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Identification of Sensory and Voltammetric Markers of Regional Typicality: Tempranillo Rioja Wines as a Case Study

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Abstract: The definition of regional typicality is a determinant for the preservation of perceived wine quality and protection of wine origin. This work firstly aims at evaluating the sensory diversity of young Tempranillo Tinto wines in the three subregions of DOCa Rioja (Alta-RALT-, Alavesa-RAVS- and Oriental-RO-) and secondly aims to explore the capacity of voltammetric signals to measure sensory differences. Thirty young Tempranillo Tinto wines, ten from each subregion, were sensory-described using a free sorting task followed by a free description task with 32 well-established Rioja winemakers. The sorting task evidenced that the salient sensory differences perceived were between RO and RALT/RAVS, attributed to differences in perceived colour intensity, body/structure and liquorice aroma. The free description task highlighted the core and shared characteristic of the young Tempranillo Tinto Rioja wines, a fresh fruit aroma, but also the unique and specific sensory profiles attached to the three regions. The RALT region presents ripe fruit and spicy and balsamic/mint aromas with powerful tannins, while RAVS's wines are mainly characterised by their gummy candy, fresh fruit, lactic and floral aromas, with a silky and mellow mouthfeel. The characteristic profile for RO was linked to jammy fruit, with spicy aromas and a light perception in the mouth. The signals derived from linear sweep voltammetry were able to measure the main sensory differences between RO and RALT/RALV, as did the sorting task. This is the first time that scientific research has established the typical regional character of young Tempranillo Tinto Rioja wines, which includes a common and shared profile combined with the specificities linked to each subregion, contributing to a better understanding of the notion of regional typicality in wine.

Keywords: typicality; free description task; origin; sorting task; wine experts

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1. Introduction

The definition of the concept of typicality (or typicity from the French *typicité*) in food in general and in wine in particular is relevant for the understanding and definition of a product´s quality. The concept of wine typicality is attached either to a specific region or to a variety. Parr et al. [1] defined geographical or regional typicality as "the originality, uniqueness, and reputation of a product from a terroir or geographical location", and varietal typicality is linked to "how well it matches expected characteristics of a particular grape variety". Regarding regional typicality, it is the result of the interaction between natural factors such as climate, soil or the plant, and human factors including cultivation techniques and winemaking processes [2]. These factors interact to generate one or various wine sensory profiles recognisable by the consumers, and are linked to a wine category of a specific region. The definition of the sensory properties or the combination of sensory properties which enable a wine to be identified as belonging to a specific region is especially important because it contributes to the quality perceived by the consumer [3]. The region of origin modulates the experienced, expected and perceived quality of a wine. Thus, a higher congruency between experienced and expected sensory cues leads to a higher perceived quality [4]. Typicality has also been associated with complexity [1], and most experts would agree that it is a rather positive term when describing a wine, yet its definition remains abstract [5]. The necessity of defining the wine sensory typicality for a given region lies not only in defining a wine's sensory profile but also on protecting its origin [6].

The definition of the typical sensory profile of a wine category is not evident, because it has to not only include a series of global sensory features that are common to a wine category in a specific region (i.e., core sensory traits), but sensory cues that promote wine diversity within the region (i.e., genuine sensory traits) have to also be preserved [6]. This concept can be easily illustrated in terms of face recognition traits. All human faces have common elements (i.e., two eyes, one nose, one mouth and two ears) that allow us to identify the object that belongs to the category of human faces, but their specific characteristics (e.g., size, colour or distance between the individual elements) and the specific combinations of their properties make every face unique.

