in both dimensions obtained in the different PCAs.  
302 Each palette consisted of a 9x9 color grid, so each of them were made up of a total of 81 different  
303 colors. By using this system, color intensity (center of the ovoid) and color hue (wine rim) of each  
304 wine is given by a pair of coordinates (CI(x), CI(y)) and (CH(x), CH(y)) respectively.

305 Figure 5 to 7 also shows where the different PDO wines evaluated since 2021 and those used for  
306 the validation process are located. The total number of PDO wines evaluated were 2,353, from  
307 which 958 were white wine, 345 were rosé wines, and 1,050 were red wines. As can be seen in  
308 these figures, the assessed wine samples analyzed during this period (2021 to 2023) covered a  
309 good part of the available color space. None of the evaluated samples had to be left out of the  
310 described color spaces. Figure 5 shows that most of the white wines evaluated are distributed on  
311 the left side of the palette. In addition, mean color hue coordinates (CHx and CHy) were located  
312 apart from those corresponding to color intensity (CIx and CIy) (Table 3). In the case of red wines,  
313 a homogeneous distribution of the evaluated wines, which cover the whole grid, can be observed  
314 (Figure 7). Again, the intensity coordinates were located in different place than their  
315 corresponding values of the color hue coordinates (Table 3). Figure 6 shows that the evaluated  
316 rosé wines are distributed throughout the palette and the distinction between color intensity and  
317 color hue is not as evident as in the case of white or red wines (Table 3).

318 Table 4 shows the criteria and results obtained when assessing the performance of the panel as a  
319 whole. For all types of wine and for all visual attributes of color intensity (CIx, CIy) and color

320 hue (CH<sub>x</sub>, CH<sub>y</sub>), the values obtained for the repeatability index (I<sub>r</sub>), the reproducibility index (I<sub>R</sub>)  
321 and the homogeneity index (I<sub>H</sub>) were within the established values previously defined and  
322 accepted by the ENAC (National Accreditation Entity, Spain). The results obtained for the  
323 discriminating capacity of the panel also showed significant differences between some of the  
324 samples ( $p < 0.05$ ) for all the attributes studied. Moreover, the results of the discriminant analysis  
325 (DA) show a percentage of correct classification of the samples (confusion matrix) for all types  
326 of wines (white, rosé and red) higher than the minimum value previously defined (66.6%) and  
327 accepted by the ENAC.

328

329 Finally, tables 5, 6 and 7 show the Pearson correlation coefficients obtained between sensory and  
330 instrumental variables for white, rosé and red wines respectively.

331 The results obtained indicate that the correlation between the two sensory dimensions (x and y  
332 axes) of both visual parameters evaluated was always low and not significant except for the white  
333 wine, where a significant correlation between both axes of 0.42 was observed (CH). In all cases,  
334 a high correlation coefficients (higher than 0.77) were obtained between the color of the center of  
335 the ovoid (CI) and the rim (CH). In any case these two parameters are supposed to assess different  
336 color nuances. Most of the instrumental parameters were highly correlated (between 0.60 and  
337 0.96) with the sensory parameters, but mainly with one of the color dimensions evaluated (x-axis  
338 in the case of white and rosé wines and y-axis in the case of red wines). The only instrumental  
339 parameter that related differently to sensory color depending on the wine color (white, rosé or  
340 red) was hue angle (h\*).

341

#### 342 **4. Discussion**

343

344 This paper proposes some references for color evaluation of wines, with the purpose of making  
345 the assessor's evaluation easier and as objective as possible. According to Guzman (2010), the  
346 observer (individual performance), the light source (illumination conditions), the object (wine  
347 sample) and the angle at which it is observed (wine glass tilted at 45°) are the basic elements to

348 be controlled to perform a valid sensory analysis. As stated by Hensel et al (2023), the subjective  
349 nature of human beings underlines the need of an objective and reliable parameter that reflects  
350 the human perception. In this sense, providing reference standards are the best way to ensure that  
351 the scores given by a panel are objective and comparable, thus increasing at the same time the  
352 panel performance (Rainey, 1986). The developed references should allow the evaluation of the  
353 wine by direct comparison in the specified environmental conditions, being part of the  
354 methodology itself.

355

356 A total of 2,353 wines of different types (young, aged, sparkling and dessert wines) and PDOs  
357 (those existing in Catalonia, Spain) have been sensory evaluated using the developed references.  
358 Figures 5, 6 and 7 show that absolutely all these wines fitted into the proposed grids, and they  
359 were well distributed throughout the available two-dimensional space. The coordinates  
360 corresponding to the color hue are located systematically in different place than the color intensity  
361 coordinates, thus indicating that the wine color can be divided into the two defined parameters  
362 (CI and CH), both measured in the same grid. The high correlation coefficient obtained between  
363 the color intensity value (CI) and color hue (CH), both for all wines (values between 0.988 and  
364 0.765) and for those used in the validation process (values between 0.996 and 0.773) seems to  
365 indicate that, in our case, these two measures (center and rim) might be redundant. Even though  
366 these correlations have been important and significant in all cases, technical specifications of the  
367 Catalan PDOs included both parameters (hue and intensity) as quality requirements, so from a  
368 commercial perspective both values should be kept. In the other hand the low correlation observed  
369 between the two dimensions (x and y) of the reference grids for both, color hue and color intensity  
370 (values between 0.406 and 0.081 and between 0.418 and 0.005 for all the wines and for those of  
371 the validation process respectively), indicates the necessity and usefulness of the two-dimensional  
372 grid proposed in this study. In fact, the use of two dimensions coincides with other authors such  
373 as Fairchild (2023), who demonstrated that a two-dimensional solution is necessary to provide an  
374 effective representation of the color of the wine. In the same vein, the “Nuancier of Provence”

375 (Pouzalgues, 2006) proposed a two-dimensional color reference chart to describe the rosé wines  
376 of Provence.

377

378 Regarding the validation of the different color grids, it is worth mentioning that when comparing  
379 the sensory values ( $CI(x)$ ,  $CI(y)$ ,  $CH(x)$ ,  $CH(y)$ ) with the instrumental values ( $L^*$ ,  $a^*$ ,  $b^*$ ,  $C^*$ ,  $h^*$ ),  
380 the instrumental data were only related with one dimension of the sensory perception (“x” axis  
381 for white and rosé color grids and “y” axis for red color grid). This single-dimensional correlation  
382 of instrumental and sensory measurements seems to indicate that sensory data provides a richer  
383 and complex information than that given by the instrumental approach. This result agrees with  
384 Martin et al. (2007) who observed good agreement between instrumental techniques, but some  
385 discrepancies when comparing these results with the sensory evaluation of the assessors,  
386 especially with respect to the hue parameter. Thus, instrumental analysis seems to not express the  
387 complete visual sensation perceived by the eye of the observers (Pouzalgues, 2006).

