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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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Abstract:

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 red or whites to develop qualitatively during aging. Previous authors who studied wine aging potential proposed a method of evaluation using a one-dimensional scale. However, during the concept description task, wine aging potential was linked to three dimensions: time; wine quality, and potential. The methods available in quantitative sensory analysis, such as Profile, Free Choice Profile and Flash Profile, do not allow for quantifying more than two dimensions simultaneously. A new, 3-dimensional scale and sensory analysis method was developed, based on cognitive definitions from professional tasters concerning the aging potential of champagne reserve wines.

This method, called "projective categorization," introduces several dependent variables, offering tasters a visual tool to evaluate the projected development of a wine's quality over time on different dynamics.

A specific, statistical analysis was developed for significant evaluation of wines and judges. This new tool was tested on 33 champagne reserve wines aged from 1 to 29 years. It demonstrated its capability in distinguishing accurately wines with different aging aptitudes. Indications concerning panel consensus and judges' performance were also provided.

This is the first time that a sensory methodology has been developed on the basis of a sensory concept in order to classify products. This method enabled obtaining a precision for categorizing champagne 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.

39

40 **Keywords:**

41 wine aging potential, sensory analysis, panel performance, wine evolution quality, projective
42 categorization

43

44 **1. Introduction**

45 Aging potential is a concept used by wine tasting experts to evaluate a wine's ability to retain quality
46 and typicity during aging (Coutier, 2013; Hardy, 1990; Langlois et al., 2011). According to this
47 positive sensory definition, wines do not all share an equal capacity for aging, indicating the
48 development over time of an aging bouquet. The bouquet denotes a set of aromas which together form
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
51 characterized by the loss of fermentative aromas, a variable attenuation of fresh fruity notes (Jackson,
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).
62 For instance, Chardonnay wines develop a complex bouquet, described by experts using aromatic
63 terms such as "hazelnut" and "flint", with overtones of "oatmeal" and "toast" (Gros et al., 2017). Some
64 sparkling Champagne wines also seem to have aging potential. Tominaga et al. (2003) described the
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
78 oaky, toasty, and prune aromatic notes (Jaffré et al., 2009). In the case of red Bordeaux wines, markers
79 of the aging potential of young wines included similar attributes, such as acidity, astringency, oak, and
80 tannins (Langlois et al., 2011). A lexical analysis performed by Langlois et al. (2011) revealed that
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
89 and is based on the taster's experience. In fact, even wines from the same vintage reveal different
90 degrees of aging over time, suggesting that not all wines possess the same positive aging potential.
91 Thus, the definition of a "young" or "old" wine is complex and eminently dependent on the context.

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".

96 At the same time, the level or intensity of the optimal "quality" achieved during aging may vary
97 between wines. These notions were applicable in both young wines (Langlois et al., 2011) and those
98 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.

104 This multi-sensory approach evaluates a wine as a whole, by associating the complexity factor,
105 predictive of its aging over time. Moreover, the notion of wine complexity is central to the mental
106 representation of the bouquet (Picard et al., 2015) and consequently to the aging potential as revealed
107 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

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

117 In addition, a wine categorization task has already been carried out by Jaffré et al. (2009) in order to
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
131 quality and high aging potential? Other limitations may exist as none of the methodologies presented
132 in the literature simultaneously measure current and future quality of wine or other food products as a
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
138 (Rosch et al., 1976; Salette, 1997). Thus, it was possible to highlight interesting differences among
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
145 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 characteristicly 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
152 maintains a consistent style in accordance with AOC regulations (Légifrance: Décret n° 2010-1441,
153 2010).

154 To guarantee constant quality and a "Champagne-house sensory style", it is essential to select young
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
164 tasting. In this context, the professional tasters of Champagne reserve wines are experts on the aging
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.

169 The experimental design consisted of three main parts. (i) Define the aging potential of Champagne
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.

176

177 **2. Materials and methods**

178 **2.1. Part (i): Aging potential of Champagne reserve wines definition**

179 **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
183 were categorized as "wine professionals", according to the criteria proposed by Parr et al. (2004) and
184 Ballester et al. (2005).

185 -All participants were familiar with the quality image of VCP Champagne.

186 All winemakers were native French-speakers, six males and four females aged between 31 and 58. The
187 average age of the panel was 39 years.

188

189 **2.1.2. Experimental procedure**

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

194

195 **2.1.3. Data analysis**

196 Grouping methodology was used to facilitate data interpretation (Lawrence et al., 2013; Sester et al.,
197 2013; Spinelli et al., 2015; Tournier et al., 2007). Several grouping levels were used to analyze
198 participant responses.

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

202 The terms were then grouped by semantic families, related to oenological knowledge, by three
203 researchers from the Institute of Vine and Wine Science-Bordeaux University, working independently
204 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
210 category in the dimensions that define the aging potential. Terms like "will appear", "initially",
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"
214 contained, for example, the "tertiary aroma" family evoked by the terms "evolutionary notes" and
215 "tertiary aromatic richness". Conversely, in the semantic category "aroma", the sub-category "initially"
216 contained the terms "fruity", "mineral", and "citrus".

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

219

220 **2.2 Part (ii): Projective categorization statistical methodology development**

221 **2.2.1 General principle**

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

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

233

234 **2.2.2 Software**

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

237

238 **2.3 Part (iii): Wine tasting using projective categorization (curves) to evaluate aging** 239 **potential**

240 **2.3.1 Panel**

241 One additional subject (male), a winemaker, was present in the panel, used for the mental definition of
242 reserve wine aging potential, described in section 2.1.1. The eleven winemakers were native French-
243 speakers, seven males and four females. The average age of the panel was 35 years and aged between
244 31 and 58.

245

246 **2.3.2 Procedure**

247 The evaluation was organized in March 2017 in a sensory room at VCP Champagne (Reims, France)
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.

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

258 These pencil marks by each wine were then converted to the (X; Y) coordinate of the orthonormal
259 system. (X; Y) corresponded to the distance in mm, measured with a ruler. The segmentation of the
260 curves also allowed defining zones according to coordinates (X; Y) for the beginning and (X; Y) for
261 the end. Using Excel® software, all (X; Y) pairs corresponding to the judges' wine scores were
262 assigned to a named zone along the segmentation levels (e.g.: very fine, fine and extensive). Then, the
263 number of different zones per wine was calculated for each segmentation level. Finally, the count
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.

