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# Development of a new sensory analysis methodology for predicting wine aging potential. Application to Champagne reserve wines

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## 18 Abstract:

19 A new analysis method was developed to evaluate a sensory concept for food products. The concept "wine aging potential" is used by experts and professionals to describe the inherent capacity of great 20 red or whites to develop qualitatively during aging. Previous authors who studied wine aging potential 21 22 proposed a method of evaluation using a one-dimensional scale. However, during the concept 23 description task, wine aging potential was linked to three dimensions: time; wine quality, and 24 potential. The methods available in quantitative sensory analysis, such as Profile, Free Choice Profile 25 and Flash Profile, do not allow for quantifying more than two dimensions simultaneously. A new, 3-26 dimensional scale and sensory analysis method was developed, based on cognitive definitions from professional tasters concerning the aging potential of champagne reserve wines. 27 28 This method, called "projective categorization," introduces several dependent variables, offering 29 tasters a visual tool to evaluate the projected development of a wine's quality over time on different 30 dynamics. 31 A specific, statistical analysis was developed for significant evaluation of wines and judges. This new 32 tool was tested on 33 champagne reserve wines aged from 1 to 29 years. It demonstrated its capability 33 in distinguishing accurately wines with different aging aptitudes. Indications concerning panel

- 34 consensus and judges' performance were also provided.
- 35 This is the first time that a sensory methodology has been developed on the basis of a sensory concept
- 36 in order to classify products. This method enabled obtaining a precision for categorizing champagne
- 37 reserve wines linked to the judges' consensus. The quality and reliability of the results seemed, in
- agreement with all sensory analysis methods, to be dependent on the number of judges.

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## 40 Keywords:

wine aging potential, sensory analysis, panel performance, wine evolution quality, projectivecategorization

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## 44 **1.** <u>Introduction</u>

45 Aging potential is a concept used by wine tasting experts to evaluate a wine's ability to retain quality and typicity during aging (Coutier, 2013; Hardy, 1990; Langlois et al., 2011). According to this 46 47 positive sensory definition, wines do not all share an equal capacity for aging, indicating the development over time of an aging bouquet. The bouquet denotes a set of aromas which together form 48 49 a perceptive equilibrium of all olfactory sensations, where individual perceptions do not clearly 50 dominate (Peynaud & Blouin, 2006). More precisely, but still applicable to all types of wine, it may be characterized by the loss of fermentative aromas, a variable attenuation of fresh fruity notes (Jackson, 51 52 2009), conservation of varietal aromas, and an evolution towards more complex and subtle new 53 aromas. The result may be a homogenous and more harmonious flavor than that experienced in the 54 first few year(s) after production.

55 In oenology, wine aging potential has been discussed in many scientific publications, as well as in 56 articles on cognitive science and sensory analysis (Jaffré et al., 2009; Langlois et al., 2011; Picard et 57 al., 2015). It has been cited in the definition of aging bouquet in red Bordeaux (Picard et al., 2015) and 58 Burgundy wines (Jaffré et al., 2009; Langlois et al., 2011). Although the aging potential concept has 59 long been used by winemakers (Hardy, 1990), only one scientific article refers to aging potential in 60 white wines (Parr et al., 2011). This is surprising, as the great Chardonnay wines of Burgundy are 61 known for their ability to age and develop specific aromas (Clarke & Rand, 2010; Robinson, 1988). For instance, Chardonnay wines develop a complex bouquet, described by experts using aromatic 62 63 terms such as "hazelnut" and "flint", with overtones of "oatmeal" and "toast" (Gros et al., 2017). Some sparkling Champagne wines also seem to have aging potential. Tominaga et al. (2003) described the 64 65 aging bouquet of these wines with empyreumatic notes of "roasted coffee bean", "grilled", "toast", and 66 "brioche".

67 To identify the sensory dimensions involved in red wine aging potential, Langlois et al. (2010) and 68 Jaffré et al. (2009) compared several tasting panels (experts and novices, accustomed to working with 69 rated and unrated wines). As expected, the expert tasters generally performed better than novices in 70 perception tasks. Experts were more familiar with the stimuli and description tasks, resulting in more 71 consensual, shared vocabulary, as confirmed by other sensory panel studies (Ballester et al., 2008; 72 Bende & Nordin, 1997; Chollet & Valentin, 2000; Hughson & Boakes, 2002; Solomon, 1990, 1997; 73 Urdapilleta et al., 2011; Valentin et al., 2003). Consequently, it has been proven that it is easier for 74 experts to evaluate and describe sensory concepts. Therefore, relying on experts, some studies have

75 identified sensory criteria used to define the aging potential concept in several wine models (Jaffré et 76 al., 2009; Langlois et al., 2011). In red Burgundy wines, the aging potential of young wines is linked 77 to the presence of several markers, including saturated color, high astringency, moderate acidity, and oaky, toasty, and prune aromatic notes (Jaffré et al., 2009). In the case of red Bordeaux wines, markers 78 79 of the aging potential of young wines included similar attributes, such as acidity, astringency, oak, and tannins (Langlois et al., 2011). A lexical analysis performed by Langlois et al. (2011) revealed that 80 81 these four attributes represented 55% of all keywords generated by professionals. All these terms can 82 be classified into three themes: wine characteristics, time and cellaring, and subjective judgment. 83 However, no previous studies have investigated the last two themes.

84 *Time and cellaring* obviously covers the concept of "aging", as well as "young" and "old". The main 85 question asked of the tasters was "how to judge whether a wine is young or old?". This status 86 assessment is based on the wine style, grape variety, geographical area of production, vintage, and 87 even the taster's experience. These parameters are then compared to the sensory age, and evaluated 88 without any pre-conceived ideas (a priori). Sensory age refers to wine age estimation by blind tasting and is based on the taster's experience. In fact, even wines from the same vintage reveal different 89 degrees of aging over time, suggesting that not all wines possess the same positive aging potential. 90 Thus, the definition of a "young" or "old" wine is complex and eminently dependent on the context. 91

92 In the *subjective judgment* theme, "quality" was a frequently-mentioned concept but difficult to define

93 in wine (Amerine & Roessler, 1983; Cadot, 2006; Charters & Pettigrew, 2007; Hopfer & Heymann,
94 2014). Furthermore, the evaluation and prediction of "current quality" and "future quality" was
95 connected to wine aging "time".

At the same time, the level or intensity of the optimal "quality" achieved during aging may vary
between wines. These notions were applicable in both young wines (Langlois et al., 2011) and those
that already showed some age but still had the potential to continue improving (Jaffré et al., 2009).

99 The concepts of quality, time, and bouquet are intimately involved in defining aging potential. The 100 connections between these concepts imply the existence of sensory and/or chemical factors used by 101 wine tasters to predict the formation of an aging bouquet. Jaffré et al. (2009) and Langlois et al. (2010) 102 clarified the importance of these factors for red Burgundy wines. Flavors, olfactory, somesthetic, and

103 visual information all participate in the assessment of wine aging potential.

This multi-sensory approach evaluates a wine as a whole, by associating the complexity factor, predictive of its aging over time. Moreover, the notion of wine complexity is central to the mental representation of the bouquet (Picard et al., 2015) and consequently to the aging potential as revealed by Parr et al. (2011). Nevertheless, professionals mainly describe a wine's complexity using specific

108 vocabulary referring to extrinsic factors such as grape variety, soil, terroir, and winemaking practices,

109 rather to specific organoleptic characteristics.