388

389 As shown in Table 5 and 6, for white and rosé wines, sensory and instrumental correlations were  
390 mostly explained on x-coordinate axis, whereas for red wines (Table 7) correlations were mostly  
391 explained on y-coordinate axis. A different behavior has only been observed in the case of the  
392 instrumental parameter  $h^*$  in rosé wines, which in contrast to the parameters  $a^*$ ,  $b^*$ ,  $L^*$  and  $C^*$ ,  
393 shows a higher correlation with the y-axis. According to Guzman (2010) the  $h^*$  value in wine  
394 allows to differentiate between red/rosé wines and white wines, but not between red and rosé  
395 wines, because  $h^*$  can have very similar values when comparing rosé and intense red samples.  
396 However, according to the same author, it does allow to differentiate between red wines, e.g.  
397 young red wines and aged red wines.

398 According to the definition of validation (ISO, 2017a) it has been verified that the sensory color  
399 data correlate with other color data on the same wine samples (e.g. measured by spectrophotometric  
400 methods) and also that the panel is able to meet the previously set performance criteria  
401 (repeatability index, reproducibility index, homogeneity index and discriminant capacity).

402 The panel performance when using the color grids developed in the present work demonstrates  
403 that their use was effective during the training of the assessors and during the subsequent  
404 evaluation of different samples. This reference evaluation process was also complemented by the  
405 results obtained and shown during the evaluation of commercial samples.

406

## 407 **5. Conclusions**

408

409 This work contributes to the development of visual color references for descriptive sensory  
410 analysis of white, rosé and red wines, which in wine are currently non-existent at the international  
411 level. Specifically, three color grids have been created and validated. The developed references  
412 could be a first step towards the standardization of a methodology for color assessment.  
413 Considering the results obtained from the sensory analysis of 2,353 wines, the usefulness of using  
414 two measures, hue and intensity, is questioned. It would be interesting to verify the existence of  
415 correlations between these two parameters in wines from other geographical areas and varieties  
416 different from those of the 11 PDOs included in this study. This would allow to check whether  
417 these results can also be extrapolated to other types of wines and PDOs. At the end, this  
418 simplification would mean a reduction of the evaluation time and the effort required to assess the  
419 color of the samples.

420 According to the high number of real samples already assessed, the color references (grids)  
421 described seems to be a useful and objective tool for the visual analysis performed by trained  
422 assessors, at least for the 11 PDOs involved in the present study. This tool can be used when  
423 training new panel evaluators for official control of PDO wines, for the characterization of wine  
424 typologies, grape varieties, and different production areas, or can even help winemakers to  
425 perform internal control during the elaboration process (as aging or color evolution). The method  
426 described in this paper has been applied within the Catalan Institute of Vine and Wine (INCAVI)  
427 under the accreditation ISO 17025 (ISO, 2017b) since 2019.

428 From a practical perspective of applying the method at a commercial level, the main limitation of  
429 the described procedure lies in how to translate the color coordinates obtained into the qualitative

430 terms included in the specifications of the different PDOs (tile red, straw yellow, etc.). This is a  
431 partially solved issue on which we are still working.

432

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439

### 440 **References**

441 Bouchard Ainé et Fils (Beaume, France). Retrieved from [https://www.bouchard-aïne.fr/en/e-](https://www.bouchard-aïne.fr/en/e-shop.r-355/our-wine-posters.r-109/les-couleurs-du-vin.p-10.html)  
442 [shop.r-355/our-wine-posters.r-109/les-couleurs-du-vin.p-10.html](https://www.bouchard-aïne.fr/en/e-shop.r-355/our-wine-posters.r-109/les-couleurs-du-vin.p-10.html) . Accessed July 2023.

443 Cayla, L., Poulzagues, N., & Masson, G. (2010). Connaissance et maîtrise de la couleur des vins  
444 rosés. In *Proceedings of the 33rd World Congress Vine and Wine, Telavi, GA, USA* (15-19).

445 CIE (1986). Commission Internationale de l'Eclairage.(1986). *Colorimetry, 2nd Ed.- Publication*  
446 *CIE 15.2*. Vienna Austria

447 DIN (1981). Standard DIN 10960:1981-12. Apparatus for sensory analysis; wine-tasting glasses.  
448 Beuth Verlag GmbH, Berlin, Germany

449

450 EC (2023). eAmbrosia. EU geographical indications register. European Commission. (Version  
451 2.9.2 - 26/05/2023). Retrieved from [https://ec.europa.eu/info/food-farming-fisheries/food-safety-](https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/geographical-indications-register/)  
452 [and-quality/certification/quality-labels/geographical-indications-register/](https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/geographical-indications-register/) . Accessed August  
453 2023.

454 Etaio, I., Pérez Elortondo, F. J., Albisu, M., Gaston, E., Ojeda, M., & Schlich, P. (2008).  
455 Development of a quantitative sensory method for the description of young red wines from Rioja  
456 Alavesa. *Journal of Sensory Studies*, 23(5), 631-655. [https://doi.org/10.1111/j.1745-](https://doi.org/10.1111/j.1745-459X.2008.00177.x)  
457 [459X.2008.00177.x](https://doi.org/10.1111/j.1745-459X.2008.00177.x)

458 EU (2023) Official website of the European Union. Agriculture and rural development section.  
459 Retrieved from <https://agriculture.ec.europa.eu/farming/geographical-indications-and-quality->  
460 [schemes/geographical-indications-and-quality-schemes-explained en](https://agriculture.ec.europa.eu/farming/geographical-indications-and-quality-schemes/geographical-indications-and-quality-schemes-explained_en) . Accessed on July 2023.

461 Hensel, M., Scheiermann, M., Fahrner, J., Durner, D. (2023). New Insights into Wine Color  
462 Analysis: A Comparison of Analytical Methods to Sensory Perception for Red and White Varietal  
463 Wines. *Journal of Agricultural and Food Chemistry* DOI: 10.1021/acs.jafc.3c01284

464 Hernandez, B., Saenz, C., de la Hoz, J. F., Alberdi, C., Alfonso, S., & Dineiro, J. M. (2009).  
465 Assessing the color of red wine like a evaluator's eye. *Color Research & Application*, 34(2), 153-  
466 162. <https://doi.org/10.1002/col.20475>

467 iColorpalette (2023). Retrieved from <https://icolorpalette.com/color>. Accessed on September  
468 2023.

469 ISO (2008). European Standard ISO 5492:2008. Sensory analysis — Vocabulary. International  
470 Organization for Standardization. Geneva, Switzerland.

