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N. Le Menn[1,2,4*], R. Marchal[2,3], D. Demarville[4], P. Casenave[4], S. Tempere[1], H. Campbell - Sills[1], G. de Revel[1], S. Marchand[1]

[1]*Université de Bordeaux, ISVV, EA 4577, INRA, USC 1366 OENOLOGIE, 33140 Villenave d'Ornon, France*
[2] *Université de Reims Champagne-Ardenne, Laboratoire d'Oenologie, BP-1039, 51687 Reims Cedex 02, France*
[3]*Université de Haute-Alsace, LVBE, 68008 Colmar Cedex, France*
[4]*Champagne Veuve Clicquot, 13 rue Albert Thomas, 51100 Reims, France*

*Corresponding author (e-mail lemenn.nicolas@gmail.com)

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.

Keywords:

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

1. Introduction

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 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 a perceptive equilibrium of all olfactory sensations, where individual perceptions do not clearly 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, 2009), conservation of varietal aromas, and an evolution towards more complex and subtle new aromas. The result may be a homogenous and more harmonious flavor than that experienced in the first few year(s) after production.

In oenology, wine aging potential has been discussed in many scientific publications, as well as in articles on cognitive science and sensory analysis (Jaffré et al., 2009; Langlois et al., 2011; Picard et al., 2015). It has been cited in the definition of aging bouquet in red Bordeaux (Picard et al., 2015) and Burgundy wines (Jaffré et al., 2009; Langlois et al., 2011). Although the aging potential concept has long been used by winemakers (Hardy, 1990), only one scientific article refers to aging potential in white wines (Parr et al., 2011). This is surprising, as the great Chardonnay wines of Burgundy are 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 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 aging bouquet of these wines with empyreumatic notes of "roasted coffee bean", "grilled", "toast", and "brioche".

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

identified sensory criteria used to define the aging potential concept in several wine models (Jaffré et al., 2009; Langlois et al., 2011). In red Burgundy wines, the aging potential of young wines is linked 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 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 these four attributes represented 55% of all keywords generated by professionals. All these terms can be classified into three themes: *wine characteristics*, *time and cellaring*, and *subjective judgment*. However, no previous studies have investigated the last two themes.

Time and cellaring obviously covers the concept of "aging", as well as "young" and "old". The main question asked of the tasters was "how to judge whether a wine is young or old?". This status assessment is based on the wine style, grape variety, geographical area of production, vintage, and even the taster's experience. These parameters are then compared to the sensory age, and evaluated 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 degrees of aging over time, suggesting that not all wines possess the same positive aging potential. Thus, the definition of a "young" or "old" wine is complex and eminently dependent on the context.

In the *subjective judgment* theme, "quality" was a frequently-mentioned concept but difficult to define in wine (Amerine & Roessler, 1983; Cadot, 2006; Charters & Pettigrew, 2007; Hopfer & Heymann, 2014). Furthermore, the evaluation and prediction of "current quality" and "future quality" was 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).

The concepts of quality, time, and bouquet are intimately involved in defining aging potential. The connections between these concepts imply the existence of sensory and/or chemical factors used by wine tasters to predict the formation of an aging bouquet. Jaffré et al. (2009) and Langlois et al. (2010) clarified the importance of these factors for red Burgundy wines. Flavors, olfactory, somesthetic, and 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 vocabulary referring to extrinsic factors such as grape variety, soil, terroir, and winemaking practices, rather to specific organoleptic characteristics.

Although aging potential involves many conceptual factors, Jaffré et al. (2009) have proceeded to a 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 differentiate wines with and without aging potential. This categorization enabled the quantitative assessment of two groups of wine with an identified aging potential. Indeed, the intensity scores showed that all the wines possessed an aging potential, along a continuum from the lowest to the highest. The task of categorization was thus necessary to define the limits. Similarly, Langlois et al. (2011) also used a categorization task to study the aging potential of Burgundy and Bordeaux wines. In summary, several sensory methodologies have been used, such as a binary categorization task, an aging potential rating task, and a hedonic rating task (Jaffré et al., 2009; Langlois et al., 2011) combined with the study of aging potential.

Even if quantitative scores were obtained to measure the degree of exemplarity of a high aging potential, the significance of a single value to measure a multi-parameter concept raises the question of the quality of the measurement strategy. Several questions need to be answered. Is it the sensory proximity to the prototype wine that has an aging potential? Or, is it its stage of evolution? Does a 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 in the literature simultaneously measure current and future quality of wine or other food products as a function of time. Moreover, the specifications described in the ISO standard for a simple continuous scale were inherently incapable of taking multiple factors into account (ISO 13299:2016). Nevertheless, many authors have used this scale in the evaluation of wine~~s~~ in relation to the prototype of a category. Indeed, this methodology enables positioning specific products according to their 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 well-defined sensory categories, including grape variety (Ballester et al., 2008), origin (Cadot et al., 2010, 2012; Garrido-Bañuelos et al., 2020; Perrin & Pagès, 2009), and winemaking practices (Francesca et al., 2016).

In the case of aging potential, the categories seem to be multiple due to the obvious sensory polymorphism of wine aging, but particularly/especially due to the factors involved, such as time, 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.