110 Although aging potential involves many conceptual factors, Jaffré et al. (2009) have proceeded to a

111 quantitative sensory evaluation using a conventional continuous scale. With this, they have shown that

there is a consensus among professionals. Generally, professional tasters are able to evaluate the aging potential of wines thanks to their professional experience, with the greatest accuracy for wines produced in areas they know well. The judges did not require training, as they had an established mental representation of the concept. However, the reliability of the measurements depends on the level of expertise and consensus of the judges (Ballester et al., 2008; Perrin & Pagès, 2009).

In addition, a wine categorization task has already been carried out by Jaffré et al. (2009) in order to 117 118 differentiate wines with and without aging potential. This categorization enabled the quantitative 119 assessment of two groups of wine with an identified aging potential. Indeed, the intensity scores 120 showed that all the wines possessed an aging potential, along a continuum from the lowest to the 121 highest. The task of categorization was thus necessary to define the limits. Similarly, Langlois et al. 122 (2011) also used a categorization task to study the aging potential of Burgundy and Bordeaux wines. 123 In summary, several sensory methodologies have been used, such as a binary categorization task, an 124 aging potential rating task, and a hedonic rating task (Jaffré et al., 2009; Langlois et al., 2011) 125 combined with the study of aging potential.

126 Even if quantitative scores were obtained to measure the degree of exemplarity of a high aging 127 potential, the significance of a single value to measure a multi-parameter concept raises the question of 128 the quality of the measurement strategy. Several questions need to be answered. Is it the sensory 129 proximity to the prototype wine that has an aging potential? Or, is it its stage of evolution? Does a 130 wine with a low aging potential imply low quality? What is the correlation between a young wine's quality and high aging potential? Other limitations may exist as none of the methodologies presented 131 in the literature simultaneously measure current and future quality of wine or other food products as a 132 133 function of time. Moreover, the specifications described in the ISO standard for a simple continuous 134 scale were inherently incapable of taking multiple factors into account (ISO 13299:2016). 135 Nevertheless, many authors have used this scale in the evaluation of wines in relation to the prototype 136 of a category. Indeed, this methodology enables positioning specific products according to their 137 typicity or their degree of exemplarity in relation to a good example of an image of a sensory category (Rosch et al., 1976; Salette, 1997). Thus, it was possible to highlight interesting differences among 138 139 well-defined sensory categories, including grape variety (Ballester et al., 2008), origin (Cadot et al., 140 2010, 2012; Garrido-Bañuelos et al., 2020; Perrin & Pagès, 2009), and winemaking practices 141 (Francesca et al., 2016).

- 142 In the case of aging potential, the categories seem to be multiple due to the obvious sensory 143 polymorphism of wine aging, but particularly/especially due to the factors involved, such as time, 144 quality and level of potential. Based on this concept, the use of a simple continuous scale would mean
- that information would be lost for the categorization of wines.
  - 146 The aims of this study were to explore whether it is possible to improve the sensory methodology for

147 assessing wine aging potential, specifically of Champagne. This appellation area produces principally

148 non-vintage sparkling wines every year. The Champagne characteristically involves, in the majority of

149 cases, blending several still wines from different vintages, varieties, and regions to produce the final 150 wine. The use of aged base wines, or "reserve wine", compensate for quality changes due to climatic 151 variations in different vintages. Therefore, Champagne reserve wines ensure that the final blend maintains a consistent style in accordance with AOC regulations (Légifrance: Décret n° 2010-1441, 152 153 2010).

To guarantee constant quality and a "Champagne-house sensory style", it is essential to select young 154 155 wines for their cellar-aging potential. Consequently, the search for wines with high aging potential is 156 recognized as a key factor by winemakers and winegrowers in the Champagne region.

157 More specifically, the unique typicity or "house flavor" of Veuve Clicquot Ponsardin (VCP) is 158 maintained by an exceptional collection of reserve wines referencing almost all vintages up to 1988. 159 Reserve wines are monovarietal, aged, still white wines made from Chardonnay, Pinot noir, or Pinot 160 Meunier grapes. They are preserved according to their ability to express qualitative sensory aging (in 161 other words, bouquet). Used in blends with younger wines, they add to the final product (Champagne) 162 an aromatic complexity recognized by the greatest tasters as the "Champagne-house sensory style". To 163 identify wines that will age qualitatively for many years, aging potential is traditionally assessed by tasting. In this context, the professional tasters of Champagne reserve wines are experts on the aging 164 165 potential of this product. Throughout the production process, Champagne wines actively undergo 166 aging processes and the concept of aging potential is widely used to predict and manage the reserve 167 wines. Therefore, the Champagne reserve wines provide an excellent tool for professionals to measure 168 quality according the concept of aging potential.

The experimental design consisted of three main parts. (i) Define the aging potential of Champagne 169 170 reserve wines using VCP winemakers' expertise. These experts possess very high knowledge 171 concerning the aging of Champagne's base wines which later become the reserve wines. (ii) Define a 172 new sensory assessment method for aging potential in both base and reserved Champagne wines, 173 thanks to the definition produced in part (i). A new statistical methodology was developed to identify 174 significant differences in the results obtained in part (ii). Finally, (iii) Test the ability to differentiate 175 the aging potential of several reserve and base wines, by using the new sensory analysis method.

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## 2. Materials and methods

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## 2.1. Part (i): Aging potential of Champagne reserve wines definition

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## **2.1.1.** Wine professional recruitment according to contextual wine expertise

180 Ten oenologists participated in this task. The characteristics of the panel judges were as follows:

181 -All tasters had at least 5 years' experience at Champagne VCP.

182 -All participants were familiar with wine aging management and tasting reserve wines. All of them were categorized as "wine professionals", according to the criteria proposed by Parr et al. (2004) and 183 184 Ballester et al. (2005).

185 -All participants were familiar with the quality image of VCP Champagne. All winemakers were native French-speakers, six males and four females aged between 31 and 58. Theaverage age of the panel was 39 years.

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### **2.1.2.** Experimental procedure

Participants had to answer the question: "In the context of VCP reserve wine, how would you define
"aging potential"?". The question was formulated in French on the Google forms® platform.
Participants were instructed to answer individually. They were invited to write their feelings and
spontaneous thoughts using a minimum of 5 words or expressions.

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## **2.1.3.** Data analysis

Grouping methodology was used to facilitate data interpretation (Lawrence et al., 2013; Sester et al.,
2013; Spinelli et al., 2015; Tournier et al., 2007). Several grouping levels were used to analyze
participant responses.

First, terms or expressions with similar meanings (e.g. nouns and adjectives) were grouped in the same
cluster (for example, "fruity", "fruits" and "fruit" were grouped together under the semantic cluster
"fruit").

The terms were then grouped by semantic families, related to oenological knowledge, by three
 researchers from the Institute of Vine and Wine Science-Bordeaux University, working independently
 according to their own criteria.

205 These classifications were analyzed and semantic families grouped together to form a broader 206 semantic category. For example, "aromas" in a broad sense includes aroma terms like "fruity", 207 "citrus", "spicy", "roasted".