471 ISO (2010). European Standard 8589: 2010. Sensory analysis. General guidance for the design of  
472 test rooms. International Organization for Standardization. Geneva, Switzerland.

473 ISO (2017a). European Standard UNE-EN ISO 11132. Sensory analysis. Methodology.  
474 Guidelines for the measurement of the performance of a quantitative descriptive sensory panel.  
475 International Organization for Standardization. Geneva, Switzerland.

476 ISO (2017b). European Standard UNE-EN ISO 17025: General requirements for the competence  
477 of testing and calibration laboratories. Geneva: International Organization for Standardization.  
478 International Organization for Standardization. Geneva, Switzerland.

479 Jackson, S. R. (2017). *Wine Tasting: A Professional Handbook*. (3<sup>rd</sup> ed.). Elsevier Science Ltd,  
480 London. United Kingdom. ISBN: 978-0-12-801813-2

481 Fan, S., Liu, C., Li, Y., & Zhang, Y. (2023). Visual Representation of Red Wine Color:  
482 Methodology, Comparison and Applications. *Foods*, 12(5), 924.  
483 <https://doi.org/10.3390/foods12050924>

484 Fairchild, M. D. (2018). The colors of wine. *Int. J. Wine Res*, 10, 13-31.  
485 <https://doi.org/10.2147/IJWR.S161891>

486 Fairchild, M. D. (2023). Visual and photographic assessment of wine color. *Color Research &*  
487 *Application*, 48(1), 21-31. <https://doi.org/10.1002/col.22787>

488 Glories, Y. (1984). La couleur des vins rouges. 2e partie : mesure, origine et interprétation. *OENO*  
489 *One*, 18(4), 253–271. <https://doi.org/10.20870/oeno-one.1984.18.4.1744>

490 Gomis-Bellmunt, A., Claret, A., Puig-Pujol, A., Pérez-Elortondo, F.J. and Guerrero, L., (2022)  
491 Development of a Descriptive Profile and References for the Assessment of Taste and Mouthfeel  
492 Descriptors of Protected Designation of Origin Wines. *Foods* 11,  
493 2970. <https://doi.org/10.3390/foods11192970>

494 Guzmán, M. (2010). Manual de espectrofotometría en enología. 1<sup>st</sup> edition. A. Madrid Vicente  
495 Ediciones. Madrid, Spain. ISBN: 978-84-96709-54-6

496 Hensel, M., Scheiermann, M., Fahrer, J., & Durner, D. (2023). New Insights into Wine Color  
497 Analysis: A Comparison of Analytical Methods to Sensory Perception for Red and White Varietal  
498 Wines. *Journal of Agricultural and Food Chemistry*. <https://doi.org/10.1021/acs.jafc.3c01284>

499 Hernández, B., Saenz, C., de la Hoz, J. F., Alberdi, C., Alfonso, S., & Dineiro, J. M. (2009).  
500 Assessing the color of red wine like a evaluator's eye. *Color Research & Application*: 34(2), 153-  
501 162. <https://doi.org/10.1002/col.20475>

502 Hutchings, J. (2002). The perception and sensory assessment of colour. In *Colour in Food*;  
503 Woodhead Publishing: Cambridge, UK, 9–32. Doi:10.1533/9781855736672.1.9.

504 Lawless, H., Heymann, H. (2010). Color and Appearance. In: *Sensory Evaluation of Food*. Food  
505 Science Text Series. Springer, New York, NY. [https://doi.org/10.1007/978-1-4419-6488-5\\_12](https://doi.org/10.1007/978-1-4419-6488-5_12)

506 Martin, M. L. G.-M., Ji, W., Luo, R., Hutchings, J., & Heredia, F. J. (2007). *Measuring colour*  
507 *appearance of red wines. Food Quality and Preference*, 18(6), 862–  
508 871. doi:10.1016/j.foodqual.2007.01.013

509 Munsell A. H., (1913) The Atlas of the Munsell Color System. Munsell Color Co., Baltimore,  
510 Mary-land, USA (<https://munsell.com/color-blog/atlas-color-system-charts/>)

511 OIV (2022). Compendium of International Analysis of Methods-OIV Chromatic Characteristics-  
512 Method OIV-MA-AS2-11 Determination of chromatic characteristics according to CIELab;  
513 International Organisation of Wine and Vine: Paris, France(2022). Retrieved from

514 <https://www.oiv.int/standards/compendium-of-international-methods-of-wine-and-must->  
515 [analysis/annex-a-methods-of-analysis-of-wines-and-musts/section-2-physical-](https://www.oiv.int/standards/compendium-of-international-methods-of-wine-and-must-analysis/annex-a-methods-of-analysis-of-wines-and-musts/section-2-physical-)  
516 [analysis/chromatic-characteristics-%28type-i%29](https://www.oiv.int/standards/compendium-of-international-methods-of-wine-and-must-analysis/chromatic-characteristics-%28type-i%29)

517 OJEU (2012). Regulation (EU) No 1151/2012 of the European Parliament and of the Council of  
518 21 November 2012 on quality schemes for agricultural products and foodstuffs. Official Journal  
519 of the European Union, 14.12.2012, L 343/1. Retrieved from  
520 <http://data.europa.eu/eli/reg/2012/1151/oj>

521 OJEU (2013). Regulation (EU) No 1308/2013 of the European Parliament and of the Council of  
522 17 December 2013 establishing a common organization of the markets in agricultural products  
523 and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and  
524 (EC) No 1234/2007. Official Journal of the European Union. 20.12.2013, L 347/671. Retrieved  
525 from <http://data.europa.eu/eli/reg/2013/1308/oj>

526 OJEU (2019). Commission Delegated Regulation (EU) 2019/33 of 17 October 2018  
527 supplementing Regulation (EU) No 1308/2013 of the European Parliament and of the Council as  
528 regards applications for protection of designations of origin, geographical indications and  
529 traditional terms in the wine sector, the objection procedure, restrictions of use, amendments to  
530 product specifications, cancellation of protection, and labelling and presentation. Official Journal  
531 of the European Union 11.1.2019, L9/2. Retrieved from  
532 [http://data.europa.eu/eli/reg\\_del/2019/33/oj](http://data.europa.eu/eli/reg_del/2019/33/oj)

533 Pouzalgues, N. (2006). Comment décrire les vins rosés de Provence Les descripteurs visuels  
534 (3). *Rosé. com*, 9.