The aims of this study were to explore whether it is possible to improve the sensory methodology for assessing wine aging potential, specifically of Champagne. This appellation area produces principally non-vintage sparkling wines every year. The Champagne characteristically involves, in the majority of

cases, blending several still wines from different vintages, varieties, and regions to produce the final wine. The use of aged base wines, or "reserve wine", compensate for quality changes due to climatic 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, 2010).

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

More specifically, the unique typicity or "house flavor" of Veuve Clicquot Ponsardin (VCP) is maintained by an exceptional collection of reserve wines referencing almost all vintages up to 1988. Reserve wines are monovarietal, aged, still white wines made from Chardonnay, Pinot noir, or Pinot Meunier grapes. They are preserved according to their ability to express qualitative sensory aging (in other words, bouquet). Used in blends with younger wines, they add to the final product (Champagne) an aromatic complexity recognized by the greatest tasters as the "Champagne-house sensory style". To 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 potential of this product. Throughout the production process, Champagne wines actively undergo aging processes and the concept of aging potential is widely used to predict and manage the reserve wines. Therefore, the Champagne reserve wines provide an excellent tool for professionals to measure quality according the concept of aging potential.

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

2. Materials and methods

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

2.1.1. Wine professional recruitment according to contextual wine expertise

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

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

-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 Ballester et al. (2005).

-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. The average age of the panel was 39 years.

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.

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.

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

Then, the broader semantic categories were analyzed in detail, focusing on adjectives and qualitative 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", "young", "old", "increasing quality" and many others formed a broader semantic category within several sub-categories. This last stage enabled, for example, classifying in the semantic category "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 "tertiary aromatic richness". Conversely, in the semantic category "aroma", the sub-category "initially" contained the terms "fruity", "mineral", and “citrus".

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

2.2 Part (ii): Projective categorization statistical methodology development

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*.

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).

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 French-speakers, seven males and four females. The average age of the panel was 35 years and aged between 31 and 58.

2.3.2 Procedure

The evaluation was organized in March 2017 in a sensory room at VCP Champagne (Reims, France) with twelve individual cubicles, positioned facing the wall, and each equipped with one spittoon. No visual and social disturbance was possible. The artificial light was white, but had no impact on the contents of the black glasses used. Room temperature was regulated at 20°C. Reserve wines (50 mL at 18°C) were poured into black INAO glasses with three-digit random numbers and the order of presentation was randomized among panelists. One set of curves on a single sheet was presented for each wine (monadic presentation). The curves were printed on a sheet of A4 paper, as shown in Figure 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.

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

2.3.3 Wines

The wines were from several vintages, ranging from 1988 to 2016, as shown in Table 1. Thirty-eight "cuvée" wines were monovarietal Chardonnay, Pinot noir or Pinot meunier, from fifteen subregions of the Champagne vineyards, anonymized under letters A to O. Six wines were "tailles", made from the 5 hL second pressing (after the 20.5 hL first pressing from 4000 kg whole grapes), and consisted of a 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 L) respectively of higher, intermediate and lower quality (Françot, 1950). Further details of the technical and winemaking process for these forty-four different reserve wines ("cuvées" and "tailles") 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 Champagne bottles with airtight caps.

Table 1: Characteristics (grape variety, subregion, vintage, and code) of the reserve wines selected 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	1st taille	2014	×		141T
PN+MN	2nd taille	2014	×		142T
PN	B	2014	×	×	14B
CH	A	2014		×	14A
CH	G	2014	×	×	14G
PN	D	2014	×	×	14D
PN+MN	2nd taille	2014		×	142T
PN	O	2014		×	14O
CH	H	2015		×	15H
CH	1st taille	2015	×		151T-B-1
PN+MN	1st 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	1st 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

3. Results

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.

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 attributes of younger ones and, therefore, enormous aging potential. Jaffré et al. (2009) already mentioned this point in a study of the aging potential of Burgundy wines. However, not all wines express better quality after aging, and dynamics will vary. For example, a young wine does not 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, and exhibit lower quality and complexity, than those labeled “high aging potential”. Moreover, “low aging potential” wines only spent a short time at their apex of complexity and quality. In contrast,

aging dynamics are slower in high potential wines, necessitating a longer period to achieve a 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 observation highlighted the fact that high quality wines take time to acquire complexity and balanced aroma and flavors. At the end of the wine aging process, irrespective of the potential and sensory quality, the peak was always followed by a rapid decline in quality. This negative evolution was characterized by the appearance of oxidation. Reserve wines' aromas related to oxidation were considered as off-flavors and justified the quality decline.

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, 3-dimensional 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.

The proposed projective categorization method consists of a 3-dimensional scale for assessing wine aging potential (Figure 2). The first dimension, "Time" is presented on the *x*-axis. The second dimension, "Quality", is on the *y*-axis. The third dimension, consisting of a categorization, is illustrated in this coordinate system by various curves, corresponding to "wine aging potential levels". 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 potential". These wines expressed a more modest qualitative improvement than "high potential" wines, but in a shorter time.

The axes are deliberately unstructured. Indeed, the wine quality concept involved many parameters related to experience and environmental factors in generating odor memory patterns that were difficult to quantify (Jackson, 2014 & 2017). For these reasons, and to give the panel freedom to define their own values on the scales, the coordinate system was not structured. The origin symbolized by "initial 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 the growing and ripening seasons, production area, grape varieties, and other parameters. Again, the 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 same rate.