Different cognitive mechanisms have been proposed to govern the representation of object categories in memory and how this information is further used to extract meaningful information from the evaluated object. Among the most accepted theories are the exemplarity and prototype approaches that are mainly differentiated in how information is stored in memory [7]. The idea behind the exemplarity-based theory is that for a given wine, its sensory profile is compared to real exemplars of the same category previously stored in the memory of the taster, and the similarity between the evaluated wine and the stored exemplars will provide an idea of typicality. In contrast, the prototype-based approach consists of the identification of a central tendency stored in the mind (i.e., representation of the "average"), and thus a theoretical typical wine prototype is compared with the evaluated wine to infer typicality. In the wine literature, most publications work under the assumption that the mechanism behind the classification of wines attending to a given category, regional typicality in our case, is based on a prototype-based approach rather than on a exemplarity-based one, even if the existence of these prototypes could not have been demonstrated [8]. Besides these two holistic mechanisms, a third one, proposed with beer and compatible with the categorisation of wine typicality, can be classed as a feature-frequency model [9]. This model assumes that the taster counts the frequency of a feature or their combinations occurring in the objects (i.e., wine) of a specific category, tasted during previous exposures, and then bases their categorisation on how often these features appear in the new object [10]. Notwithstanding this, it cannot be ruled out that the prototype, exemplarity and the feature-frequency mechanisms occur simultaneously [9], with their importance being dependent on the level of exposure of the taster to the product category as well as on the structure of the category [11]. Experts, through exposure to a product category (i.e., category learning), detect common features of the stimuli that they repeatedly encounter. Consequently, when they are confronted with a new product, it is categorised by paying special attention to the regularities that were found in previous exposures and discarding irrelevant dimensions [12]. This effect is explained in terms of "statistical learning" or "perceptual learning", and supports the idea that repeated exposure increases the ability to extract important information that will help in the categorisation process [13]. This suggests that wine experts from a given region, with higher exposure to specific wine categories, would be able to adequately infer regional typicality.

Of the various approaches used to assess wine typicality, the typicality assessment (TA) was introduced by Rosch [14] and applied by Ballester et al. [5] in the wine domain. It is also known as the "goodness of exemplar" rating task (i.e., how *good of an example* an item is of its category [14]), and it is among the most widely used. In this approach, the typicality of a wine is evaluated by regional experts on a structured scale, anchored on the left with a "very bad example" and on the right with "a very good example". The fact that the typicality associated with a wine region is a blurry concept means that the scores obtained from this TA might not represent a stand-alone method if a full understanding of wine typicality is sought. Alternatively, nonverbal approaches such as the sorting task [15] or projective mapping [16] are employed. In these approaches, a similarity map on which samples are projected is obtained. Here, the most salient sensory differences among samples are revealed and thus the regionality effect can be measured through the distances between the wines on the maps (closer samples are more similar and thus share sensory profiles). However, these strategies might not be enough for understanding the specific sensory profiles attached to a region, and their combination with purely descriptive tasks can be useful. Among them, classical descriptive analysis with trained panels [17] or the Just About Right (JAR) method [18] have been applied with a list of predetermined attributes. However, these approaches can hinder the identification of attributes or sensory profiles not contemplated within the list. In this regard, Gonzaga et al. [19] carried out a content analysis of published free sensory descriptions of Cabernet Sauvignon wines to successfully identify sensory specificities among Australian wine regions without constraints in the use of descriptors.

The importance of defining regional sensory typicality is evident for determining wine origin, increasing wine quality perception and favouring communication among wine agents (i.e., consumers, winemakers, communicators, marketers or distributors). However, the acquisition of sensory data requires the important spending of resources; thus, it is of major importance to infer sensory results from simple, rapid and cheap chemical data. In this regard, voltammetric methods with direct analysis of wine samples can be an interesting technique given the simplicity (i.e., convenience and ease of use) and applicability in the classification of wines [20]. Voltammetric signals provide information about the analyte by measuring the current produced by the system with time as a result of the electrode reaction when applying a specific voltage profile to a working electrode. This strategy has been applied to measure a range of antioxidants, including phenolic acids and flavonoids, ascorbic acid, SO_2 and general resistance to oxidation [20,21].

In this context, the first objective of this work was to evaluate the regional sensory typicality of young Tempranillo Tinto wines from the DOCa Rioja following two different sensory tasks with winemakers of the region. The first approach employed was a free sorting task aimed at identifying the most salient regional sensory differences. The second was a free description task that enabled the identification of more specific descriptors and profiles attached to a region without restrictions in the use of terms. The second objective of this paper was to explore the capacity of linear sweep voltammetry using disposable sensors to evaluate the sensory differences identified in the first objective. Rioja wines are especially interesting to study in the context of typicality because they come from three subregions, RALT, RAVS and RO, that share common territory (DOCa Rioja) and thus sensory traits. Simultaneously, these subregions claim to have their own sensory specificities linked to differences in human and natural factors involved in shaping their own subregional sensory profiles. Regarding the natural factors, in RAVS, an Atlantic climate and calcareous-clay soils located on terraces and small plots dominate; in RALT, the Atlantic climate also dominates, while its soils are divided between calcareous-clay, ferrous-clay and alluvial; and finally, the RO subregion has a drier and warmer climate due to the Mediterranean influence, predominating the alluvial and clay-ferrous soils. The category of young Tempranillo Tinto wines was considered in this study, assuming that wine ageing would dissipate differences attached to the territory.