535 Pridmore, R. W. (2005). Color variability of wine in a glass, and general comments on contrast  
536 effects. *Color Res Appl*, 30, 146–149. <https://doi.org/10.1002/col.20093>

537 Rainey, B. A. (1986). Importance of reference standards in training panelists. *J. Sensory Stud.*, 1,  
538 149-154. <https://doi.org/10.1111/j.1745-459X.1986.tb00167.x>

539 Sáenz Gamasa, C., Hernández, B., de Santiago, J. V., Alberdi, C., Alfonso, S., & Diñeiro, J. M.  
540 (2009). Measurement of the colour of white and rosé wines in visual tasting conditions. *European*  
541 *Food Research and Technology*, 229, 263-276. <https://doi.org/10.1007/s00217-009-1050-z>

542 Wine Folly (2013). Wine color chart <https://winefolly.com/tips/wine-color-chart/>. Consulted  
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546 **Conflict of Interest Statement**

547 The authors declare that there is no conflict of interest.

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555 **Authorship Statements**

556 Anna Gomis- Bellmunt: Conceptualization, Methodology, Formal analysis, Writing – original  
557 draft, Writing – review, Editing, Resources, Project administration & Funding acquisition. Luis  
558 Guerrero: Conceptualization, Methodology, Formal analysis, Supervision & editing. Anna Claret:  
559 Methodology & Writing – review. Francisco José Pérez- Elortondo: Conceptualization,  
560 Supervision, Writing – review & editing. All authors have read and agreed to the published  
561 version of the manuscript.

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563

564 **Ethical Statements**

565 The study was approved by the Ethical Committee of the Institute of Agrifood Research and  
566 Technology (IRTA), registration number CCSC 23/2022, in accordance with the Code of Ethics  
567 of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

**Table 1.** Colour coordinates for white wine and red wines, chosen by the tasters and converted into hexadecimal (HEX) format and RGB system. N refers to the maximum number of tasters who coincided in the choice of the PMS (Pantone ID) colour code.

White wine colour codes				Red wine colour codes			
PMS	N	HEX	RGB	PMS	N	HEX	RGB
PMS100	17	f4ed7c	244,237,124	PMS188	17	7c2128	124,33,40
PMS106	17	f7e859	247,232,89	PMS194	17	992135	153,33,53
PMS109	18	f9d616	249,214,22	PMS195	17	772d35	119,45,53
PMS113	17	f9e55b	249,229,91	PMS202	17	8c2633	140,38,51
PMS116	17	fcd116	252,209,22	PMS207	18	af003d	175,0,61
PMS121	17	f9e070	249,224,112	PMS208	18	8e2344	142,35,68
PMS122	17	fcd856	252,216,86	PMS209	18	75263d	117,38,61
PMS123	18	ffc61e	255,198,30	PMS215	18	a50544	165,5,68
PMS128	17	f4db60	244,219,96	PMS216	18	7c1e3f	124,30,63
PMS129	17	f2d13d	242,209,61	PMS221	17	930042	147,0,66
PMS130	18	eaaf0f	234,175,15	PMS222	18	70193d	112,25,61
PMS137	17	fca311	252,163,17	PMS228	17	8c004c	140,0,76
PMS138	18	d88c02	216,140,2	PMS242	17	7c1c51	124,28,81
PMS601	17	f2ed9e	242,237,158	PMS484	17	9b301c	155,48,28
PMS602	17	f2ea87	242,234,135	PMS491	17	752828	117,40,40
PMS810	17	ffcc1e	255,204,30	PMS492	17	913338	145,51,56
PMS1205	17	f7e8aa	247,232,170	PMS505	17	661e2b	102,30,43
PMS1235	17	fc514	252,181,20	PMS506	17	7a2638	122,38,56
PMS167	17	bc4f07	188,79,7	PMS683	17	7f284f	127,40,79
				PMS690	17	702342	112,35,66
				PMS1805	17	af2626	175,38,38
				PMS1807	17	a03033	160,48,51
				PMS1945	18	a80c35	168,12,53
				PMS1955	17	931638	147,22,56

**Table 2.** Colour coordinates, for rosé wines, chosen by the tasters and converted into hexadecimal (HEX) format and RGB system. N refers to the maximum number of tasters who coincided in the choice of the PMS (Pantone ID) colour code.

Rosé wine colour codes											
PMS	N	HEX	RGB	PMS	N	HEX	RGB	PMS	N	HEX	RGB
PMS032	17	ef2b2d	239,43,45	PMS206	18	d30547	211,5,71	PMS707	18	fcadaf	252,173,175
PMS148	17	ffd69b	255,214,155	PMS207	17	af003d	175,0,61	PMS708	18	f98e99	249,142,153
PMS149	18	fcc93	252,204,147	PMS217	18	f4bfd1	244,191,209	PMS709	18	f26877	242,104,119
PMS162	17	f9c6aa	249,198,170	PMS486	18	ed9e84	237,158,132	PMS710	18	e04251	224,66,81
PMS163	18	fc9e70	252,158,112	PMS487	18	efb5a0	239,181,160	PMS1345	18	ffd691	255,214,145
PMS164	18	fc7f3f	252,127,63	PMS488	18	f2c4af	242,196,175	PMS1355	17	fcce87	252,206,135
PMS169	18	f9baaa	249,186,170	PMS493	18	db828c	219,130,140	PMS1485	18	ffb777	255,183,119
PMS170	18	f98972	249,137,114	PMS494	18	f2adb2	242,173,178	PMS1555	18	f9bf9e	249,191,158
PMS171	18	f9603a	249,96,58	PMS495	18	f4bcbf	244,188,191	PMS1565	17	fca577	252,165,119
PMS176	17	f9afad	249,175,173	PMS496	17	f7c9c6	247,201,198	PMS1575	18	fc8744	252,135,68
PMS177	17	f9827f	249,130,127	PMS501	17	eab2b2	234,178,178	PMS1625	17	f9a58c	249,165,140
PMS178	18	f95e59	249,94,89	PMS502	18	f2c6c4	242,198,196	PMS1635	17	f98e6d	249,142,109
PMS179	17	e23d28	226,61,40	PMS503	18	f4d1cc	244,209,204	PMS1645	18	f97242	249,114,66
PMS182	18	f9bfc1	249,191,193	PMS508	17	e8a5af	232,165,175	PMS1765	18	f99ea3	249,158,163
PMS183	18	fc8c99	252,140,153	PMS517	17	f4ccd8	244,204,216	PMS1767	17	f9b2b7	249,178,183
PMS184	18	fc5e72	252,94,114	PMS670	17	f2d6d8	242,214,216	PMS1775	18	f9848e	249,132,142
PMS185	18	e8112d	232,17,45	PMS671	18	efc6d3	239,198,211	PMS1777	18	fc6675	252,102,117
PMS186	18	ce1126	206,17,38	PMS672	18	eaac4	234,170,196	PMS1785	18	fc4f59	252,79,89
PMS187	18	af1e2d	175,30,45	PMS678	18	eacce	234,204,206	PMS1787	18	f43f4f	244,63,79
PMS189	18	ffa3b2	255,163,178	PMS679	18	e5bfc6	229,191,198	PMS1788	18	ef2b2d	239,43,45
PMS190	17	fc758e	252,117,142	PMS684	17	efcce	239,204,206	PMS1795	18	d62828	214,40,40
PMS191	17	f4476b	244,71,107	PMS692	17	e8bfba	232,191,186	PMS1797	18	cc2d30	204,45,48
PMS192	18	e5053a	229,5,58	PMS693	18	dba8a5	219,168,165	PMS1805	18	af2626	175,38,38
PMS193	17	bf0a30	191,10,48	PMS698	17	f7d1cc	247,209,204	PMS1895	17	fcbf9	252,191,201
PMS196	18	f4c9c9	244,201,201	PMS699	18	f7bfbf	247,191,191	PMS1905	18	fc9bb2	252,155,178
PMS197	18	ef99a3	239,153,163	PMS700	18	f2a5aa	242,165,170	PMS1915	18	f4547c	244,84,124