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.

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.

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.

The zone delimitation is related to oenological interest. For example, in Figure 3A the green curve (G 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 zones. This reasoning also applies to the decline phases of high and intermediate wine-aging potential. Reserve wines that have reached this zone should be used in blends as soon as possible. The very fine segmentation curve (Figure 3B) proposes a status just prior to the decline in wine quality, labeled "Rep" or "Bo2". These present a particular interest in this context for reserve wine management optimization.

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 more precise positioning of the product if the consensus of the panel is high.

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 the zone where the greatest number of tasters positioned the same wine. This “step 2” involved counting the wines positioned in each zone according to the levels of segmentation. As an example, Figure 4 presents the compilation of the results from the evaluation of the same wine by 11 judges using the curves (projective categorization). Three levels of segmentation were considered. Figure 4 "A", shows a very fine zone segmentation, where the Rp zone was chosen by 3 judges out of 11. The other very fine zones were chosen less often (e.g. Ri3) or not at all (Rd). Figure 4 "B", shows a fine zone segmentation, where the Ri zone was chosen most frequently, by 4 judges out of 11. Figure 4 "C" shows an extensive zone segmentation, where Rc was chosen by 6 judges out of 11. In this example of 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 that the wine is significantly positioned in this zone? In the same way, was there a smaller zone significantly chosen by fewer judges? It was therefore necessary to determine whether the number of 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.

3.3.4 Determination of threshold values

Statistical processing was conditioned by the probability of an event occurring in an Ω universe (Caumont & Ivanaj, 2017; Saporta, 2006). Incidentally, this was the foundation of the significant result for a triangular test (ISO 4120:2004). The purpose of applying threshold values on the sensory analysis curve was to identify whether the same wine was significantly positioned by several judges in the same zone. Consequently, the threshold value to ensure that this result was not at random was the 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” α (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 (β) (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 ($\alpha \leq 5\%$) 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.

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.

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

= 14 zones, at least 5 out of 11 judges must place the same wine in the same zone to conclude that the wine was significantly associated with one zone. The calculation of the threshold values "n" given in Table 2 had to be reproduced for each value of the pair "N" and "k".

Table 2 : p-values (probabilities) calculated from the multinomial distribution function for “k” zones varying from 3 to 14 and compared to the number of times where the same zone was chosen “n” for “N”= 11 judges. The gray cells indicated the probability threshold <5%, used to determine the 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	1.69×10^{-5}
4	1	1	1	0.912	0.449	0.137	0.030	0.005	5.04×10^{-4}	3.24×10^{-5}	9.54×10^{-7}
5	1	1	1	0.711	0.25	0.058	0.010	1.18×10^{-3}	9.47×10^{-5}	4.61×10^{-6}	1.02×10^{-7}
6	1	1	0.979	0.532	0.147	0.028	0.004	3.65×10^{-4}	2.37×10^{-5}	9.26×10^{-7}	1.65×10^{-8}
7	1	1	0.929	0.398	0.091	0.014	0.002	1.33×10^{-4}	7.25×10^{-6}	2.37×10^{-7}	3.54×10^{-9}
8	1	1	0.862	0.302	0.059	0.008	0.001	5.53×10^{-5}	2.58×10^{-6}	7.26×10^{-8}	9.31×10^{-10}
9	1	1	0.788	0.233	0.039	0.005	4.13×10^{-4}	2.53×10^{-5}	1.04×10^{-6}	2.55×10^{-8}	2.87×10^{-10}
10	1	1	0.716	0.182	0.027	0.003	2.29×10^{-4}	1.25×10^{-5}	4.56×10^{-7}	1.00×10^{-8}	1.00×10^{-10}
11	1	1	0.648	0.145	0.02	0.002	1.34×10^{-4}	6.58×10^{-6}	2.16×10^{-7}	4.28×10^{-9}	3.86×10^{-11}
12	1	0.999	0.587	0.117	0.014	0.001	8.17×10^{-5}	3.66×10^{-6}	1.09×10^{-7}	1.97×10^{-9}	1.62×10^{-11}
13	1	0.998	0.532	0.096	0.011	0.001	5.18×10^{-5}	2.13×10^{-6}	5.84×10^{-8}	9.65×10^{-10}	7.25×10^{-12}
14	1	0.996	0.483	0.079	0.008	0.001	3.39×10^{-5}	1.29×10^{-6}	3.26×10^{-8}	4.98×10^{-10}	3.46×10^{-12}

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

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

Figure 4 shows an example of an analysis procedure for the evaluation of one wine by 11 judges. The 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 with 11 judges in "Rc", which signifies a wine with high aging potential that is expected to continue to increase in quality over time.

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

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

3.4.1 Results concerning the positioning of the wines

Thirty-three wines were tasted twice by eleven judges in three tasting sessions. In accordance with the independence of observation necessary for using the multinomial distribution (Albert & Denis, 2012), the threshold values were calculated considering N=11 judges who tasted each wine once. Therefore, results were available for wines evaluated at the first tasting and further results for the second tasting.