272 The wine evaluation sessions took place two weeks after the calibration sessions. The panel
273 individually evaluated thirty-three different reserve wines twice, so a total of sixty-six samples were
274 presented in three series of twenty-two (Table 1) on three non-consecutive days. The wines were
275 successively served one by one (monadic presentation) in the random order defined for each judge. A
276 3 to 4-minute delay was applied before the judge was served with the next wine.

277

278 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
284 three different qualities named “cuvée” (2050 L), “première taille” (300 L) and “seconde taille” (200
285 L) respectively of higher, intermediate and lower quality (Françot, 1950). Further details of the
286 technical and winemaking process for these forty-four different reserve wines (“cuvées” and “tailles”)
287 are available in Le Menn et al. (2017).

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

290

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

| Reserve wines presented |

Grape variety	Champagne subregion code	Vintage	Calibration session	Wine evaluation session	Wine Code (vintage + subregion)
PN	A	1988		×	88A
PN	B	1996	×		96B
CH	A	1999	×		99A
CH	C	2000	×	×	00C
CH	C	2004	×	×	04C
PN	D	2006		×	06D
CH	C	2007	×	×	07C
PN	L	2007	×	×	07D
CH	C	2008		×	08C
PN	D	2008	×	×	08M
PN	K	2009		×	09K
CH	M	2009		×	09M
CH	A	2010		×	10A
PN	D	2010		×	10D
CH	C	2012		×	12C
PN	F	2012	×	×	12F
CH	C	2013	×		13C
PN	E	2013	×	×	13E
PN	F	2013		×	13F
PN	D	2013	×	×	13D
CH	M	2013		×	13M
PN+MN	1 st taille	2014	×		141T
PN+MN	2 nd taille	2014	×		142T
PN	B	2014	×	×	14B
CH	A	2014		×	14A
CH	G	2014	×	×	14G
PN	D	2014	×	×	14D
PN+MN	2 nd taille	2014		×	142T
PN	O	2014		×	14O
CH	H	2015		×	15H
CH	1 st taille	2015	×		151T-B-1
PN+MN	1 st taille	2015	×		151T-N
CH	I	2015	×		15I
CH	A	2015	×		15A
CH	J	2015	×		15J
PN	K	2015	×		15K
PN	F	2015		×	15F
PN	D	2015		×	15D-1
PN	D	2015		×	15D-2
CH	1 st taille	2015		×	151T-B-2
CH	N	2016	×	×	16N-1
CH	N	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

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

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

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

312 The “Flavor dynamics”, “Balance”, “Structure”, “Sensation”, “Acidity”, “Aromas”, and “Absence of
313 off-flavors” categories were used in wine descriptions, representing 62% of all the cited words.
314 Several terms referred to wine concepts such as “Minerality” or “Finesse” or “Pure” and others were
315 not studied any further. These descriptors were cited for reserve wines considered to have "high aging
316 potential". Concerning the "Capacity" category, the terms were synonymous with the potential notion,
317 which is always linked to the notion of "quality" and "high potential". Consequently, the majority of
318 the terms (67%) described wines with a high aging potential.

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

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

324 In the “time dimension”, the balance between “real wine age” and “apparent sensory age” was a
325 decisive element in evaluating its aging potential. Indeed, some older wines still had the sensory
326 attributes of younger ones and, therefore, enormous aging potential. Jaffré et al. (2009) already
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
330 dimensions: quality and aging potential. Wines evaluated as “low aging potential” may mature faster,
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
335 "plateau", the duration of this stability was difficult to estimate but lasted up to several years. This
336 observation highlighted the fact that high quality wines take time to acquire complexity and balanced
337 aroma and flavors. At the end of the wine aging process, irrespective of the potential and sensory
338 quality, the peak was always followed by a rapid decline in quality. This negative evolution was
339 characterized by the appearance of oxidation. Reserve wines' aromas related to oxidation were
340 considered as off-flavors and justified the quality decline.

341

342 **3.2 Proposal for an illustrated Champagne reserve wine aging potential** 343 **representation (projective categorization) suitable for quantitative sensory** 344 **analysis**

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

350 Following a meeting with the tasters who participated in the conceptual definition (section 2.2 and
351 Figure 1), three different levels of Champagne reserve wine aging potential were proposed to reflect
352 production considerations, i.e. to represent the principal profiles of wine evolution according to time
353 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
359 potential", illustrated a wine category with intermediate potential, between "high potential" and "low
360 potential". These wines expressed a more modest qualitative improvement than "high potential" wines,
361 but in a shorter time.

362 The axes are deliberately unstructured. Indeed, the wine quality concept involved many parameters
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
367 wines, this point defined the production year and the quality was variable according to climate during
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.

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

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

377

378 **3.3 Part (ii): Development of data analysis for projective categorization**

379 **3.3.1 Objectives**

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

386

387 **3.3.2 Step 1: Delimiting curve zones**

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

393 Initially the boundaries of the zones were defined as extensive i.e. very wide or large zones.
394 Consequently, a minimum number of zones delimited the curves (Figure 3A). The number of zones
395 increased by adding boundary markers. Following this procedure, it was possible to compare the
396 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
399 aging potential will not be kept in the cellar, so it was irrelevant to segment this potential into several
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
404 optimization.

405 The level of segmentation may thus be variable, involving more or less zones. Consequently, two
406 levels of segmentation are represented in Figures 3 A and B, showing examples of extensive and fine

407 delimitation respectively. The aim of increasing the fineness of the segmentation is to achieve a more
408 precise positioning of the product if the consensus of the panel is high.

409

410 **3.3.3** Step 2: Enumeration of the wines positioned on the curves and 411 segmentation

412 In accordance with the panel consensus calculation formulated in 3.1.4.1., it was necessary to identify
413 the zone where the greatest number of tasters positioned the same wine. This “step 2” involved
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
422 highest number of selections for a single zone. However, do 6 out of 11 judges allow us to conclude
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.

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

431

432 **3.3.4** Determination of threshold values

433 Statistical processing was conditioned by the probability of an event occurring in an Ω 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.