PMS198	18	e5566d	229,86,109	PMS701	18	e8878e	232,135,142	PMS1925	17	e00747	224,7,71
PMS199	17	d81c3f	216,28,63	PMS702	18	d6606d	214,96,109	PMS1935	18	c10538	193,5,56
PMS200	18	c41e3a	196,30,58	PMS705	18	f9ddd6	249,221,214	PMS2365	18	f7c4d8	247,196,216
PMS204	17	ed7a9e	237,122,158	PMS706	18	fcc9c6	252,201,198	PMS4685	18	edd3bc	237,211,188

**Table 3:** Mean colour intensity (CI) and hue (CH) coordinates for white, rosé and red wine

	$\bar{X}_{CI(x)}$	$\bar{X}_{CI(y)}$	$\bar{X}_{CH(x)}$	$\bar{X}_{CH(y)}$
White wine	2.6	6.6	2.1	8.4
Rosé wine	3.4	4.4	2.3	4.6
Red wine	3.5	5.4	2.9	8.5

**Table 5:** Pearson correlation coefficients between sensory and instrumental measurements obtained for white wines.

Variables	CI(x)	CI(y)	CH(x)	CH(y)
CI(x)	<b>1</b>	0.083	<b>0.989</b>	<b>0.497</b>
CI(y)	0.083	<b>1</b>	-0.008	<b>0.773</b>
CH(x)	<b>0.989</b>	-0.008	<b>1</b>	<b>0.418</b>
CH(y)	<b>0.497</b>	<b>0.773</b>	<b>0.418</b>	<b>1</b>
L*	<b>-0.856</b>	0.332	<b>-0.911</b>	-0.101
a*	<b>0.727</b>	<b>-0.495</b>	<b>0.801</b>	-0.091
b*	<b>0.877</b>	-0.268	<b>0.927</b>	0.184
h*	<b>-0.932</b>	0.195	<b>-0.960</b>	-0.224
C*	<b>0.870</b>	-0.281	<b>0.921</b>	0.169

Values in bold are statistically different from zero ( $p \leq 0.05$ ). CI and CH are the sensory analysed parameters corresponding to the Colour Intensity and Hue colour, in each of the x and y dimensions. a\*, b\*, L\*, h\* and C\* are the CIELAB parameters obtained by spectrophotometry.

**Table 6:** Pearson correlation coefficients between sensory and instrumental measurements obtained for rosé wines.

Variables	CI(x)	CI(y)	CH(x)	CH(y)
CI(x)	<b>1</b>	0.354	<b>0.974</b>	-0.019
CI(y)	0.354	<b>1</b>	0.366	<b>0.897</b>
CH(x)	<b>0.974</b>	0.366	<b>1</b>	0.022
CH(y)	-0.019	<b>0.897</b>	0.022	<b>1</b>
L*	<b>-0.947</b>	-0.356	<b>-0.949</b>	-0.055
a*	<b>0.954</b>	0.093	<b>0.940</b>	-0.264
b*	<b>0.792</b>	<b>0.693</b>	<b>0.755</b>	0.438
h*	-0.448	<b>0.604</b>	-0.421	<b>0.765</b>
C*	<b>0.964</b>	0.445	<b>0.932</b>	0.104

Values in bold are statistically different from zero ( $p \leq 0.05$ ). CI and CH are the sensory analysed parameters corresponding to the Colour Intensity and Hue colour, in each of the x and y dimensions. a\*, b\*, L\*, h\* and C\* are the CIELAB parameters obtained by spectrophotometry.

**Table 7:** Pearson correlation coefficients between sensory and instrumental measurements obtained for red wines.

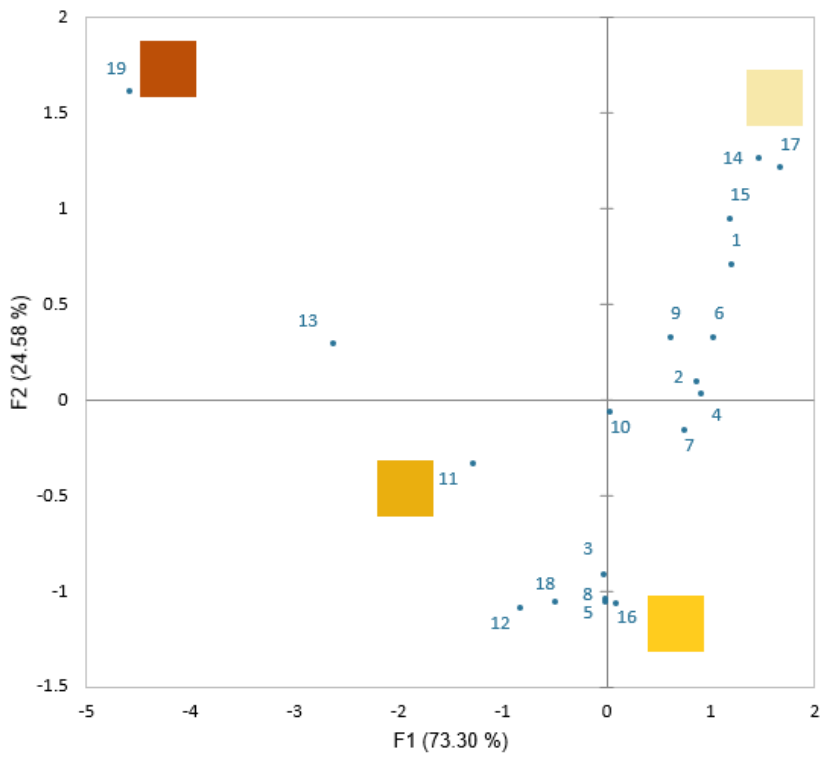
Variables	CI(x)	CI(y)	CH(x)	CH(y)
CI(x)	<b>1</b>	0.060	<b>0.996</b>	-0.030
CI(y)	0.060	<b>1</b>	0.085	<b>0.903</b>
CH(x)	<b>0.996</b>	0.085	<b>1</b>	-0.005
CH(y)	-0.030	<b>0.903</b>	-0.005	<b>1</b>
L*	0.036	<b>-0.870</b>	-0.006	<b>-0.849</b>
a*	-0.015	<b>-0.869</b>	-0.047	<b>-0.856</b>
b*	0.304	<b>-0.599</b>	0.293	<b>-0.601</b>
h*	<b>0.439</b>	<b>-0.414</b>	<b>0.438</b>	<b>-0.449</b>
C*	0.138	<b>-0.780</b>	0.114	<b>-0.769</b>