3.4.1.1 Results for wines evaluated at the first tasting

Using fine segmentation with the pairs N=11, k=10 (zone), at least 5 judges had to place the same 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 positioned significantly above chance in a single zone (Figure 5). The results for all 33 wines are presented in Table 3. Only 12% of wines obtained a not-significant assignment due to lack of consensus among judges. Two wines, 12C and 16N-2, were positioned on the intermediate potential (blue curve).

Concerning the reserve wines positioned in the "Ri" and "Rp" zones, several vintages were referenced. In the "Ri" zone, wines aged from 7 to 1 years old (2010 to 2016 vintage) were present while the "Rp" zone had wines aged from 11 to 3 years old (2006 to 2014 vintage). According to Table 3, the grape variety had no impact on the categorization of the wines’ aging potential compared to their real age.

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 (extensive segmentation). The reserve wines 14A, 15D-1 and 16K-1 could thus be significantly positioned in the zone "Rc" as shown in Figure 3A (k=7). Only the 15F wine did not obtain any agreement in the positioning by the judges. Indeed, 15F was positioned by 4 judges on the intermediate potential (blue curve), 4 on the high (red curve) and 3 on the low potential (green curve).

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 "Rp" were neighbors and reflect a close qualitative status on the same high potential (red curve) for the particular wine.

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**	

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 for the first and second tastings.

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.

On the other hand, the wines significantly placed during the second tasting in the same zone were 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 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 "By", while in the second tasting zone "Ri" was chosen. Although the panel did not choose the same zone for both tastings, it did choose two zones with aging potential indicating that the wine would 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 placed in 2 different neighboring zones (Rp & Ri) whereas in the second tasting it was assigned to only one of these zones (Ri). The "14O" wine was placed in the first tasting to only one of the zones (Ri), whereas in the second tasting it was assigned to 2 different neighboring zones (Rp & Ri). Thus, 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).

3.4.2 Analysis of the judges' results

3.4.2.1 Accordance of zone choice between judges and panel

The dissimilarity between the placement chosen by each judge and the zone selected by the group was calculated. This consisted of counting the number of judges who had placed a given wine in a different

zone from the rest of the group. The choice of these judges was not influenced by the origin, vintage 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.

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.

4 Discussion

Concerning the wines evaluated at the first tasting, the wines seemed well-positioned in accordance with their ages (Figure 5). The wines positioned on the low potential (green curve) were made from the "tailles" during grape pressing. This result corresponded with their low quality, often described with vegetal off-flavors and low acidity. The reserve wines positioning in the "Ri" and "Rp" zones highlights the different aging quality dynamics between the origin of the wines and their vintage. The ‘terroir’ effect may explain these observations as an interaction between vintage and sub-region. 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 sensory development independently of their age.

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 categories of aged wines. Following Rosch et al. (1976), these various sensory categories could be represented by their prototypes. In the current study, the prototype was identifiable by the sensory 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 from the panel. These were typically the wines shown in Figure 5. In agreement with Rosch & Mervis (1975), these reserve wines had to present sensory similarities close to the prototype of their category.

Following this hypothesis, and taking into consideration that the panel revealed a consensus with the 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 recognition of wines in this category, represented by the wines 06D, 07L, 07C, 08C, 09M, 09K, 10A, 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 greatest number of sensory attributes with the prototype wine, which the panel recognized with a high level of consensus. This analysis could be associated with each zone of the curves, which was significantly chosen by the judges. These observations agreed with studies concerning typicity, which highlights the consensus recognition and the definition of an ideo-type, which is a model or a reference by a panel of experts (Salette, 1997).

However, the sensory attributes could equally be shared between several prototypes representing 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 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 et al., 2015). For the potential aging evaluation of reserve wines, it seems that some wines do not fit into any obvious category, as they share sensory attributes from several different categories. Each judge has a personal sensibility to the wine sensory characteristics which results in variability in the wine's category association. This hypothesis would confirm why some wines are evaluated with a weak consensus (14A, 15D-1, 15F, and 16K-1) while others provoke a very strong consensus.

Finally, as shown in Figure 5 and Table 3, the 08D wine seemed to generate some mixed judgements for its future quality. Half of the judges assessed that the quality of this wine may improve in the following few years, while the other half assessed that the wine had reached a stable optimum quality. These two conflicting judgments of the aging potential for this wine may be related to the boundary definition for zones "Rc" and "Rd". For this example (08D), the consideration of a new overlapped 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 applied to all wines, with the risk of certain wines changing position from one to two significantly 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 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

the aging potential probably changed during the second tasting, as they tasted and evaluated the whole 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 concerning the reliability of wine categorization in one zone. Table 3 demonstrates wines that were 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 wines. To evaluate these younger wines, a larger number of judges should be recruited, or the zone significantly chosen during the first or second tasting should be reconsidered.

Concerning the analysis of the judges' results and accordance of zone choice between judges and panel, the disagreement of these judges' choices compared to the rest of the panel indicates the variability in judge/wine interactions, which is based on the judges' individual opinion, experience, intrinsic sensitivity, or use of the projective categorization (curves). It is unrealistic to expect a 100% consensus in a predictive evaluation of such a complex product as wine.