439 This result was associated with a “Risk of rejecting the "Ho" hypothesis wrongly, with Ho: a wine is
440 not associated with a specific zone” α (type I) set at 5%, the standard value used in sensory analysis to
441 determine significant results. Another risk discussed in sensory analysis are type II errors (β) (Lawless
442 & Heymann, 1998): calculating the probability of erroneously concluding that no perceptible
443 difference exists. This value is dependent on the segmentation level. It is higher with fine than with

444 extensive segmentation. Generally, type II errors are calculated by comparison with other common
445 sensory analysis methods. However, there was no other methodology aimed at obtaining results
446 similar to those obtained by positioning wines on the curves, so type II could not be calculated.
447 To determine the threshold value, it was necessary to calculate the probability that the judges
448 randomly placed the same wine in the same zone. The following variables were defined: let "n" be the
449 minimum number of judges required to place a given wine in the same zone, "N" the number of total
450 judges participating in the sensory analysis, and "k" the total number of zones considered (depending
451 on the segmentation level used). The calculation was based on finding the number "n" of judges
452 required with "N" and "k" fixed for the probability of this event occurring at random was less than
453 0.05 ($\alpha \leq 5\%$) and to conclude that the wine was thus significantly associated with the particular zone.
454 The number of zones, "k", was at least three, so a multinomial distribution function was used to
455 calculate these probabilities. The number of judges "N" was known for each tasting session. The
456 probability that one judge placed a wine randomly was defined as $1/k$. The value of "n" varied from 0
457 to "N".
458 The calculation of the threshold value "n" involved adding the probabilities of several events. Indeed,
459 certain events lead to the same result, i.e., the most chosen zone by the judges. The judges who did not
460 position the wine in this zone raised several possible combinations. If the same number of judges
461 chose the same zone, the events had an identical probability. In addition, the probability that a number
462 of judges positioned the same wine in the same zone implied that the considered zone was not defined
463 in advance, but was the one with the highest count.
464 The probabilities of the events and their sum were calculated according to the sensory analysis
465 variables using R software for all values of "n", "k" and "N". Thus, when the probability that "n"
466 judges out of "N" for "k" zones was less than 0.05, the attribution of a wine to a zone was significant
467 and "n" was the threshold value.

468

469 **3.3.5** Step 3: Calculation of threshold values by R

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

477 At the end of the script, an example of the calculation synthesis is presented (Table 2). When $N = 11$
478 judges and $k = 7$ zones, with the probability of being wrong less than 5%, according to the calculations
479 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
 488 threshold value "n".

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 ⁻⁵
4	1	1	1	0.912	0.449	0.137	0.030	0.005	5.04 x10 ⁻⁴	3.24 x10 ⁻⁵	9.54 x10 ⁻⁷
5	1	1	1	0.711	0.25	0.058	0.010	1.18 x10 ⁻³	9.47 x10 ⁻⁵	4.61 x10 ⁻⁶	1.02 x10 ⁻⁷
6	1	1	0.979	0.532	0.147	0.028	0.004	3.65 x10 ⁻⁴	2.37 x10 ⁻⁵	9.26 x10 ⁻⁷	1.65 x10 ⁻⁸
7	1	1	0.929	0.398	0.091	0.014	0.002	1.33 x10 ⁻⁴	7.25 x10 ⁻⁶	2.37 x10 ⁻⁷	3.54 x10 ⁻⁹
8	1	1	0.862	0.302	0.059	0.008	0.001	5.53 x10 ⁻⁵	2.58 x10 ⁻⁶	7.26 x10 ⁻⁸	9.31 x10 ⁻¹⁰
9	1	1	0.788	0.233	0.039	0.005	4.13 x10 ⁻⁴	2.53 x10 ⁻⁵	1.04 x10 ⁻⁶	2.55 x10 ⁻⁸	2.87 x10 ⁻¹⁰
10	1	1	0.716	0.182	0.027	0.003	2.29 x10 ⁻⁴	1.25 x10 ⁻⁵	4.56 x10 ⁻⁷	1.00 x10 ⁻⁸	1.00 x10 ⁻¹⁰
11	1	1	0.648	0.145	0.02	0.002	1.34 x10 ⁻⁴	6.58 x10 ⁻⁶	2.16 x10 ⁻⁷	4.28 x10 ⁻⁹	3.86 x10 ⁻¹¹
12	1	0.999	0.587	0.117	0.014	0.001	8.17 x10 ⁻⁵	3.66 x10 ⁻⁶	1.09 x10 ⁻⁷	1.97 x10 ⁻⁹	1.62 x10 ⁻¹¹
13	1	0.998	0.532	0.096	0.011	0.001	5.18 x10 ⁻⁵	2.13 x10 ⁻⁶	5.84 x10 ⁻⁸	9.65 x10 ⁻¹⁰	7.25 x10 ⁻¹²
14	1	0.996	0.483	0.079	0.008	0.001	3.39 x10 ⁻⁵	1.29 x10 ⁻⁶	3.26 x10 ⁻⁸	4.98 x10 ⁻¹⁰	3.46x10 ⁻¹²

489
 490 **3.3.6 Step 4: Determination of wine (product) assigned significantly**
 491 **to one zone**
 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.
 498 Figure 4 "A" presents 14 delimited zones. According to Table 2, for 11 judges and 14 zones, at least 5
 499 judges out of 11 had to place the same wine in the same zone to conclude that the wine was
 500 significantly associated with one zone. Nevertheless, Figure 4 "A" shows that no zone was chosen
 501 more than 4 times. Figure 4 "B" shows that 9 zones were defined. According to Table 2, 5 judges had
 502 to place the same wine in the same zone to obtain a significant result. However, these conditions were
 503 still not met. With the segmentation presented in Figure 4 "C", 6 judges positioned the same wine in
 504 "Rc" zone. According to Table 2, the probability that this result was obtained at random was 0.014.

505 Therefore, the extensive segmentation (Figure 4 "C") resulted in a significant positioning for the wine
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.

508 This procedure was repeated for each wine. Therefore, the higher the consensus among judges the
509 more zones were retained (increase of "k").

510

511 **3.4 Part (iii): Sensory analysis results by projective categorization**

512 **3.4.1 Results concerning the positioning of the wines**

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.

521 The analysis of the wine placement by the judges showed that 29 out of 33 wines tasted (88%) were
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
531 number of considered zones, (k=7), 3 wines out of 4 had a significant assignment in a larger zone
532 (extensive segmentation). The reserve wines 14A, 15D-1 and 16K-1 could thus be significantly
533 positioned in the zone "Rc" as shown in Figure 3A (k=7). Only the 15F wine did not obtain any
534 agreement in the positioning by the judges. Indeed, 15F was positioned by 4 judges on the
535 intermediate potential (blue curve), 4 on the high (red curve) and 3 on the low potential (green curve).

536 Finally, as shown in Figure 5 and Table 3, the 08D wine was significantly positioned in two zones,
537 "Ri" and "Rp". Five judges chose both zones and only one chose the "Bo" zone. The zones "Ri" and
538 "Rp" were neighbors and reflect a close qualitative status on the same high potential (red curve) for the
539 particular wine.