Values in bold are statistically different from zero ( $p \leq 0.05$ ). CI and CH are the sensory analysed parameters corresponding to the Colour Intensity and Hue colour, in each of the x and y dimensions. a\*, b\*, L\*, h\* and C\* are the CIELAB parameters obtained by spectrophotometry.

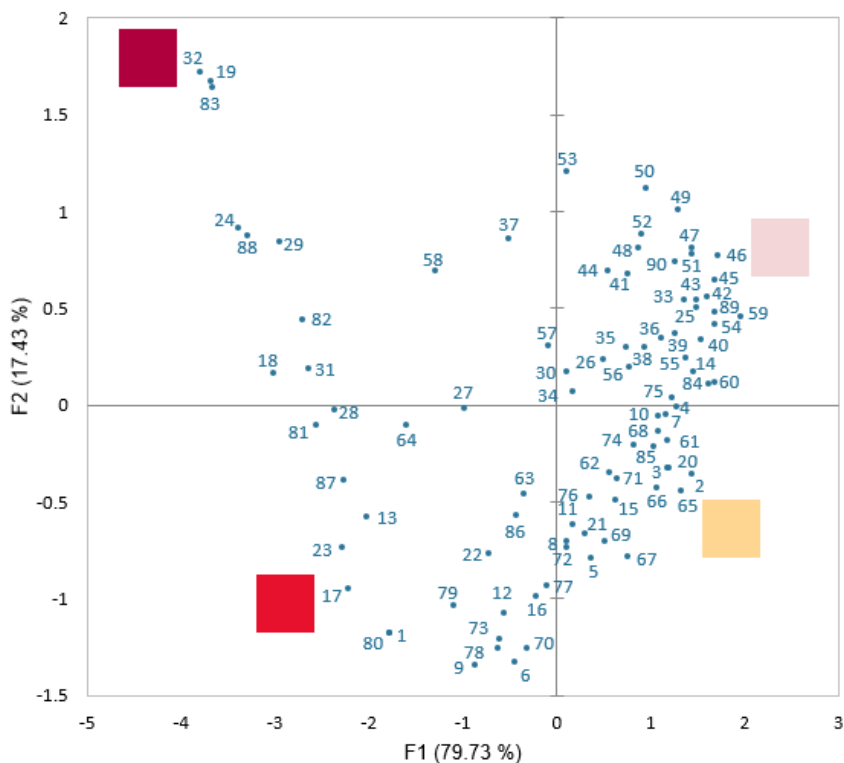
**Table 4:** Results obtained from overall panel performance for white, rosé and red wine

	White wines				Rosé wines				Red wines			
	CI(x)	CI(y)	CH(x)	CH(y)	CI(x)	CI(y)	CH(x)	CH(y)	CI(x)	CI(y)	CH(x)	CH(y)
$I_r$	2.250	1.630	2.183	1.748	2.421	1.333	2.390	1.451	2.598	1.233	2.038	1.044
$I_R$	1.417	1.186	1.443	1.179	0.984	1.220	1.684	1.422	1.745	1.032	1.155	1.124
$I_H$	2.080	1.667	2.264	2.275	2.309	1.552	1.684	1.294	1.311	1.195	1.283	1.548
$P_{(ANOVA)}$	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.009	0.045	<0.0001	<0.0001	<0.0001
% CC <sub>(DA)</sub>	74%				73%				70%			

*CI and CH are the sensory analysed parameters corresponding to the Colour Intensity and Hue colour, in each of the x and y dimensions.  $I_r$  correspond to repeatability index (minimum acceptable value of 0.970),  $I_R$  to the reproducibility index (minimum acceptable value of 0.970),  $I_H$  to the homogeneity index (minimum acceptable value of 1.100).  $p_{(ANOVA)}$  and % CC<sub>(DA)</sub> are parameters to measure the discriminant capacity of the panel:  $p_{(ANOVA)}$  refers to the significance level obtained between samples in the ANOVA test and %CC<sub>(DA)</sub> refers to the percentage of correct sample classification based on 8 types of wines and 3 replicates.*



ID	HEX	F1	F2
1	f4ed7c	<b>0.732</b>	0.253
2	f7e859	<b>0.905</b>	0.010
3	f9d616	0.000	<b>0.827</b>
4	f9e55b	<b>0.979</b>	0.001
5	fcd116	0.000	<b>0.955</b>
6	f9e070	<b>0.894</b>	0.089
7	fcd856	<b>0.908</b>	0.043
8	ffc61e	0.000	<b>0.981</b>
9	f4db60	<b>0.778</b>	0.216
10	f2d13d	0.022	0.083
11	eaaf0f	<b>0.913</b>	0.064
12	fca311	0.305	<b>0.528</b>
13	d88c02	<b>0.982</b>	0.012
14	f2ed9e	<b>0.572</b>	0.427
15	f2ea87	<b>0.609</b>	0.388
16	ffcc1e	0.008	<b>0.991</b>
17	f7e8aa	<b>0.630</b>	0.332
18	fc514	0.169	<b>0.771</b>
19	bc4f07	<b>0.889</b>	0.110