Finally, the heterogeneity of the panel members' evaluations always resulted in a wine being significantly located in one zone, thanks to a core consensus among the judges, thus demonstrating the 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 ability to position a wine significantly in one zone, the panel compensated for the variability of individual judges. This highlighted the usefulness of working with a tasting committee: every member contributes their own experience and personal variability to build and consolidate a reliable evaluation of the reserve wines' aging potential. Furthermore, as regards the positions which are not in agreement with the panel consensus, 20% of these positions could easily be improved with more in-depth training to accustom the judges to the evaluation curves and improve the group consensus. In this way, more wines would be positioned in fine segmentation zones as shown in Figure 3B (k=14).

5 Conclusion

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

parameter for improving panel consensus. This training may be obtained through a judge's calibration 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 use for projective categorization is in the aging of bottled, still, white and red wines. It may also be used to measure the quality of any food product over time, especially in quality control.

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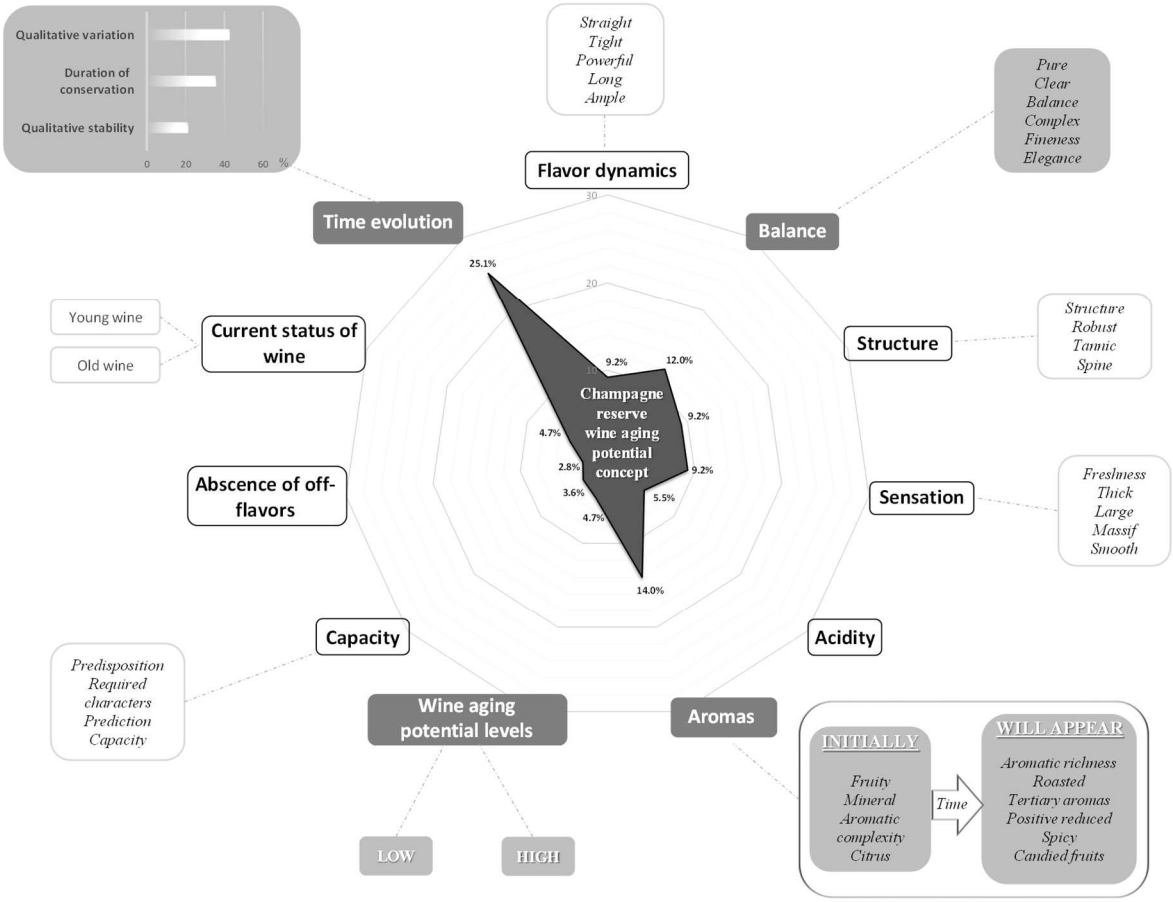
Champagne reserve wine aging potential concept
Flavor dynamics
Straight
Tight
Powerful
Long
Ample
Balance
Pure
Clear
Balance
Complex
Fineness
Elegance
Structure
Structure
Robust
Tannic
Spine
Sensation
Freshness
Thick
Large
Massif
Smooth
Acidity
Aromas
INITIALLY
Fruity
Mineral
Aromatic complexity
Citrus
Time
WILL APPEAR
Aromatic richness
Roasted
Tertiary aromas
Positive reduced
Spicy
Candied fruits
Wine aging potential levels
LOW
HIGH
Capacity
Predisposition
Required characters
Prediction
Capacity
Abscence of off-flavors
Current status of wine
Young wine
Old wine
Time evolution
Qualitative variation
Duration of conservation
Qualitative stability
0
20
40
60
%
25.1%
12.0%
9.2%
9.2%
5.5%
14.0%
4.7%
3.6%
2.8%
4.7%
9.2%

Figure 1:

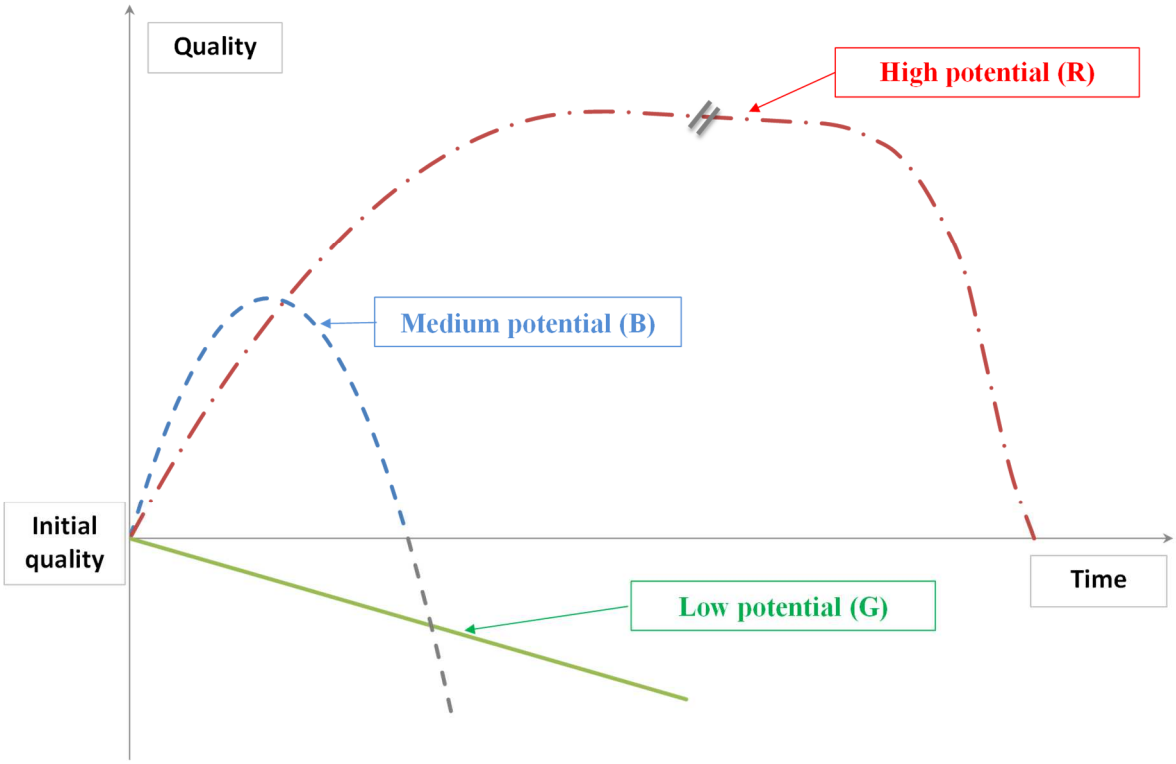
Quality
High potential (R)
Medium potential (B)
Initial quality
Time
Low potential (G)

Figure 2:

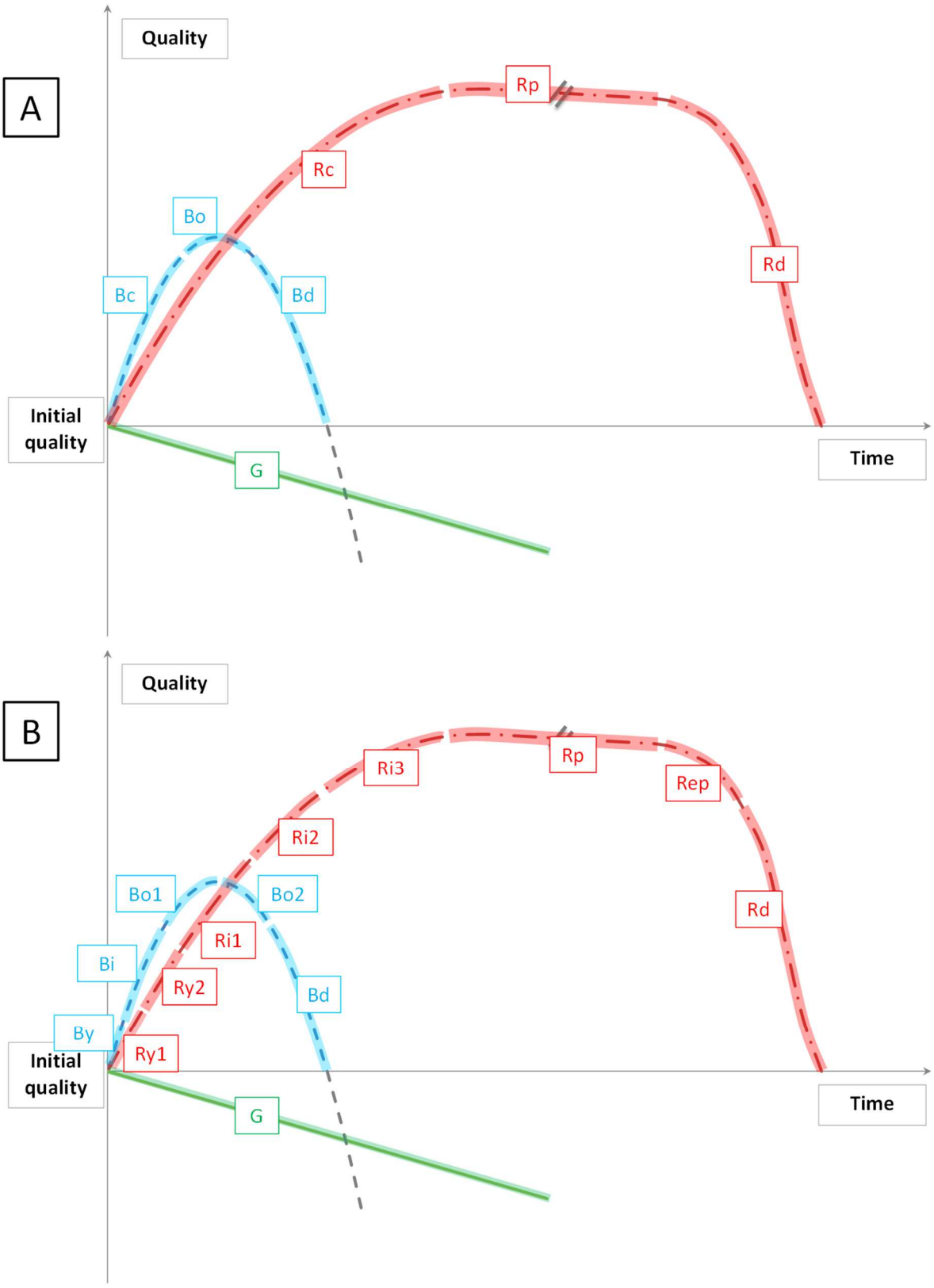
A
Quality
Rp
Rc
Bo
Rd
Bc
Bd
Initial quality
G
Time
B
Quality
Ri3
Rp
Rep
Ri2
Bo1
Bo2
Rd
Ri1
Bi
Ry2
Bd
By
Ry1
Initial quality
G
Time