540

541
542

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
CH	88A	Rep	Rep	No
CH	00C	Rep	Rep	No
CH	04C	Rep	Rep	No
PN	06D	Rp	Rp	No
PN	07C	Rp	Ri	neighboring zones
CH	07L	Rp	Rp	No
CH	08C	Rp	Rp	No
PN	08D	Rp&Ri	Ri	neighboring zones & no difference
CH	09K	Rp	Rp	No
PN	09M	Rp	Rp	No
CH	10A	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	13E	Ri	Ri	No
CH	13F	Ri	Ri	No
PN	13M	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	14O	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	

543

544

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

547 The same wines were evaluated twice with projective categorization. The comparison of the results
548 obtained (Table 3) also corresponded to the evaluation of the panel's reproducibility. The same
549 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
552 numerous, compared to the first tasting. Nevertheless, the success rate of the panel was high with 79%
553 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.
556 Several cases were highlighted. Firstly, judges chose significantly a different potential (different
557 curve), for the wine 12C (Table 3). For example, judges assigned wine 12C to a different potential
558 curve significantly above chance. During the first tasting this wine was assigned significantly to zone
559 "By", while in the second tasting zone "Ri" was chosen. Although the panel did not choose the same
560 zone for both tastings, it did choose two zones with aging potential indicating that the wine would
561 further improve in the future.

562 Secondly, in Table 3 the wines "08D" and "14O" obtained a significant placement in two different,
563 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.

568 Thirdly, the wines were positioned in a neighboring zone with the same potential. In table 3, the wines
569 "07C" and "12F" were placed in the "Rp" zone during the first tasting and in the "Ri" zone during the
570 second tasting.

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

574
575
576 **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.

583 Interestingly, no individual taster was totally in agreement with the choice of the whole panel for all
584 the wines. The greatest similarity observed between the choice of one judge and that of the panel was
585 73%, versus 52% for a lesser similarity.

586

587

3.4.2.2 Reproducibility of judges

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

592 Another performance indicator was the distribution of all positions on the curves assigned to a given
593 wine by all the judges. All wines were significantly associated with one zone thanks to panel
594 consensus, even if all the judges did not position each wine in the same zone. The "neighboring zones"
595 concept was applied to the two zones "upstream" and "downstream" from the one significantly chosen
596 by consensus. In addition, the term "distant zone" was used to describe a position chosen by a judge
597 that was not close to the one chosen by consensus. Positions not in agreement with the panel
598 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.,
608 2018), the results of the current study converge on the capacity of certain wines to express positive
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
611 zones, the low consensus of the panel may be explained by the existence of different sensory
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
615 category. These were those recognized by the majority of tasters and which gained a strong consensus
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
620 zones of the curves. For example, the "Rp" zone was defined by the sensory attributes involved in the
621 recognition of wines in this category, represented by the wines 06D, 07L, 07C, 08C, 09M, 09K, 10A,
622 12F, and 14B. Concerning the prototype wine of this category (Rp), reserve wines such as 07L, 08C,
623 09M, and 14B were positioned by the highest number of judges (7 out of 11). These wines shared the
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 typicality, 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
631 overlapping boundaries (Rosch & Mervis, 1975). This proposal has already been put forward in
632 conceptual oenology studies, notably by highlighting a sensory continuum for product typicality rather
633 than a strict categorization (Ballester et al., 2005, 2008; Cadot et al., 2010; Jaffré et al., 2011; Schüttler
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
645 overlapped zone for this wine. However, if this modification had been considered, it should have been
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
648 (N=11). A larger number of judges could increase the significant differentiation and therefore increase
649 the level of segmentation used ($k > 10$).

650 Following the comparison of the results of the first tasting vs. the second tasting of the same wines, the
651 difference in the obtained results for wines "08D" and "14O" may be explained by the limits of the
652 boundaries of the two zones, as well as by the small number of panel members. In Table 3, the results
653 obtained for wines "07C" and "12F" may be explained by the difficulty for the panel to estimate any
654 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
657 the quality of the 31 other wines. In addition, the small number of judges may lead to limitations
658 concerning the reliability of wine categorization in one zone. Table 3 demonstrates wines that were
659 significantly placed in a different zones (10D, 14A, 14B, 15D-2, 15F, 15H, 16K-1, 16K-2, 16N-2) or
660 not in any zone (15D-1), thus highlighting the difficulty of predicting the future quality of very young
661 wines. To evaluate these younger wines, a larger number of judges should be recruited, or the zone
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.

671 Finally, in regard to reproducibility of judges, when these results were compared with the group's
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 Conclusion**

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

685 Projective categorization was applied in real conditions using thirty-three Champagne reserve wines
686 tasted twice by a panel of eleven judges. At the first tasting, 88% of the wines obtained a significant
687 categorization for aging potential. During the second tasting, 60% of the wines obtained the same
688 classification, demonstrating a certain efficacy in this methodology, but also that panel assessments
689 were not in agreement between the two tasting sessions. These results may be improved using a larger
690 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 calibration
692 in the use of the projective categorization scale.

693 The greater the consensus of the panel, the more accurate the results obtained. These results, obtained
694 thanks to projective categorization, are proportionally linked to the panel consensus. Compared to
695 other conventional sensory analysis methods, projective categorization adapts to the panel's
696 performance to obtain a significant categorization of the sample. However, the reliability of this
697 categorization depends on the number of judges, as is the case for all sensory analysis methods. The
698 statistics calculated would be unchanged according to the number of judges and the level of the
699 categorization used to process the responses.

700 Finally, this evaluation was of particular interest for improving the profitability of storage and
701 optimizing the wine aging strategy. In addition, sensory concepts are used in many industry sectors
702 and projective categorization may be adapted to address specific requirements or problems. One likely
703 use for projective categorization is in the aging of bottled, still, white and red wines. It may also be
704 used to measure the quality of any food product over time, especially in quality control.