208 Then, the broader semantic categories were analyzed in detail, focusing on adjectives and qualitative 209 words referring to time, wine quality, and context. The objective was to classify the major semantic category in the dimensions that define the aging potential. Terms like "will appear", "initially", 210 211 "young", "old", "increasing quality" and many others formed a broader semantic category within 212 several sub-categories. This last stage enabled, for example, classifying in the semantic category 213 "aromas", the semantic sub-categories "will appear" and "initially". The sub-category "will appear" contained, for example, the "tertiary aroma" family evoked by the terms "evolutionary notes" and 214 215 "tertiary aromatic richness". Conversely, in the semantic category "aroma", the sub-category "initially" contained the terms "fruity", "mineral", and "citrus". 216

217 Quotation frequencies were calculated by dividing the number of words cited in a broader semantic218 category or sub-category by the total number of terms cited in response to the question.

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- 220 2.2 Part (ii): Projective categorization statistical methodology development
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**2.2.1** General principle

The evolution of wine quality as a function of time was represented by three curves in an orthonormal coordinate system. They correspond to three aging potentials (high potential, medium potential and low potential) for the Champagne base wines, Figure 2. During a sensory analysis session, the tasters were invited to interpret the ageing potential by positioning the tasted wine on one of these three curves. Their choice was oriented by the temporal notion (with the abscissa axis) and the qualitative notion (with the ordinate axis) following the aging potential evaluation. This sensory methodology evaluation was named "projective categorization".

The development of data analysis for projective categorization consisted in defining the zones on the curves. The scores of the judges were then counted in these zones. The more judges positioned the same wine in the same zone, the higher was the consensus. A strong consensus resulted in a significant wine positioning in the zone. Each of this step is discussed and detailed in the section *3.3*.

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### **234 2.2.2** Software

Free software used was R 3.6.0, partitions 1.9-22 (Millstein et al., 2020) and DescTools 0.99.39
(Andri et mult. al., 2021).

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## 2.3 Part (iii): Wine tasting using projective categorization (curves) to evaluate aging potential 2.3.1 Panel

One additional subject (male), a winemaker, was present in the panel, used for the mental definition of reserve wine aging potential, described in section 2.1.1. The eleven winemakers were native Frenchspeakers, seven males and four females. The average age of the panel was 35 years and aged between 31 and 58.

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## 2.3.2 Procedure

The evaluation was organized in March 2017 in a sensory room at VCP Champagne (Reims, France) 247 248 with twelve individual cubicles, positioned facing the wall, and each equipped with one spittoon. No 249 visual and social disturbance was possible. The artificial light was white, but had no impact on the 250 contents of the black glasses used. Room temperature was regulated at 20°C. Reserve wines (50 mL at 251 18°C) were poured into black INAO glasses with three-digit random numbers and the order of 252 presentation was randomized among panelists. One set of curves on a single sheet was presented for 253 each wine (monadic presentation). The curves were printed on a sheet of A4 paper, as shown in Figure 254 2, without displaying the caption of aging potentials.

Judges were invited to taste the wines using only olfactory and gustatory evaluation. Following this assessment, judges were asked to position the wine by a pencil mark on one of the three curves, according to its aging potential.

258 These pencil marks by each wine were then converted to the (X; Y) coordinate of the orthonormal system. (X; Y) corresponded to the distance in mm, measured with a ruler. The segmentation of the 259 curves also allowed defining zones according to coordinates (X; Y) for the beginning and (X; Y) for 260 the end. Using Excel® software, all (X; Y) pairs corresponding to the judges' wine scores were 261 assigned to a named zone along the segmentation levels (e.g.: very fine, fine and extensive). Then, the 262 number of different zones per wine was calculated for each segmentation level. Finally, the count 263 264 value was compared to the threshold value describe in section 3.3.4. The panel was first trained in 265 using this new sensory analysis method. As the curves illustrated the mental definition of reserve wine 266 aging potential by the panel, three calibration sessions (different from training) were conducted during 267 one week. Eight reserve wines (Table 1) were presented per calibration, without any indication of age 268 or origin, giving a total of twenty-four different wines. The wines were tasted one after the other, in a 269 monadic presentation. After each wine, panel members had to verbally justify their decision to the 270 other judges. The aim of this discussion was to encourage tasters to reach a consensus on positioning 271 each wine on the curves.

The wine evaluation sessions took place two weeks after the calibration sessions. The panel individually evaluated thirty-three different reserve wines twice, so a total of sixty-six samples were presented in three series of twenty-two (Table 1) on three non-consecutive days. The wines were successively served one by one (monadic presentation) in the random order defined for each judge. A 3 to 4-minute delay was applied before the judge was served with the next wine.

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### 2.3.3 Wines

279 The wines were from several vintages, ranging from 1988 to 2016, as shown in Table 1. Thirty-eight 280 "cuvée" wines were monovarietal Chardonnay, Pinot noir or Pinot meunier, from fifteen subregions of 281 the Champagne vineyards, anonymized under letters A to O. Six wines were "tailles", made from the 5 282 hL second pressing (after the 20.5 hL first pressing from 4000 kg whole grapes), and consisted of a 283 blend of all three grape varieties. The grape juice released during a pressing cycle is separated into three different qualities named "cuvée" (2050 L), "première taille" (300 L) and "seconde taille" (200 284 L) respectively of higher, intermediate and lower quality (Françot, 1950). Further details of the 285 286 technical and winemaking process for these forty-four different reserve wines ("cuvées" and "tailles") 287 are available in Le Menn et al. (2017).

All wines, stored in stainless steel tanks, were sampled over a two-day period and kept in Champagnebottles with airtight caps.

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Table 1: Characteristics (grape variety, subregion, vintage, and code) of the reserve wines selected
for the tasting sessions.

Grane	Champagne		Calibration	Wine	Wine Code
variety	subregion code	Vintage	session	evaluation session	(Vintage + subregion)
DN	٨	1000		~	00 4
PN PN	R	1988	×	×	96R
СН	A A	1999	×		99A
СН	C	2000	×	×	00C
СН	Č	2004	×	×	04C
PN	D	2006		×	06D
СН	C	2007	×	×	07C
PN	L	2007	×	×	07D
СН	С	2008		×	08C
PN	D	2008	×	×	08M
PN	Κ	2009		×	09K
CH	М	2009		×	09M
CH	А	2010		×	10A
PN	D	2010		×	10D
CH	С	2012		×	12C
PN	F	2012	×	×	12F
CH	С	2013	×		13C
PN	E	2013	×	×	13E
PN	F	2013		×	13F
PN	D	2013	×	×	13D
CH	Μ	2013		×	13M
PN+MN	1 <sup>st</sup> taille	2014	×		141T
PN+MN	2 <sup>nd</sup> taille	2014	×		142T
PN	В	2014	×	×	14B
CH	А	2014		×	14A
CH	G	2014	×	×	14G
PN	D	2014	×	×	14D
PN+MN	2 <sup>nd</sup> taille	2014		×	142T
PN	0	2014		×	14O
СН	Н	2015		×	15H
СН	1 <sup>st</sup> taille	2015	×		151T-B-1
PN+MN	1 <sup>st</sup> taille	2015	×		151T-N
CH	Ι	2015	×		15I
CH	А	2015	×		15A
CH	J	2015	×		15J
PN	K	2015	×		15K
PN	F	2015		×	15F
PN	D	2015		×	15D-1
PN	D	2015		×	15D-2
СН	1 <sup>st</sup> taille	2015		×	151T-B-2
СН	Ν	2016	×	×	16N-1
СН	Ν	2016		×	16N-2
PN	K	2016		×	16K-1
PN	K	2016	×	×	16K-2

293 294

## 3. Results

295

3.1 Part (i): Aging potential of Champagne reserve wines definition

One hundred and eight attributes generated by the wine professionals were clustered into eleven
semantic groups (Figure 1). The most frequently-cited categories (51%) were "Time evolution",
"Aromas" and "Balance", representing 25%, 14%, and 12% of total terms cited, respectively.