Figure 3 :

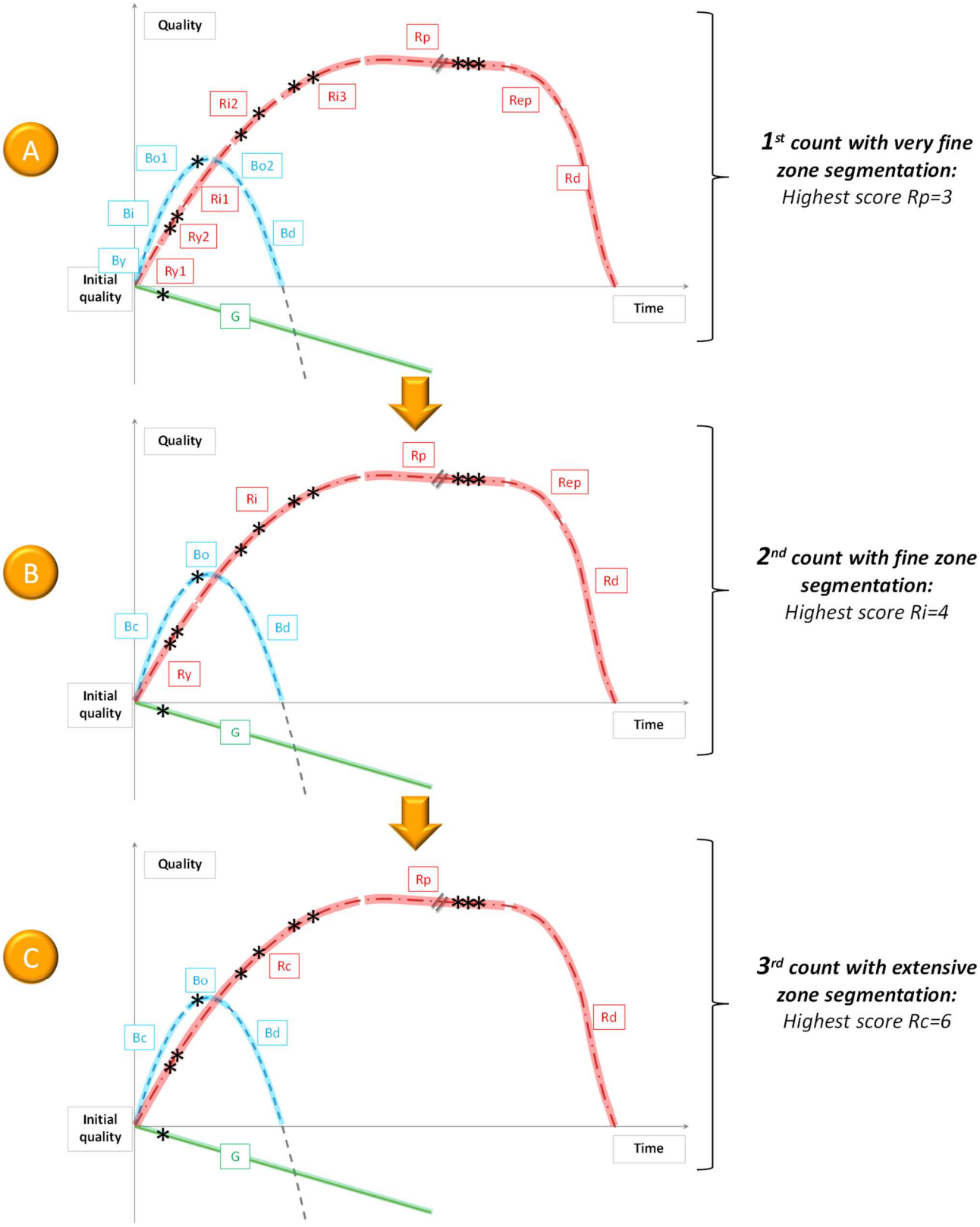
A
Quality
Rp
Ri2
Ri3
Rep
Bo1
Bo2
Rd
Ri1
Bi
Bd
Ry2
By
Ry1
Initial quality
G
Time
1st count with very fine zone segmentation:
Highest score Rp=3
B
Quality
Rp
Ri
Rep
Bo
Rd
Bc
Bd
Ry
Initial quality
G
Time
2nd count with fine zone segmentation:
Highest score Ri=4
C
Quality
Rp
Rc
Bo
Rd
Bc
Bd
Initial quality
G
Time
3rd count with extensive zone segmentation:
Highest score Rc=6