705 **References:**

- 706 Andri S., et mult. al. (2021). DescTools: Tools for descriptive statistics. R package version 0.99.41,
707 <https://cran.r-project.org/package=DescTools>. Accessed Mai 25, 2021
- 708 Albert, I., & Denis, J. B. (2012). Dirichlet and multinomial distributions: properties and uses in jags.
709 *Unite Mathematiques et Informatique Appliquees, INRA*, Technical Report 2012–5.
- 710 Amerine, M. A., & Roessler, E. B. (1983). *Wines, their sensory evaluation* (2nd ed.). San Francisco,
711 CA: Freeman.
- 712 Ballester, J., Dacremont, C., Fur, Y. L., & Etiévant, P. (2005). The role of olfaction in the elaboration
713 and use of the Chardonnay wine concept. *Food Quality and Preference*, 16(4), 351–359.
- 714 Ballester, J., Patris, B., Symoneaux, R., & Valentin, D. (2008). Conceptual vs. perceptual wine spaces:
715 Does expertise matter? *Food Quality and Preference*, 19(3), 267–276.
- 716 Bende, M., & Nordin, S. (1997). Perceptual learning in olfaction: Professional wine tasters versus
717 controls. *Physiology & Behavior*, 62(5), 1065–1070.
- 718 Cadot, Y. (2006). Le lien du vin au terroir: Complexité du concept de typicité. *Revue des œnologues et*
719 *des techniques vitivinicoles et œnologiques*, 118, 9–11.
- 720 Cadot, Y., Caillé, S., Samson, A., Barbeau, G., & Cheynier, V. (2010). Sensory dimension of wine
721 typicality related to a terroir by Quantitative Descriptive Analysis, Just About Right analysis
722 and typicality assessment. *Analytica Chimica Acta*, 660(1), 53–62.
- 723 Cadot, Y., Caillé, S., Thiollet-Scholtus, M., Samson, A., Barbeau, G., & Cheynier, V. (2012).
724 Characterisation of typicality for wines related to terroir by conceptual and by perceptual
725 representations. An application to red wines from the Loire Valley. *Food Quality and*
726 *Preference*, 24(1), 48–58.
- 727 Caumont, D., & Ivanaj, S. (2017). *Analyse des données*. Paris: Dunod.
- 728 Charters, S., & Pettigrew, S. (2007). The dimensions of wine quality. *Food Quality and Preference*,
729 18(7), 997–1007.
- 730 Chollet, S., & Valentin, D. (2000). Le degré d'expertise a-t-il une influence sur la perception
731 olfactive ? Quelques éléments de réponse dans le domaine du vin. *L'Année psychologique*,
732 100(1), 11–36.
- 733 Clarke, O., & Rand, M. (2010). *Grapes & Wines: A Comprehensive Guide to Varieties and Flavours*.
734 Sterling Epicure.
- 735 Coutier, M. (2013). *Dictionnaire de la langue du vin*. CNRS éditions.
- 736 Francesca, N., Gaglio, R., Alfonzo, A., Settanni, L., Corona, O., Mazzei, P., Romano, R., Piccolo, A.,
737 & Moschetti, G. (2016). The Wine: Typicality or Mere Diversity? The Effect of Spontaneous
738 Fermentations and Biotic Factors on the Characteristics of Wine. *Agriculture and Agricultural*
739 *Science Procedia*, 8, 769–773.
- 740 Françot, P. (1950) Champagne et qualité par le pressurage. Différenciations organoleptiques,
741 biologiques et chimiques des divers moûts et vins provenant de la fragmentation du pressurage
742 champenois. *Le Vigneron Champenois*, France, pp 250–283, 342–351.
- 743 Garrido-Bañuelos, G., Ballester, J., Buica, A., & Mihnea, M. (2020). Exploring the Typicality,
744 Sensory Space, and Chemical Composition of Swedish Solaris Wines. *Foods*, 9(8), 1107.
- 745 Gros, J., Lavigne, V., Thibaud, F., Gammacurta, M., Moine, V., Dubourdiou, D., Darriet, P., &
746 Marchal, A. (2017). Toward a Molecular Understanding of the Typicality of Chardonnay
747 Wines: Identification of Powerful Aromatic Compounds Reminiscent of Hazelnut. *Journal of*
748 *Agricultural and Food Chemistry*, 65(5), 1058–1069.
- 749 Hardy, G. (1990). Le pressurage: Élément primordial de la qualité des vins de base en méthode
750 champenoise. *La Revue des Œnologues*, 55, 17–25.

751 Hopfer, H., & Heymann, H. (2014). Judging wine quality: Do we need experts, consumers or trained
752 panelists? *Food Quality and Preference*, 32, 221–233.

753 Hughson, A. L., & Boakes, R. A. (2002). The knowing nose: The role of knowledge in wine expertise.
754 *Food Quality and Preference*, 13(7), 463–472.

755 ISO 4120:2004, Sensory analysis. Methodology. Triangle test.

756 ISO 13299:2016, Sensory analysis. Methodology. General guidance for establishing a sensory profile

757 Jackson, R. S. (2009). *Wine tasting: A professional handbook* (2nd ed.). San Diego: Food Science and
758 technology, International series.

759 Jackson, R. S. (2014). 11- Sensory Perception and Wine Assessment. In *Wine Science. Principles and*
760 *Applications* (4th ed.). *Food Science and Technology* (pp. 831–888). Academic Press

761 Jackson, R. S. (2017). Nature and Origins of Wine Quality. In *Wine Tasting* (pp. 337–370). Academic
762 Press

763 Jaffré, J., Valentin, D., Dacremont, C., & Peyron, D. (2009). Burgundy red wines: Representation of
764 potential for aging. *Food Quality and Preference*, 20(7), 505–513.

765 Jaffré, J., Valentin, D., Meunier, J.-M., Siliani, A., Bertuccioli, M., & Le Fur, Y. (2011). The
766 Chardonnay wine olfactory concept revisited: A stable core of volatile compounds, and fuzzy
767 boundaries. *Food Research International*, 44(1), 456–464.

768 Langlois, J., Ballester, J., Campo, E., Dacremont, C., & Peyron, D. (2010). Combining Olfactory and
769 Gustatory Clues in the Judgment of Aging Potential of Red Wine by Wine Professionals.
770 *American Journal of Enology and Viticulture*, 61(1), 15–22.

771 Langlois, J., Dacremont, C., Peyron, D., Valentin, D., & Dubois, D. (2011). Lexicon and types of
772 discourse in wine expertise: The case of vin de garde. *Food Quality and Preference*, 22(6),
773 491–498.

774 Lawless, H. T., & Heymann, H. (1998). Descriptive analysis. In *Sensory evaluation of food: Principles*
775 *and practices*. (pp.341-378). New York: C. & Hall ed.

776 Lawrence, G., Symoneaux, R., Maitre, I., Brossaud, F., Maestrojuan, M., & Mehinagic, E. (2013).
777 Using the free comments method for sensory characterisation of Cabernet Franc wines:
778 Comparison with classical profiling in a professional context. *Food Quality and Preference*,
779 30(2), 145–155.