Terms in the "Time evolution" category were divided into three sub-categories. The "Qualitative variation" sub-category represented 43% of the "Time evolution" terms. Positive evolution and wine maturation were the main terms cited. "Duration of conservation" included terms such as "long life", "long time" and "several years", representing 36% of the "Time evolution" category. Finally, the "Qualitative stability" sub-category described old wines that had acquired a stable quality level over time. A "plateau" quality concept was cited for Champagne reserve wines.

In the "Aromas" category, several terms were cited in association with the current status of a wine, leading to the definition of a distinct category, representing 4.7% of total terms cited. The "Aromas" category was always associated with a time qualifying word. The adverb "initially" always described a young wine, while "will appear" referred to a future projection concerning the aromatic expression of an aged Champagne reserve wine. The terms cited in the "will appear" sub-category referred to aromas identified in the aging bouquet of these wines, corresponding to those of aged Champagnes (Tominaga et al., 2003). This highlighted the fact that the tasters were engaged in a projective task.

The "Flavor dynamics", "Balance", "Structure", "Sensation", "Acidity", "Aromas", and "Absence of off-flavors" categories were used in wine descriptions, representing 62% of all the cited words. Several terms referred to wine concepts such as "Minerality" or "Finesse" or "Pure" and others were not studied any further. These descriptors were cited for reserve wines considered to have "high aging potential". Concerning the "Capacity" category, the terms were synonymous with the potential notion, which is always linked to the notion of "quality" and "high potential". Consequently, the majority of

the terms (67%) described wines with a high aging potential.

Finally, two adjectives were cited in the "wine aging potential levels" category: "low" and "high".
Thus, Champagne reserve wine aging potential was described by words indicating different intensity
levels, associated with different dynamics of wine quality evolution over time.

The definition of wine aging potential was organized around three connected dimensions: time, wine quality, and level of potential.

324 In the "time dimension", the balance between "real wine age" and "apparent sensory age" was a decisive element in evaluating its aging potential. Indeed, some older wines still had the sensory 325 attributes of younger ones and, therefore, enormous aging potential. Jaffré et al. (2009) already 326 327 mentioned this point in a study of the aging potential of Burgundy wines. However, not all wines 328 express better quality after aging, and dynamics will vary. For example, a young wine does not 329 necessarily have "high aging potential". In fact, these observations converge on the obvious dimensions: quality and aging potential. Wines evaluated as "low aging potential" may mature faster, 330 331 and exhibit lower quality and complexity, than those labeled "high aging potential". Moreover, "low 332 aging potential" wines only spent a short time at their apex of complexity and quality. In contrast,

333 aging dynamics are slower in high potential wines, necessitating a longer period to achieve a 334 qualitative apex. This higher quality remained stable for some time. Described by tasters as a "plateau", the duration of this stability was difficult to estimate but lasted up to several years. This 335 observation highlighted the fact that high quality wines take time to acquire complexity and balanced 336 aroma and flavors. At the end of the wine aging process, irrespective of the potential and sensory 337 quality, the peak was always followed by a rapid decline in quality. This negative evolution was 338 characterized by the appearance of oxidation. Reserve wines' aromas related to oxidation were 339 340 considered as off-flavors and justified the quality decline.

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## **3.2** Proposal for an illustrated Champagne reserve wine aging potential representation (projective categorization) suitable for quantitative sensory analysis

Previous authors who studied wine aging potential proposed an evaluation on a one-dimensional scale (Jaffré et al., 2009; Langlois et al., 2011). However, during the concept description task, wine aging potential was linked to three dimensions: time; wine quality, and potential. The dynamics of wine complexity and quality evaluation differ according to the composition of young wines. A new, 3dimensional scale was developed.

Following a meeting with the tasters who participated in the conceptual definition (section 2.2 and Figure 1), three different levels of Champagne reserve wine aging potential were proposed to reflect production considerations, i.e. to represent the principal profiles of wine evolution according to time and quality values.

354 The proposed projective categorization method consists of a 3-dimensional scale for assessing wine 355 aging potential (Figure 2). The first dimension, "Time" is presented on the x-axis. The second 356 dimension, "Quality", is on the y-axis. The third dimension, consisting of a categorization, is 357 illustrated in this coordinate system by various curves, corresponding to "wine aging potential levels". 358 Although only two aging potentials were mentioned in the definition, a third level, "Medium potential", illustrated a wine category with intermediate potential, between "high potential" and "low 359 360 potential". These wines expressed a more modest qualitative improvement than "high potential" wines, 361 but in a shorter time.

The axes are deliberately unstructured. Indeed, the wine quality concept involved many parameters 362 363 related to experience and environmental factors in generating odor memory patterns that were difficult 364 to quantify (Jackson, 2014 & 2017). For these reasons, and to give the panel freedom to define their 365 own values on the scales, the coordinate system was not structured. The origin symbolized by "initial 366 quality" defined the supposed quality of the wine during its year of production. In the case of reserve wines, this point defined the production year and the quality was variable according to climate during 367 368 the growing and ripening seasons, production area, grape varieties, and other parameters. Again, the 369 free scale was more suitable for projecting all wines to the same initial position.

Applying a similar logic, the "Time" axis was also on a free scale, as not all wines develop at the samerate.

Figure 2 thus proposes an illustration of the aging potential of Champagne reserve wines in the potential, time, and quality dimensions (projective categorization). In order to use these projective categorization curves in sensory analysis, the next stage was to develop a strategy for processing the results given by the tasters. This concerned, in particular, checking the panel's capacity to generate consensual evaluations of wines.

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## 3.3 Part (ii): Development of data analysis for projective categorization

## 3.3.1 Objectives

The results of the positioning of the wines on the curves by the panel could be explored from two points of view: the panel's performance or the differences between products. In both cases, there was a common problem for the results exploitation: What is the consensus of the panel to evaluate the same wine using these curves? Data analysis development was built to answer this question. It was based on the assumption that if the results obtained were not due to chance, there was agreement among the judges, and therefore the existence of a consensus.

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## 387

### **3.3.2** Step 1: Delimiting curve zones

This step consisted of delimiting the zones on the curves. The aim of this strategy was to quantify the number of judges who positioned the same wine in delimited zones on curves. Two examples of delimitation are shown in Figure 3 A and B with extensive and very fine delimitations respectively. The entire surface of a curve is defined by a zone. Each wine positioned on a curve corresponded to one defined zone.