2. Materials and Methods

2.1. Wine Samples

A set of 30 young red wines (in their first or second year, vintage 2020 or 2021) under the generic DOCa Rioja label (i.e., green label) and produced mainly (80% minimum) using Tempranillo Tinto grapes were used in this experiment. Ten commercial wines representative of each subregion of DOCa Rioja were selected in consultation with wine experts of the region. They were purchased from local wine stores and wineries (Table 1). The subregions were RALT, RAVS and RO.

Table 1. Code, origin, vintage and varieties of the 30 wines studied.

Code	Origin	Vintage	Varieties
RAVS1	Rioja Alavesa	2021	Tempranillo; Garnacha; Viura
RAVS2		2021	Tempranillo; Viura
RAVS3		2021	Tempranillo; Graciano; Mazuelo; Viura
RAVS4		2021	Tempranillo; Viura
RAVS5		2021	Tempranillo; Viura
RAVS6		2021	Tempranillo
RAVS7		2021	Tempranillo; Viura
RAVS8		2021	Tempranillo
RAVS9		2020	Tempranillo
RAVS10		2020	Tempranillo; Viura
RALT1	Rioja Alta	2021	Tempranillo
RALT2		2021	Tempranillo; Garnacha; Viura
RALT3		2021	Tempranillo
RALT4		2021	Tempranillo
RALT5		2021	Tempranillo; Garnacha; Viura
RALT6		2021	Tempranillo
RALT7		2020	Tempranillo
RALT8		2021	Tempranillo
RALT9		2021	Tempranillo
RALT10		2021	Tempranillo
RO1	Rioja Oriental	2021	Tempranillo
RO2		2021	Tempranillo
RO3		2020	Tempranillo
RO4		2020	Tempranillo
RO5		2020	Tempranillo; Garnacha
RO6		2021	Tempranillo
RO7		2020	Tempranillo
RO8		2020	Tempranillo
RO9		2021	Tempranillo; Viura
RO10		2021	Tempranillo

The 30 samples were submitted to sensory analysis (a sorting task and a free description task) and chemical analysis (conventional oenological parameters, colour coordinates and voltammetric analysis).

2.2. Sensory Analysis

A total of 32 well-established Rioja winemakers, 24 men and 8 women (between 22 and 57 years old, average = 40.5 ± 9.2 years), with an average of 16.6 years of experience in winemaking in the region (between 5 and 35 years of experience), participated in the study. They were recruited by sending emails to the database of the ICVV and by sharing the information with the association of Rioja winemakers (AR).

All participants attended two tasting sessions (the first was devoted to the sorting task and the second was devoted to the free description task), one week apart from each other, at the sensory facilities of Universidad de La Rioja in Logroño.

No information about the wines or the experiment was shared with the panellists prior to the sessions to limit top-down effects. All wines were opened one hour before the sessions and served at room temperature, approximately 21 °C. Pectin was selected as the rinsing agent (1 g/L), along with water to avoid saturation and carry-over effects during the sessions. All participants signed a consent sheet, declaring that their participation was voluntary, and no remuneration was provided.

Ethical approval for the involvement of human subjects in this study was granted by the CSIC Research Ethics Committee on 23 March 2021, with reference number 211/2020.

2.2.1. Free Sorting Task

The 30 wines were simultaneously and randomly presented to the panellists, with the sample order being different for every participant. The panellists, 31 in total for this session, had to form groups of wines based on their sensory similarity. More similar wines were placed together on the table, while different samples were put in different groups. No restriction regarding the number of groups was imposed. They could put as many wines as they desired in each group; one-sample groups were allowed. Wines were coded (3-digit numbers) and placed on the table, forming three rows. A total of 25 mL of wine was poured into transparent wine glasses and covered with plastic Petri dishes. The average duration of this session was 45 min (ranging from 20 to 60 min). Once the participants finished the task, they were provided with a sheet and a pen to record their responses.

The acquired data were encoded in 31 individual matrices (by subject), each consisting of a wines $\times$ wines matrix, where 1 was allocated for pairs of samples grouped together and 0 was given for samples placed in different groups. These individual matrices were summed across subjects; the resulting co-occurrence matrix represented the global similarity matrix, where the diagonal was the number of participants (31). Higher numbers indicated higher similarity between the samples. The matrix was submitted to Multidimensional Scaling (MDS) analysis using a non-parametric scaling algorithm (absolute method). The obtained MDS graph projected similar samples (i.e., more frequently grouped together) closer in the plot.