Figure 4 :

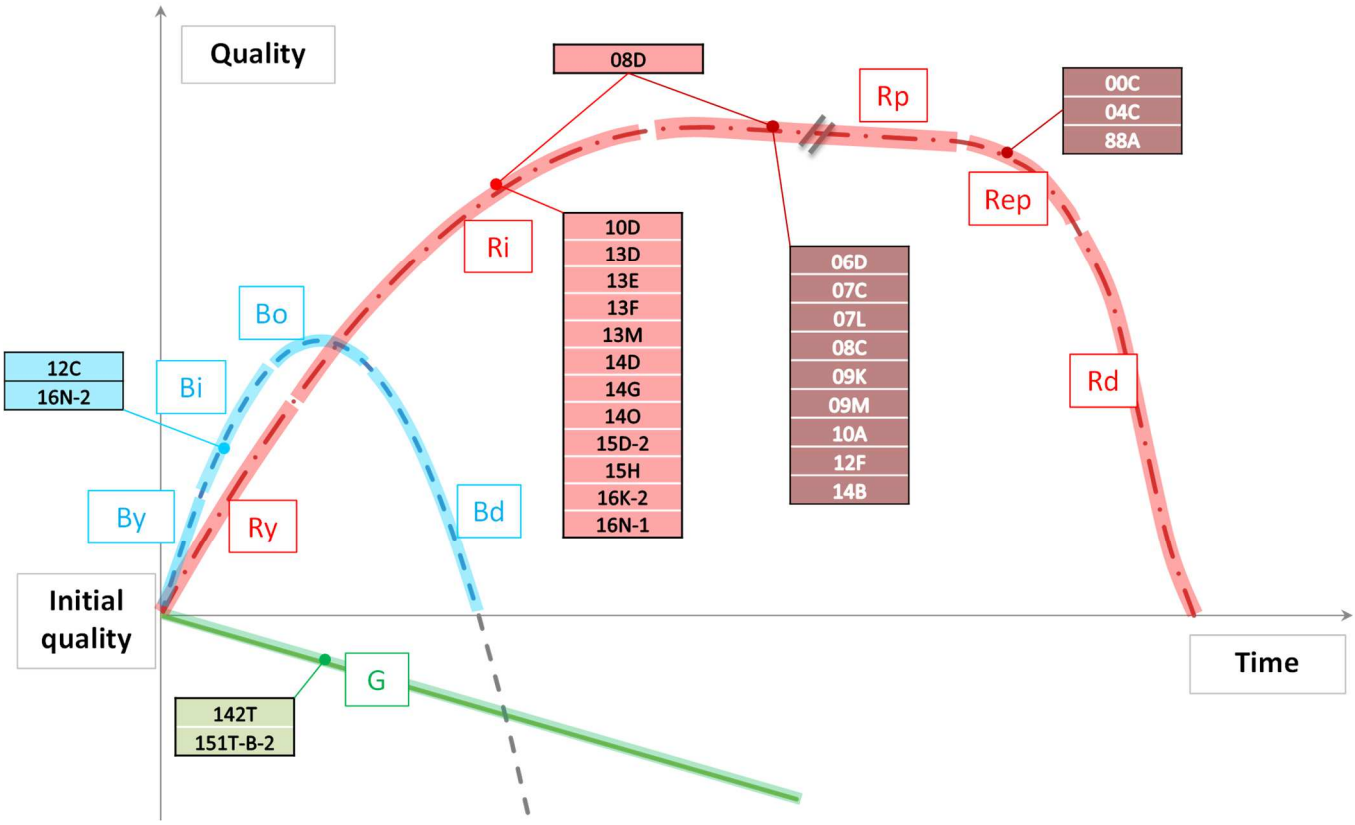
Quality
08D
Rp
00C
04C
88A
Rep
Ri
10D
13D
13E
13F
13M
14D
14G
14O
15D-2
15H
16K-2
16N-1
06D
07C
07L
08C
09K
09M
10A
12F
14B
Rd
Bo
12C
16N-2
Bi
By
Ry
Bd
Initial quality
G
142T
151T-B-2
Time

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.