Initially the boundaries of the zones were defined as extensive i.e. very wide or large zones. Consequently, a minimum number of zones delimited the curves (Figure 3A). The number of zones increased by adding boundary markers. Following this procedure, it was possible to compare the significant assignment of wines to a zone using different segmentation levels.

397 The zone delimitation is related to oenological interest. For example, in Figure 3A the green curve (G 398 corresponds to low potential) consists of a single segment. In practice, reserve wines with very low aging potential will not be kept in the cellar, so it was irrelevant to segment this potential into several 399 400 zones. This reasoning also applies to the decline phases of high and intermediate wine-aging potential. 401 Reserve wines that have reached this zone should be used in blends as soon as possible. The very fine 402 segmentation curve (Figure 3B) proposes a status just prior to the decline in wine quality, labeled 403 "Rep" or "Bo2". These present a particular interest in this context for reserve wine management optimization. 404

The level of segmentation may thus be variable, involving more or less zones. Consequently, two levels of segmentation are represented in Figures 3 A and B, showing examples of extensive and fine delimitation respectively. The aim of increasing the fineness of the segmentation is to achieve a moreprecise positioning of the product if the consensus of the panel is high.

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**3.3.3** Step 2: Enumeration of the wines positioned on the curves and segmentation

In accordance with the panel consensus calculation formulated in 3.1.4.1., it was necessary to identify 412 the zone where the greatest number of tasters positioned the same wine. This "step 2" involved 413 414 counting the wines positioned in each zone according to the levels of segmentation. As an example, 415 Figure 4 presents the compilation of the results from the evaluation of the same wine by 11 judges 416 using the curves (projective categorization). Three levels of segmentation were considered. Figure 4 417 "A", shows a very fine zone segmentation, where the Rp zone was chosen by 3 judges out of 11. The 418 other very fine zones were chosen less often (e.g. Ri3) or not at all (Rd). Figure 4 "B", shows a fine 419 zone segmentation, where the Ri zone was chosen most frequently, by 4 judges out of 11. Figure 4 "C" 420 shows an extensive zone segmentation, where Rc was chosen by 6 judges out of 11. In this example of 421 three-enumeration procedures (A, B, C), extensive zone segmentation (Figure 4 "C") resulted in the highest number of selections for a single zone. However, do 6 out of 11 judges allow us to conclude 422 423 that the wine is significantly positioned in this zone? In the same way, was there a smaller zone 424 significantly chosen by fewer judges? It was therefore necessary to determine whether the number of 425 judges who chose this zone was not due to chance.

This possibility implied, for each wine evaluated, the existence of a threshold value which enabled deciding whether a particular attribution of a wine to a zone was significant. This value depended on the number of zones (depending on segmentation levels employed) and the number of judges present during the sensory assessment. This threshold value was then compared with the number of judges having chosen each zone to determine whether there existed one that was chosen significantly.

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## **3.3.4** Determination of threshold values

433 Statistical processing was conditioned by the probability of an event occurring in an  $\Omega$  universe 434 (Caumont & Ivanaj, 2017; Saporta, 2006). Incidentally, this was the foundation of the significant 435 result for a triangular test (ISO 4120:2004). The purpose of applying threshold values on the sensory 436 analysis curve was to identify whether the same wine was significantly positioned by several judges in 437 the same zone. Consequently, the threshold value to ensure that this result was not at random was the 438 minimum number of judges required to position the same wine in the same zone.

This result was associated with a "Risk of rejecting the "Ho" hypothesis wrongly, with Ho: a wine is not associated with a specific zone"  $\alpha$  (type I) set at 5%, the standard value used in sensory analysis to determine significant results. Another risk discussed in sensory analysis are type II errors ( $\beta$ ) (Lawless & Heymann, 1998): calculating the probability of erroneously concluding that no perceptible difference exists. This value is dependent on the segmentation level. It is higher with fine than with extensive segmentation. Generally, type II errors are calculated by comparison with other common
sensory analysis methods. However, there was no other methodology aimed at obtaining results
similar to those obtained by positioning wines on the curves, so type II could not be calculated.

To determine the threshold value, it was necessary to calculate the probability that the judges randomly placed the same wine in the same zone. The following variables were defined: let "n" be the minimum number of judges required to place a given wine in the same zone, "N" the number of total judges participating in the sensory analysis, and "k" the total number of zones considered (depending on the segmentation level used). The calculation was based on finding the number "n" of judges required with "N" and "k" fixed for the probability of this event occurring at random was less than 0.05 ( $\alpha \le 5\%$ ) and to conclude that the wine was thus significantly associated with the particular zone.

The number of zones, "k", was at least three, so a multinomial distribution function was used to calculate these probabilities. The number of judges "N" was known for each tasting session. The probability that one judge placed a wine randomly was defined as 1/k. The value of "n" varied from 0 to "N".

The calculation of the threshold value "n" involved adding the probabilities of several events. Indeed, certain events lead to the same result, i.e., the most chosen zone by the judges. The judges who did not position the wine in this zone raised several possible combinations. If the same number of judges chose the same zone, the events had an identical probability. In addition, the probability that a number of judges positioned the same wine in the same zone implied that the considered zone was not defined in advance, but was the one with the highest count.

The probabilities of the events and their sum were calculated according to the sensory analysis variables using R software for all values of "n", "k" and "N". Thus, when the probability that "n" judges out of "N" for "k" zones was less than 0.05, the attribution of a wine to a zone was significant and "n" was the threshold value.

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## 469

## **3.3.5** Step 3: Calculation of threshold values by R

The probabilities of the threshold values conditioned by "n", "N", and "k", described in the previous section 3.3.4, were calculated using R software. The script is available in the supplementary material. Matrices were generated with the aim of enumerating all the possible zone choices (all the possible events for "n", "N", and "k"). Then, the probability of each row in the matrix was calculated using the multinomial distribution function. The probability of events was multiplied by the number of identical events in relation to the problem, considering the most frequently chosen zone rather than a specific zone.

477 At the end of the script, an example of the calculation synthesis is presented (Table 2). When N = 11

judges and k = 7 zones, with the probability of being wrong less than 5%, according to the calculations

given in Table 2, at least 6 judges out of 11 must place the same wine in the same zone to conclude

480 that the wine was significantly associated with one zone. In the same Table, when N = 11 judges and k

- 481 = 14 zones, at least 5 out of 11 judges must place the same wine in the same zone to conclude that the
  482 wine was significantly associated with one zone. The calculation of the threshold values "n" given in
  483 Table 2 had to be reproduced for each value of the pair "N" and "k".
  484
  485 Table 2 : p-values (probabilities) calculated from the multinomial distribution function for "k" zones
  486 varying from 3 to 14 and compared to the number of times where the same zone was chosen "n" for
  487 "N"= 11 judges. The gray cells indicated the probability threshold <5%, used to determine the</li>
- 487 488