780 Légifrance: Décret n° 2010-1441. (2010). Décret n° 2010-1441 du 22 novembre 2010 relatif à
781 l'appellation d'origine contrôlée « Champagne ». Retrieved from
782 <https://www.legifrance.gouv.fr/loda/id/JORFTEXT000023126020/2020-11-09/>. Accessed
783 November 9, 2020

784 Le Menn, N., Marchand, S., de Revel, G., Demarville, D., Laborde, D., & Marchal, R. (2017). N,S,O-
785 Heterocycles in Aged Champagne Reserve Wines and Correlation with Free Amino Acid
786 Concentrations. *Journal of Agricultural and Food Chemistry*, 65(11), 2345–2356.

787 Millstein, J., Battaglin, F., Barrett, M., Cao, S., Zhang, W., Stintzing, S., Heinemann, V., & Lenz, H.-
788 J. (2020). Partition: a surjective mapping approach for dimensionality reduction.
789 *Bioinformatics*, 36(3), 676–681.

790 Parr, W. V., Mouret, M., Blackmore, S., Pelquest-Hunt, T., & Urdapilleta, I. (2011). Representation of
791 complexity in wine: Influence of expertise. *Food Quality and Preference*, 22(7), 647–660.

792 Parr, Wendy V, White, K. G., & Heatherbell, D. A. (2004). Exploring the nature of wine expertise:
793 What underlies wine experts' olfactory recognition memory advantage? *Food Quality and*
794 *Preference*, 15(5), 411–420.

795 Peynaud, E., & Blouin, J. (2006). *Le goût du vin. Le grand livre de la dégustation* (4th ed.). Paris:
796 Dunod.

797 Perrin, L., & Pagès, J. (2009). A methodology for the analysis of sensory typicality judgments.
798 *Journal of Sensory Studies*, 24(5), 749–773.

- 799 Picard, M., Tempere, S., de Revel, G., & Marchand, S. (2015). A sensory study of the aging bouquet
800 of red Bordeaux wines: A three-step approach for exploring a complex olfactory concept.
801 *Food Quality and Preference*, 42, 110–122.
- 802 Robinson, J. (1988). *Le Livre des cépages*. Hachette.
- 803 Rosch, E., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of
804 categories. *Cognitive Psychology*, 7(4), 573–605.
- 805 Rosch, E., Simpson, C., & Miller, R. S. (1976). Structural bases of typicality effects. *Journal of*
806 *Experimental Psychology: Human Perception and Performance*, 2(4), 491–502.
- 807 Salette, J. (1997). La typicité: Une notion nouvelle au service du produit, de ceux qui l'élaborent, et de
808 ceux qui le consomment en l'appréciant. *Revue des œnologues et des techniques vitivinicoles*
809 *et œnologiques*, 24(85), 11–13.
- 810 Saporta, G. (2006). *Probabilités, analyse des données et statistique*. Ed. Technip.
- 811 Schüttler, A., Friedel, M., Jung, R., Rauhut, D., & Darriet, P. (2015). Characterizing aromatic
812 typicality of Riesling wines: Merging volatile compositional and sensory aspects. *Food*
813 *Research International*, 69, 26–37.
- 814 Seguin, G. (1986). 'Terroirs' and pedology of wine growing. *Experientia*, 42(8), 861–873.
- 815 Sester, C., Dacremont, C., Deroy, O., & Valentin, D. (2013). Investigating consumers' representations
816 of beers through a free association task: A comparison between packaging and blind
817 conditions. *Food Quality and Preference*, 28(2), 475–483.
- 818 Solomon, G. (1990). Psychology of Novice and Expert Wine Talk. *The American Journal of*
819 *Psychology*, 103, 495.
- 820 Solomon, G. E. A. (1997). Conceptual Change and Wine Expertise. *Journal of the Learning Sciences*,
821 6(1), 41–60.
- 822 Spinelli, S., Masi, C., Zoboli, G. P., Prescott, J., & Monteleone, E. (2015). Emotional responses to
823 branded and unbranded foods. *Food Quality and Preference*, 42, 1–11.
- 824 Tominaga, T., Guimbertau, G., & Dubourdieu, D. (2003). Role of Certain Volatile Thiols in the
825 Bouquet of Aged Champagne Wines. *Journal of Agricultural and Food Chemistry*, 51(4),
826 1016–1020.
- 827 Tournier, C., Martin, C., Guichard, E., Issanchou, S., & Sulmont-Rossé, C. (2007). Contribution to the
828 understanding of consumers' creaminess concept: A sensory and a verbal approach.
829 *International Dairy Journal*, 17(5), 555–564.
- 830 Urdapilleta, I., Parr, W., Dacremont, C., & Green, J. (2011). Semantic and perceptive organisation of
831 Sauvignon blanc wine characteristics: Influence of expertise. *Food Quality and Preference*,
832 22(1), 119–128.
- 833 Valentin, D., Chollet, S., & Abdi, H. (2003). Les mots du vin: Experts et novices diffèrent-ils quand ils
834 décrivent des vins ? *Corpus (Laboratoire Language)* 2.
- 835 Van Leeuwen, C., Roby, J.-P., & De Ressaiguier, L. (2018). Soil-related terroir factors: A review.
836 *OENO One*, 52(2), 173–188.