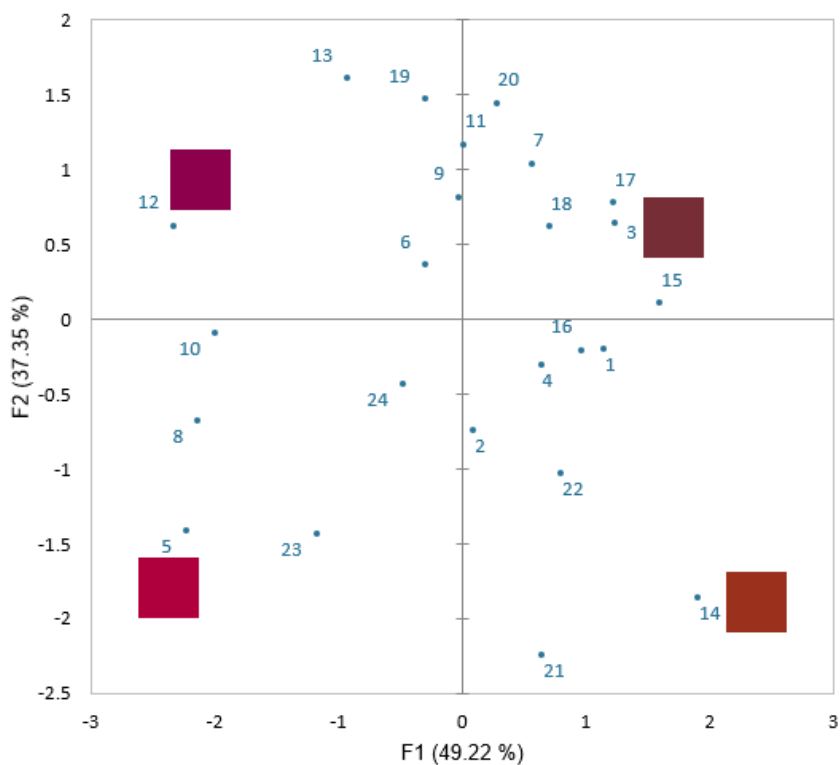


ID	HEX	F1	F2
1	ef2b2d	<b>0.695</b>	0.305
2	ffd69b	<b>0.842</b>	0.053
3	fcc93	<b>0.787</b>	0.061
4	f9c6aa	<b>0.973</b>	0.000
5	fc9e70	0.150	<b>0.685</b>
6	fc7f3f	0.084	<b>0.765</b>
7	f9baaa	<b>0.994</b>	0.002
8	f98972	0.023	<b>0.933</b>
9	f9603a	0.284	<b>0.677</b>
10	f9afad	<b>0.992</b>	0.003
11	f9827f	0.079	<b>0.909</b>
12	f95e59	0.214	<b>0.785</b>
13	e23d28	<b>0.900</b>	0.073
14	f9bfc1	<b>0.979</b>	0.014
15	fc8c99	<b>0.557</b>	0.332
16	fc5e72	0.039	<b>0.846</b>
17	e8112d	<b>0.835</b>	<b>0.153</b>
18	ce1126	<b>0.997</b>	0.003
19	af1e2d	<b>0.819</b>	0.170
20	ffa3b2	<b>0.868</b>	0.065
21	fc758e	0.127	<b>0.623</b>
22	f4476b	0.395	<b>0.439</b>
23	e5053a	<b>0.864</b>	0.091
24	bf0a30	<b>0.933</b>	0.067

ID	HEX	F1	F2
25	f4c9c9	<b>0.897</b>	0.101
26	ef99a3	<b>0.785</b>	0.168
27	e5566d	<b>0.968</b>	0.000
28	d81c3f	<b>0.993</b>	0.000
29	c41e3a	<b>0.925</b>	0.074
30	ed7a9e	0.051	0.152
31	d30547	<b>0.961</b>	0.005
32	af003d	<b>0.829</b>	0.170
33	f4bfd1	<b>0.860</b>	0.114
34	ed9e84	0.223	0.034
35	efb5a0	<b>0.791</b>	0.131
36	f2c4af	<b>0.886</b>	0.085
37	db828c	0.260	<b>0.735</b>
38	f2adb2	<b>0.900</b>	0.091
39	f4bcbf	<b>0.917</b>	0.078
40	f7c9c6	<b>0.953</b>	0.046
41	eab2b2	<b>0.557</b>	0.441
42	f2c6c4	<b>0.864</b>	0.136
43	f4d1cc	<b>0.893</b>	0.107
44	e8a5af	0.382	<b>0.614</b>
45	f4ccd8	<b>0.862</b>	0.127
46	f2d6d8	<b>0.833</b>	0.166
47	efc6d3	<b>0.753</b>	0.239
48	eaaac4	<b>0.515</b>	0.440

ID	HEX	F1	F2
49	eaccce	<b>0.624</b>	0.376
50	e5bfc6	0.420	<b>0.580</b>
51	efccce	<b>0.771</b>	0.229
52	e8bfba	<b>0.513</b>	0.479
53	dba8a5	0.008	<b>0.961</b>
54	f7d1cc	<b>0.941</b>	0.058
55	f7bfbf	<b>0.966</b>	0.030
56	f2a5aa	<b>0.925</b>	0.061
57	e8878e	0.069	<b>0.926</b>
58	d6606d	<b>0.774</b>	0.223
59	f9ddd6	<b>0.948</b>	0.052
60	fcc9c6	<b>0.992</b>	0.005
61	fcadaf	<b>0.960</b>	0.023
62	f98e99	<b>0.652</b>	0.241
63	f26877	0.316	<b>0.564</b>
64	e04251	<b>0.995</b>	0.004
65	ffd691	<b>0.751</b>	0.085
66	fcce87	<b>0.641</b>	0.103
67	ffb777	0.385	<b>0.404</b>
68	f9bf9e	<b>0.927</b>	0.015
69	fca577	0.286	<b>0.548</b>
70	fc8744	0.047	<b>0.764</b>
71	f9a58c	<b>0.701</b>	0.246
72	f98e6d	0.018	<b>0.867</b>

ID	HEX	F1	F2
73	f97242	0.186	<b>0.720</b>
74	f99ea3	<b>0.909</b>	0.056
75	f9b2b7	<b>0.982</b>	0.001
76	f9848e	0.318	<b>0.562</b>
77	fc6675	0.011	<b>0.892</b>
78	fc4f59	0.188	<b>0.781</b>
79	f43f4f	<b>0.514</b>	0.461
80	ef2b2d	<b>0.695</b>	0.305
81	d62828	<b>0.991</b>	0.002
82	cc2d30	<b>0.964</b>	0.025
83	af2626	<b>0.816</b>	0.163
84	fc9bb2	<b>0.973</b>	0.004
85	fc9bb2	<b>0.841</b>	0.037
86	f4547c	0.233	<b>0.423</b>
87	e00747	<b>0.909</b>	0.027
88	c10538	<b>0.933</b>	0.065
89	f7c4d8	<b>0.896</b>	0.073
90	edd3bc	<b>0.719</b>	0.247