Number of zones "k"		Number of times "n" that the same zone was chosen with 10 judges ("N")									
	n=1	n=2	n=3	n=4	n=5	n=6	n=7	n=8	n=9	n=10	n=11
3	1	1	1	1	0.804	0.366	0.116	0.026	0.004	0.0004	1.69 x10 <sup>-5</sup>
4	1	1	1	0.912	0.449	0.137	0.030	0.005	5.04 x10 <sup>-4</sup>	3.24 x10 <sup>-5</sup>	9.54 x10 <sup>-7</sup>
5	1	1	1	0.711	0.25	0.058	0.010	1.18 x10 <sup>-3</sup>	9.47 x10 <sup>-5</sup>	4.61 x10 <sup>-6</sup>	1.02 x10 <sup>-7</sup>
6	1	1	0.979	0.532	0.147	0.028	0.004	3.65 x10 <sup>-4</sup>	2.37 x10 <sup>-5</sup>	9.26 x10 <sup>-7</sup>	1.65 x10 <sup>-8</sup>
7	1	1	0.929	0.398	0.091	0.014	0.002	1.33 x10 <sup>-4</sup>	7.25 x10 <sup>-6</sup>	2.37 x10 <sup>-7</sup>	3.54 x10 <sup>-9</sup>
8	1	1	0.862	0.302	0.059	0.008	0.001	5.53 x10 <sup>-5</sup>	2.58 x10 <sup>-6</sup>	7.26 x10 <sup>-8</sup>	9.31 x10 <sup>-10</sup>
9	1	1	0.788	0.233	0.039	0.005	4.13 x10 <sup>-4</sup>	2.53 x10 <sup>-5</sup>	1.04 x10 <sup>-6</sup>	2.55 x10 <sup>-8</sup>	2.87 x10 <sup>-10</sup>
10	1	1	0.716	0.182	0.027	0.003	2.29 x10 <sup>-4</sup>	1.25 x10 <sup>-5</sup>	4.56 x10 <sup>-7</sup>	1.00 x10 <sup>-8</sup>	1.00 x10 <sup>-10</sup>

0.002

0.001

0.001

0.001

threshold value "n".

14 **489** 

11

12

13

1

1

1

1

1

0.999

0.998

0.996

0.648

0.587

0.532

0.483

0.145

0.117

0.096

0.079

0.02

0.014

0.011

0.008

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- 491

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## **3.3.6** Step 4: Determination of wine (product) assigned significantly to one zone

6.58 x10<sup>-6</sup>

3.66 x10<sup>-6</sup>

2.13 x10<sup>-6</sup>

1.29 x10<sup>-6</sup>

2.16 x10<sup>-7</sup>

 $1.09 \text{ x} 10^{-7}$ 

5.84 x10<sup>-8</sup>

3.26 x10<sup>-8</sup>

1.34 x10<sup>-4</sup>

8.17 x10<sup>-5</sup>

5.18 x10<sup>-5</sup>

3.39 x10<sup>-5</sup>

4.28 x10<sup>-9</sup> 3.86 x10<sup>-11</sup>

1.97 x10<sup>-9</sup> 1.62 x10<sup>-11</sup>

9.65 x10<sup>-10</sup> 7.25 x10<sup>-12</sup>

4.98 x10<sup>-10</sup> 3.46x10<sup>-12</sup>

492 Depending on the number of judges present during the sensory analysis "N" and the levels of curve 493 segmentation used (step 1), the threshold value "n" (step 3) was compared to the responses counted in 494 each zone (step 2). A wine is significantly assigned to a zone when the number of judges who selected 495 it was greater than or equal to the threshold value "n".

496 Figure 4 shows an example of an analysis procedure for the evaluation of one wine by 11 judges. The

497 ratings by 11 judges were compiled on the same three curves.

Figure 4 "A" presents 14 delimited zones. According to Table 2, for 11 judges and 14 zones, at least 5 judges out of 11 had to place the same wine in the same zone to conclude that the wine was significantly associated with one zone. Nevertheless, Figure 4 "A" shows that no zone was chosen more than 4 times. Figure 4 "B" shows that 9 zones were defined. According to Table 2, 5 judges had to place the same wine in the same zone to obtain a significant result. However, these conditions were still not met. With the segmentation presented in Figure 4 "C", 6 judges positioned the same wine in

"Rc" zone. According to Table 2, the probability that this result was obtained at random was 0.014.

Therefore, the extensive segmentation (Figure 4 "C") resulted in a significant positioning for the wine 505 506 with 11 judges in "Rc", which signifies a wine with high aging potential that is expected to continue to 507 increase in quality over time. This procedure was repeated for each wine. Therefore, the higher the consensus among judges the 508 509 more zones were retained (increase of "k"). 510 511 3.4 Part (iii): Sensory analysis results by projective categorization 512 Results concerning the positioning of the wines 3.4.1 513 Thirty-three wines were tasted twice by eleven judges in three tasting sessions. In accordance with the 514 independence of observation necessary for using the multinomial distribution (Albert & Denis, 2012), 515 the threshold values were calculated considering N=11 judges who tasted each wine once. Therefore, 516 results were available for wines evaluated at the first tasting and further results for the second tasting. 517 518 3.4.1.1 Results for wines evaluated at the first tasting 519 Using fine segmentation with the pairs N=11, k=10 (zone), at least 5 judges had to place the same 520 wine in the same zone for the selected positioning to be significant. The analysis of the wine placement by the judges showed that 29 out of 33 wines tasted (88%) were 521 522 positioned significantly above chance in a single zone (Figure 5). The results for all 33 wines are 523 presented in Table 3. Only 12% of wines obtained a not-significant assignment due to lack of 524 consensus among judges. Two wines, 12C and 16N-2, were positioned on the intermediate potential 525 (blue curve). 526 Concerning the reserve wines positioned in the "Ri" and "Rp" zones, several vintages were referenced. 527 In the "Ri" zone, wines aged from 7 to 1 years old (2010 to 2016 vintage) were present while the "Rp" 528 zone had wines aged from 11 to 3 years old (2006 to 2014 vintage). According to Table 3, the grape 529 variety had no impact on the categorization of the wines' aging potential compared to their real age. 530 Four wines (14A, 15D-1, 15F, 16K-1) were not positioned in one of the 10 zones. By decreasing the number of considered zones, (k=7), 3 wines out of 4 had a significant assignment in a larger zone 531 (extensive segmentation). The reserve wines 14A, 15D-1 and 16K-1 could thus be significantly 532 positioned in the zone "Rc" as shown in Figure 3A (k=7). Only the 15F wine did not obtain any 533 agreement in the positioning by the judges. Indeed, 15F was positioned by 4 judges on the 534 intermediate potential (blue curve), 4 on the high (red curve) and 3 on the low potential (green curve). 535 536 Finally, as shown in Figure 5 and Table 3, the 08D wine was significantly positioned in two zones, "Ri" and "Rp". Five judges chose both zones and only one chose the "Bo" zone. The zones "Ri" and 537 538 "Rp" were neighbors and reflect a close qualitative status on the same high potential (red curve) for the 539 particular wine.

540

 Table 3 : Synthesis of the results obtained after the first and second tasting of the reserve wines by projective categorization. Segmentation used (k=10) as presented in Figure 5.