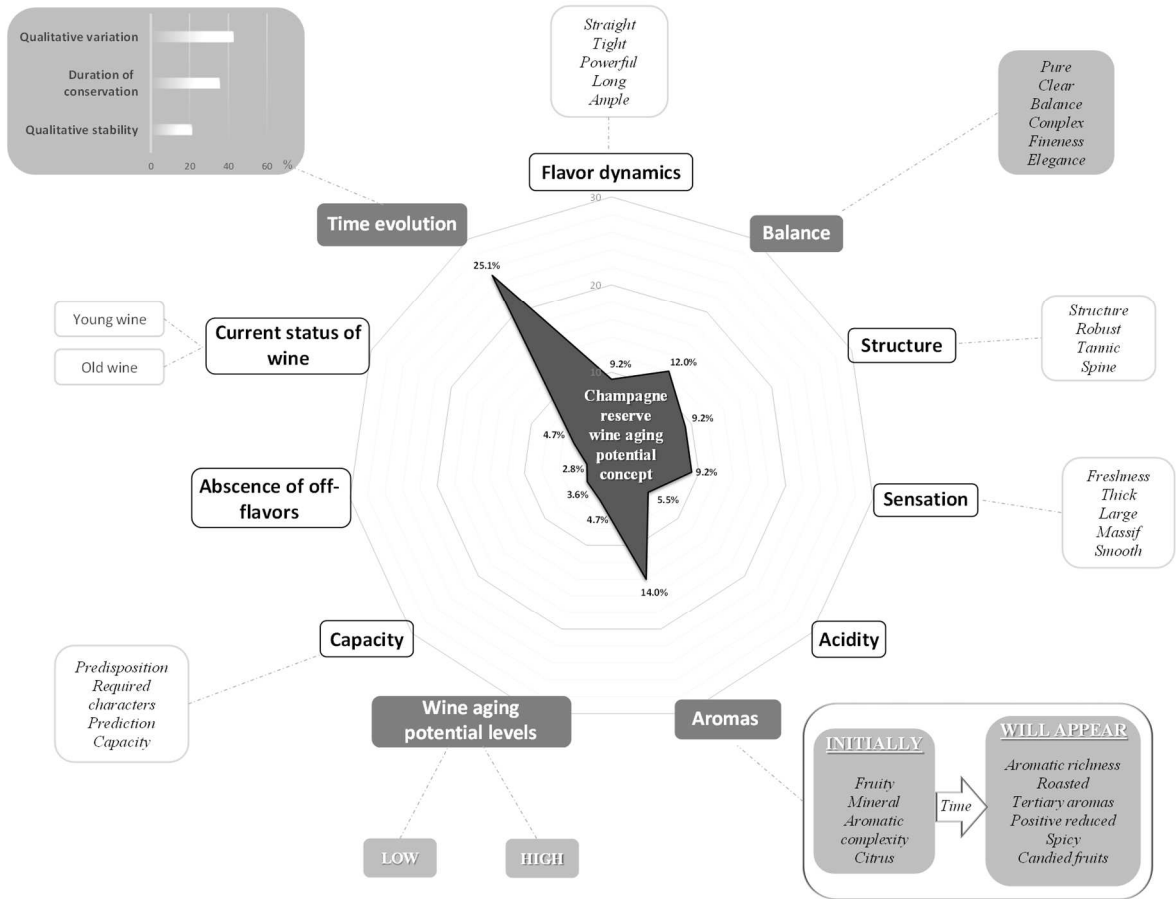


Figure 1:

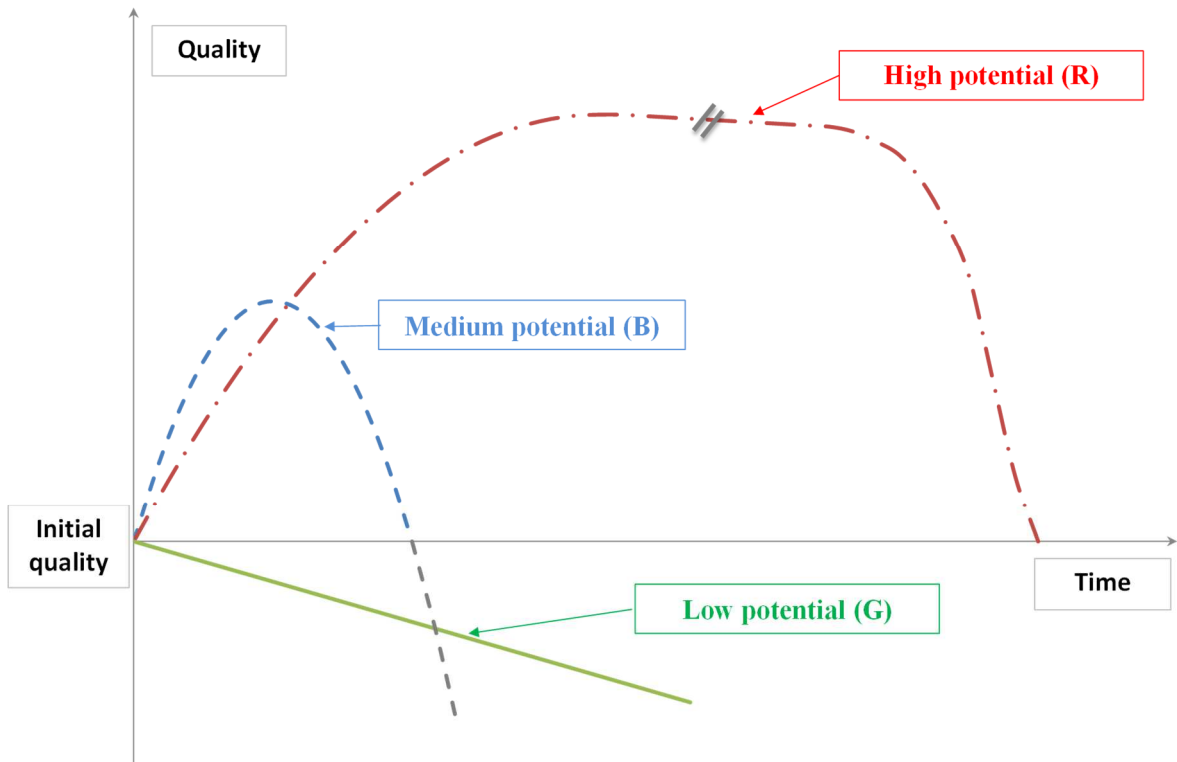


Figure 2:

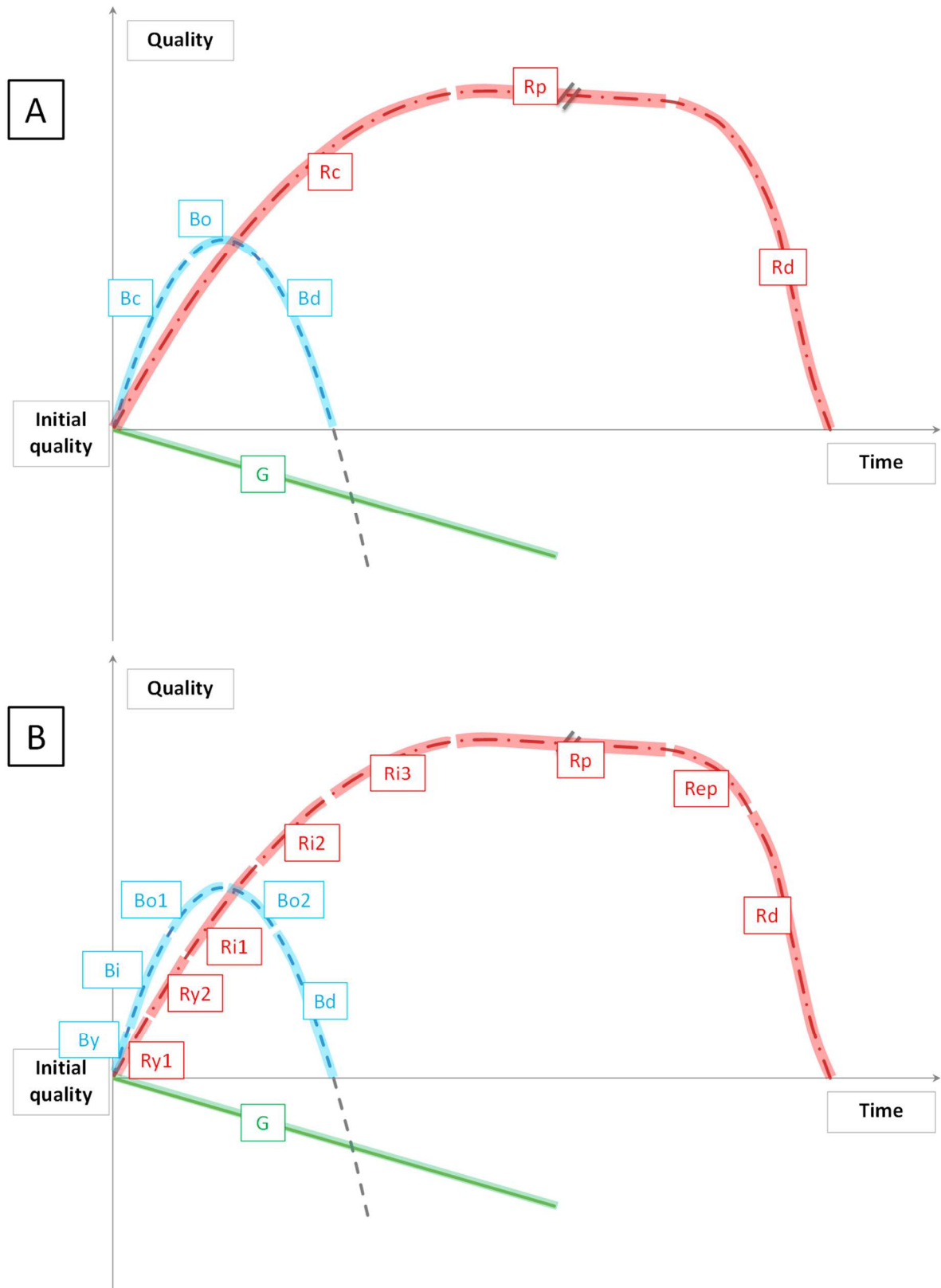


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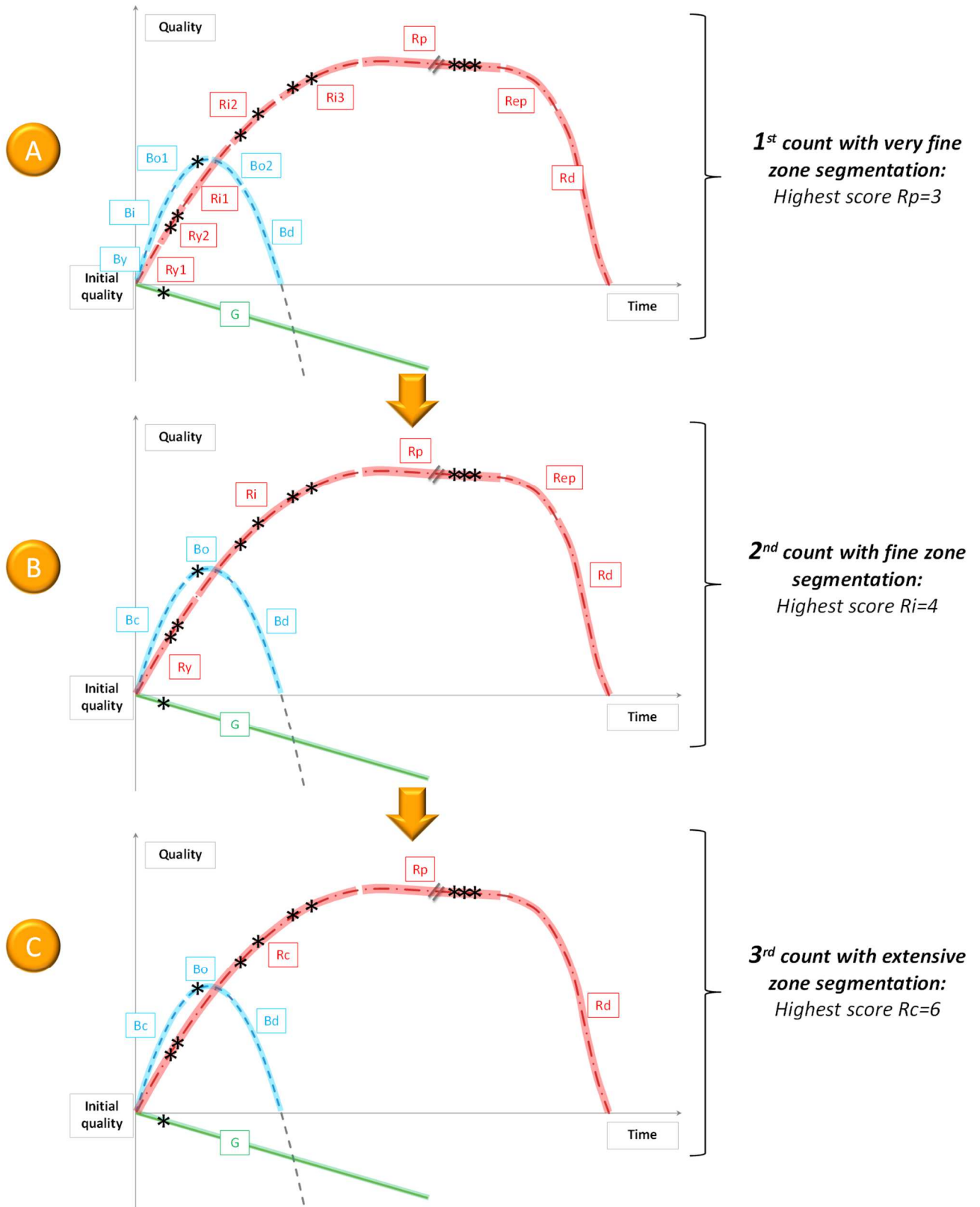


Figure 4 :

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.