ID	HEX	F1	F2
1	7c2128	<b>0.592</b>	0.018
2	992135	0.014	<b>0.842</b>
3	772d35	<b>0.788</b>	0.210
4	8c2633	<b>0.786</b>	0.176
5	af003d	<b>0.706</b>	0.284
6	8e2344	0.099	0.150
7	75263d	0.231	<b>0.766</b>
8	a50544	<b>0.907</b>	0.093
9	7c1e3f	0.001	<b>0.997</b>
10	930042	<b>0.892</b>	0.002
11	70193d	0.000	<b>0.782</b>
12	8c004c	<b>0.908</b>	0.065
13	7c1c51	0.218	<b>0.663</b>
14	9b301c	<b>0.511</b>	0.487
15	752828	<b>0.803</b>	0.004
16	913338	0.454	0.021
17	661e2b	0.363	0.145
18	7a2638	<b>0.567</b>	0.431
19	7f284f	0.025	<b>0.591</b>
20	702342	0.037	<b>0.962</b>
21	af2626	0.076	<b>0.902</b>
22	a03033	0.233	0.383
23	a80c35	0.391	<b>0.588</b>
24	931638	<b>0.508</b>	0.423



(a)



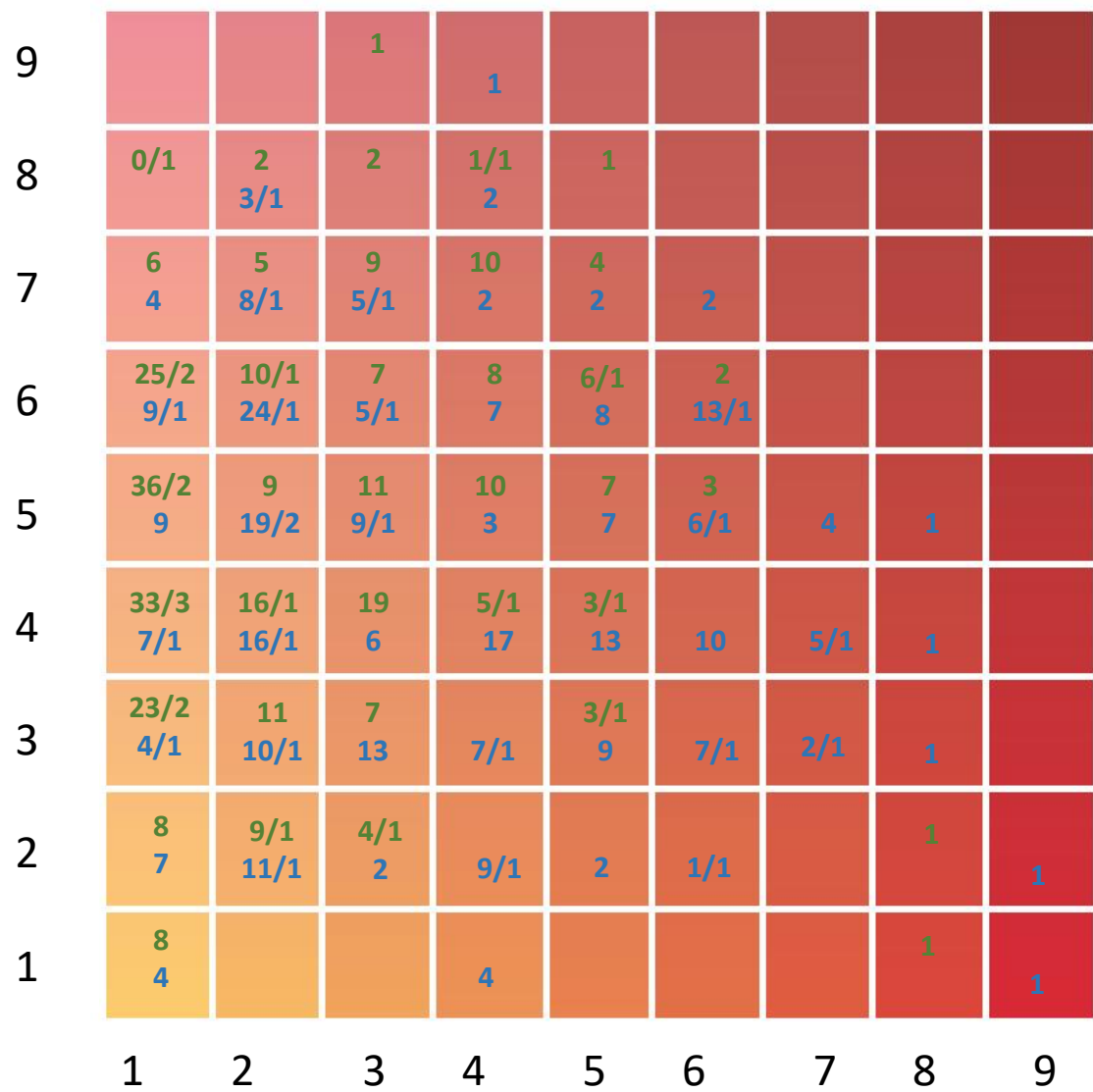
(b)



(c)

9	26/1	6		1 1				1	6/1 12/1
8	229/6 8	167/2 4	16/1 1	6	1			1	3 4
7	67/1 78/3	187/7 69/2	59/2 7	8 2	6	2	1	7/1 2	3
6	3 62/2	48 236/1	32 28	6/1 9	2/2 2	5/1 1	6/1	1 2	1 3/1
5	4/1	6 136/4	4 75/3	3 22	2 5	1 5/1	2 1/1	1/1 3/2	3
4	1	21/1	1 49/2	19/1	7	2 1	1 5/1	2 3	1
3		4	11	3	2	3	2/1	3	
2		2		1			1	1	1
1		1							
	1	2	3	4	5	6	7	8	9

● Colour Intensity (CI) ● Colour Hue (CH)



● Colour Intensity (CI) ● Colour Hue (CH)

9	1	13	14 2	10	10 1	6	1	3	5 1
8	5	44/3 2	57/3 4	44/1 3	39/1	30/1 1	30/1	16 1	4 1
7	21/1 1	59/1 8	88/4 8/1	85/2 6	70/1 8	56/1 1	24/4 1	8/1 1	1 1
6	24 1	45/3 23/1	49/1 21/2	41/1 15/2	35 18	15 10	4/1 2	1/1 2	1
5	13/1 3	15 24/1	7/1 45/3	7 34	5 39	3 30/1	1 24/1	6	1
4	2 7	2 34	1 53/3	68/1	42/2	20/1	19/2	7/1	1
3	1 10/1	1 43	46/3	46	46	29/1	11/1	3	1
2	13/1	39/3	33	23	20	22	7/1	2/1	
1	8	3	2	4	1	2	1		
	1	2	3	4	5	6	7	8	9

● Colour Intensity (CI) ● Colour Hue (CH)