Zone significantly chosen by the panel (5% error)						
Grape variety	Wine Code	1st tasting 2nd tasting		Difference 1st vs 2nd tasting		
СН	88A	Rep	Rep	No		
CH	<b>00C</b>	Rep Rep		No		
CH	<b>04C</b>	Rep	Rep	No		
PN	06D	Rp	Rp	No		
PN	07C	Rp	Ri	neighboring zones		
CH	07L	Rp	Rp	No		
CH	<b>08C</b>	Rp	Rp	No		
PN	08D	Rp&Ri	Ri	neighboring zones & no difference		
CH	09K	Rp	Rp	No		
PN	<b>09M</b>	Rp	Rp	No		
CH	<b>10A</b>	Rp	Rp	No		
PN	10D	Ri	No assigned zone	Yes		
PN	12C	By	Ri	Yes		
CH	12F	Rp	Ri	neighboring zones		
PN	13D	Ri	Ri	No		
PN	<b>13E</b>	Ri	Ri	No		
CH	<b>13F</b>	Ri	Ri	No		
PN	<b>13M</b>	Ri	Ri	No		
noirs	142T	G	G	No		
PN	14A	No assigned zone	Ri	Yes		
CH	14B	Rp	No assigned zone	Yes		
PN	14D	Ri	Ri	No		
CH	14G	Ri	Ri	No		
PN	140	Ri	Rp & Ri	neighboring zones & no difference		
CH	151T-B-2	G	G	No		
PN	15D-1	No assigned zone	No assigned zone	No		
CH	15D-2	Ri	No assigned zone	Yes		
PN	15F	No assigned zone	Ri	Yes		
PN	15H	Ri	No assigned zone	Yes		
CH	16K-1	No assigned zone	Ri	Yes		
CH	16K-2	Ri	No assigned zone	Yes		
PN	16N-1	Ri	Ri	No		
PN	16N-2	By	No assigned zone	Yes		
% of wines significantly positioned in a zone (success rate)		88	79			

545 546 3.4.1.2 Comparison of the results of the first tasting vs. second tasting of the same wines.

The same wines were evaluated twice with projective categorization. The comparison of the results obtained (Table 3) also corresponded to the evaluation of the panel's reproducibility. The same segmentation (N=11 and k=10) was used to analyze the placement of the wines provided by the judges

550 for the first and second tastings.

551 In Table 3, the wines tasted the second time which were significantly assigned to one zone were less

numerous, compared to the first tasting. Nevertheless, the success rate of the panel was high with 79%of the wines significantly positioned in a zone.

554 On the other hand, the wines significantly placed during the second tasting in the same zone were 555 20/33, i.e. 60%. These results suggested different assignments between the first and the second tasting. Several cases were highlighted. Firstly, judges chose significantly a different potential (different 556 557 curve), for the wine 12C (Table 3). For example, judges assigned wine 12C to a different potential curve significantly above chance. During the first tasting this wine was assigned significantly to zone 558 "By", while in the second tasting zone "Ri" was chosen. Although the panel did not choose the same 559 560 zone for both tastings, it did choose two zones with aging potential indicating that the wine would 561 further improve in the future.

Secondly, in Table 3 the wines "08D" and "14O" obtained a significant placement in two different,
neighboring, zones between the first and the second tastings (Table 3). In the first tasting, "08D" was

564 placed in 2 different neighboring zones (Rp & Ri) whereas in the second tasting it was assigned to 565 only one of these zones (Ri). The "14O" wine was placed in the first tasting to only one of the zones

566 (Ri), whereas in the second tasting it was assigned to 2 different neighboring zones (Rp & Ri). Thus,

567 both wines were placed in a common zone (Ri) for both tastings.

Thirdly, the wines were positioned in a neighboring zone with the same potential. In table 3, the wines "07C" and "12F" were placed in the "Rp" zone during the first tasting and in the "Ri" zone during the second tasting.

Finally, in Table 3, some wines were significantly placed in a different zones during the first and
second tastings (10D, 14A, 14B, 15D-2, 15F, 15H, 16K-1, 16K-2, 16N-2) or not in any zone (15D-1).
They were all young wines (1 and 2 years old).

- 575 They were all young whiles (1 and 2 ye
- 574 575

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#### **3.4.2** Analysis of the judges' results

577 3.4.2.1 Accordance of zone choice between judges
578 and panel
579 The dissimilarity between the placement chosen by each judge and the zone selected by the group was

580 calculated. This consisted of counting the number of judges who had placed a given wine in a different

581 zone from the rest of the group. The choice of these judges was not influenced by the origin, vintage 582 or variety of the wines tasted.

Interestingly, no individual taster was totally in agreement with the choice of the whole panel for all
the wines. The greatest similarity observed between the choice of one judge and that of the panel was
73%, versus 52% for a lesser similarity.

586

#### 587

## 3.4.2.2 Reproducibility of judges

Reproducibility was calculated for the fine segmentation (10 zones) for all judges. Reproducibility in
terms of judges positioning the same wine in the same zone twice (out of thirty-three different wines)
was 32.5% (average of individual reproducibility for the whole set of wines). The highest judge
reproducibility score was 47.5%.

Another performance indicator was the distribution of all positions on the curves assigned to a given wine by all the judges. All wines were significantly associated with one zone thanks to panel consensus, even if all the judges did not position each wine in the same zone. The "neighboring zones" concept was applied to the two zones "upstream" and "downstream" from the one significantly chosen by consensus. In addition, the term "distant zone" was used to describe a position chosen by a judge that was not close to the one chosen by consensus. Positions not in agreement with the panel consensus represented a total of 56%, including 20% in neighboring zones and 36% in distant zones.

599

## 600 4 Discussion

601 Concerning the wines evaluated at the first tasting, the wines seemed well-positioned in accordance 602 with their ages (Figure 5). The wines positioned on the low potential (green curve) were made from 603 the "tailles" during grape pressing. This result corresponded with their low quality, often described 604 with vegetal off-flavors and low acidity. The reserve wines positioning in the "Ri" and "Rp" zones 605 highlights the different aging quality dynamics between the origin of the wines and their vintage. The 606 'terroir' effect may explain these observations as an interaction between vintage and sub-region. 607 Indeed, considering the 'terroir' definition (Picard et al., 2015; Seguin, 1986; Van Leeuwen et al., 2018), the results of the current study converge on the capacity of certain wines to express positive 608 609 sensory development independently of their age.

610 Regarding the four wines,14A, 15D-1, 15F, 16K-1, that they were not positioned in one of the 10 zones, the low consensus of the panel may be explained by the existence of different sensory 611 612 categories of aged wines. Following Rosch et al. (1976), these various sensory categories could be 613 represented by their prototypes. In the current study, the prototype was identifiable by the sensory 614 attributes specific to a reserve wine. Consequently, some wines seemed to belong to a well-defined category. These were those recognized by the majority of tasters and which gained a strong consensus 615 616 from the panel. These were typically the wines shown in Figure 5. In agreement with Rosch & Mervis 617 (1975), these reserve wines had to present sensory similarities close to the prototype of their category.

618 Following this hypothesis, and taking into consideration that the panel revealed a consensus with the 619 wines in Figure 5, the categories were defined by specific sensory attributes for the 10 delimiting zones of the curves. For example, the "Rp" zone was defined by the sensoriy attributes involved in the 620 recognition of wines in this category, represented by the wines 06D, 07L, 07C, 08C, 09M, 09K, 10A, 621 622 12F, and 14B. Concerning the prototype wine of this category (Rp), reserve wines such as 07L, 08C, 09M, and 14B were positioned by the highest number of judges (7 out of 11). These wines shared the 623 624 greatest number of sensory attributes with the prototype wine, which the panel recognized with a high 625 level of consensus. This analysis could be associated with each zone of the curves, which was 626 significantly chosen by the judges. These observations agreed with studies concerning typicity, which 627 highlights the consensus recognition and the definition of an ideo-type, which is a model or a 628 reference by a panel of experts (Salette, 1997).

629 However, the sensory attributes could equally be shared between several prototypes representing 630 different categories. This would imply the existence of less clearly-defined categories with overlapping boundaries (Rosch & Mervis, 1975). This proposal has already been put forward in 631 632 conceptual oenology studies, notably by highlighting a sensory continuum for product typicity rather than a strict categorization (Ballester et al., 2005, 2008; Cadot et al., 2010; Jaffré et al., 2011; Schüttler 633 634 et al., 2015). For the potential aging evaluation of reserve wines, it seems that some wines do not fit 635 into any obvious category, as they share sensory attributes from several different categories. Each 636 judge has a personal sensibility to the wine sensory characteristics which results in variability in the 637 wine's category association. This hypothesis would confirm why some wines are evaluated with a 638 weak consensus (14A, 15D-1, 15F, and 16K-1) while others provoke a very strong consensus.

639 Finally, as shown in Figure 5 and Table 3, the 08D wine seemed to generate some mixed judgements 640 for its future quality. Half of the judges assessed that the quality of this wine may improve in the 641 following few years, while the other half assessed that the wine had reached a stable optimum quality. 642 These two conflicting judgments of the aging potential for this wine may be related to the boundary 643 definition for zones "Rc" and "Rd". For this example (08D), the consideration of a new overlapped 644 zone between "Rc" and the beginning of "Rp" would result in a significant choice of a single overlapped zone for this wine. However, if this modification had been considered, it should have been 645 646 applied to all wines, with the risk of certain wines changing position from one to two significantly 647 chosen zones. Also, this observation highlights the limitations of using a small number of judges (N=11). A larger number of judges could increase the significant differentiation and therefore increase 648 649 the level of segmentation used (k>10).

Following the comparison of the results of the first tasting vs. the second tasting of the same wines, the difference in the obtained results for wines "08D" and "14O" may be explained by the limits of the boundaries of the two zones, as well as by the small number of panel members. In Table 3, the results obtained for wines "07C" and "12F" may be explained by the difficulty for the panel to estimate any future improvement, or otherwise, in the quality of these wines. The opinion of the judges concerning 655 the aging potential probably changed during the second tasting, as they tasted and evaluated the whole 656 set of the 33 wines the first time. This may have been a re-evaluation of these two wines in relation to the quality of the 31 other wines. In addition, the small number of judges may lead to limitations 657 concerning the reliability of wine categorization in one zone. Table 3 demonstrates wines that were 658 659 significantly placed in a different zones (10D, 14A, 14B, 15D-2, 15F, 15H, 16K-1, 16K-2, 16N-2) or not in any zone (15D-1), thus highlighting the difficulty of predicting the future quality of very young 660 wines. To evaluate these younger wines, a larger number of judges should be recruited, or the zone 661 662 significantly chosen during the first or second tasting should be reconsidered.

- 663 Concerning the analysis of the judges' results and accordance of zone choice between judges and 664 panel, the disagreement of these judges' choices compared to the rest of the panel indicates the 665 variability in judge/wine interactions, which is based on the judges' individual opinion, experience, 666 intrinsic sensitivity, or use of the projective categorization (curves). It is unrealistic to expect a 100% 667 consensus in a predictive evaluation of such a complex product as wine.
- 668 Finally, the heterogeneity of the panel members' evaluations always resulted in a wine being 669 significantly located in one zone, thanks to a core consensus among the judges, thus demonstrating the 670 decision-making power of the group. The relevance of the results obtained with the panel was verified. Finally, in regard to reproducibility of judges, when these results were compared with the group's 671 672 ability to position a wine significantly in one zone, the panel compensated for the variability of 673 individual judges. This highlighted the usefulness of working with a tasting committee: every member 674 contributes their own experience and personal variability to build and consolidate a reliable evaluation 675 of the reserve wines' aging potential. Furthermore, as regards the positions which are not in agreement 676 with the panel consensus, 20% of these positions could easily be improved with more in-depth training 677 to accustom the judges to the evaluation curves and improve the group consensus. In this way, more 678 wines would be positioned in fine segmentation zones as shown in Figure 3B (k=14).
- 679

## 680 5 <u>Conclusion</u>

Evaluating potential aging by projective categorization is an innovative approach in sensory analysis.
The mental definition given by winemakers accustomed to using this concept enabled developing an
illustration using curves and to classify the wines' sensory analysis. A statistical method was
developed for processing responses in order to obtain significant product rankings.

Projective categorization was applied in real conditions using thirty-three Champagne reserve wines tasted twice by a panel of eleven judges. At the first tasting, 88% of the wines obtained a significant categorization for aging potential. During the second tasting, 60% of the wines obtained the same classification, demonstrating a certain efficacy in this methodology, but also that panel assessments were not in agreement between the two tasting sessions. These results may be improved using a larger number of judges. In addition, the "training" and "practice" of the judges seems to be an important

- 691 parameter for improving panel consensus. This training may be obtained through a judge's calibration692 in the use of the projective categorization scale.
- The greater the consensus of the panel, the more accurate the results obtained. These results, obtained thanks to projective categorization, are proportionally linked to the panel consensus. Compared to other conventional sensory analysis methods, projective categorization adapts to the panel's performance to obtain a significant categorization of the sample. However, the reliability of this categorization depends on the number of judges, as is the case for all sensory analysis methods. The statistics calculated would be unchanged according to the number of judges and the level of the categorization used to process the responses.
- Finally, this evaluation was of particular interest for improving the profitability of storage and
  optimizing the wine aging strategy. In addition, sensory concepts are used in many industry sectors
  and projective categorization may be adapted to address specific requirements or problems. One likely

vue for projective categorization is in the aging of bottled, still, white and red wines. It may also be

visual to measure the quality of any food product over time, especially in quality control.

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Figure 1:



Figure 2:











Figure 5 :

**Figure 1:** Mental representation of Champagne reserve wine aging potential by wine professionals. Percentages of semantic classes correspond to the quotation frequency of responses.

**Figure 2:** Model showing three levels of Champagne reserve wine aging potential from its mental definition for projective categorization sensory analysis processing

**Figure 3:** Two types of curve segmentation representative of aging potentials in the area with "A" extensive segmentation and "B" very fine segmentation. Abbreviations: By (young blue); Bi (intermediate blue); Bc (increasing blue); Bo (optimal blue); Bo1 (optimal blue 1); Bo2 (optimal blue 2); Bd (blue decline); Rc (red increasing); Ry1 (young red 1); Ry2 (young red 2); Ri1 (intermediate red 1); Ri2 (intermediate red 2); Ri3 (intermediate red 3); Rp (red plateau); Rep (end of red plateau); Rd (red decline); G (green).

**Figure 4:** Example of the procedure (A to C) used to counting the wines positioned on more or less finely-segmented zones. Eleven judges positioned the same wine at different locations indicated by the "\*" symbol.

**Figure 5:** Significant positioning of 29 out of 33 reserve wines on the curves delimited by 10 zones during the first tasting.