In order to identify the MDS dimensions linked to the subregion of samples, the MDS coordinates of the wines for significant dimensions (stress value ≤ 0.2) were submitted to one-way ANOVA considering the subregion (RALT, RAVS or RO) as a fixed factor. For significant effects ($p \leq 0.05$), a Fisher post hoc means comparison test was carried out to identify differences among the three regions. Analyses were conducted using the XLSTAT extension for Microsoft Office Excel (version 2023.1.1).

2.2.2. Free Description Task

The goal of the free description task was to acquire a description of the wine samples without any limitations regarding the vocabulary used. The panellists, 29 in total, were asked to provide descriptions of the 30 samples using their own words. The same wines as in the sorting task were monadically presented to the panellists under the same conditions as in the first session, but with different coding to avoid bias. Each panellist assessed all 30 of the wines, with a five-minute break every five wines, to avoid carry-over effects. Descriptions were recorded on paper ballots by each participant. The average duration of this session was 75 min (between 60 and 90 min).

The descriptions were digitised, and a first list of terms was extracted by isolating all of the unique entries mentioned (i.e., sensory descriptive terms) and via the removal of non-descriptive terms (i.e., hedonic or related to the varieties or the winemaking process). With this initial list, lemmatisation was conducted (i.e., terms sharing the same root were identified and substituted by one selected term, for example, the terms "astringent" and "astringency" were fused into "astringency"). After lemmatisation, a categorisation step was performed by three experimenters. Terms belonging to a similar category were grouped together to create the main categories. For example, entries like red fruit, black fruit, cherry, strawberry and plum were fused into a main category called "fresh fruit". The terms colour and aroma intensity were also categorised into three intensity levels: low (slight, low, pale colour), medium (medium, average, moderate) and high (intense, expressive, powerful, strong, explosive). The final list of terms (after lemmatisation and categorisation) was elaborated upon by consensus among the three experimenters (triangulation process). In the final list, three levels of intensity were applicable: low, medium and high.

A frequency matrix with the wines (30) in rows and the final terms in columns was built and underwent Correspondence Analysis (CA). Descriptors mentioned by less than 15% of the panellists were excluded to facilitate the interpretation of results. With the CA coordinates, Hierarchical Cluster Analysis (HCA) was further conducted to identify specific sensory profiles among the studied wines. The subregions were projected as nominal variables. The characterisation of the wine clusters was performed considering significant test-values ($p < 0.05$) for the active (terms) and nominal (subregion) variables. The test-value corresponded to a statistical criterion akin to a standardised variable (zero mean and unit variance). Significance was obtained when the absolute test-value was 1.96, which corresponded to an error threshold of 5%. Ranking of the terms according to their test-values provided a quick characterisation of each cluster [22].

In order to understand the dimensions derived from the sorting task, Spearman correlation coefficients between the wine coordinates for each MDS dimension and the frequency of citation of terms derived from the free description task were calculated. The RV coefficient was calculated between the MDS coordinates and the CA factors in order to evaluate the similarity between the sensory spaces.

Analyses were performed using SPAD (Decisia, Paris, France) Software (version 5.5).

2.3. Chemical Analysis

2.3.1. Conventional Oenological Analysis

The 30 wines were chemically analysed for pH, volatile acidity, total acidity, reducing sugars, malic acid, lactic acid and % ethanol (*v*/*v*) using WineScan™ FT 120 (Hillerød, Denmark), calibrated via the official OIV practices.

2.3.2. Spectrophotometric Analysis

The samples were filtered using Chromafil® Xtra PA-45/25 (Billerica, MA, USA) polyamide syringe filters of 0.45 µm pore size prior to the analyses.

The spectra (between 380 nm and 770 nm) of the 30 wine samples were recorded using a Shimadzu UV-1800 Spectrophotometer (Kyoto, Japan) in order to calculate the CIELab colour coordinates. The parameters calculated were luminosity (L*) (L* = 0 black and L* = 100 colourless), the red/green colour coordinate ($a_{10}^* > 0$ red, $a_{10}^* < 0$ green) and the yellow/blue colour coordinate ($b_{10}^* > 0$ yellow, $b_{10}^* < 0$ blue). The protocol that was followed is as described by the OIV practices.

Colour intensity (CI) was measured using 2 mm precision crystal cells. Absorbance was measured at 420, 520 and 620 nm [23]. CI was calculated as the sum of the absorbances at these three wavelengths, referring to a 10 mm cuvette.

To determine the total polyphenol index (TPI) of the samples, 1 mL of wine sample was firstly diluted with 50 mL of distilled water, and its absorbance at 280 nm was recorded using a Shimadzu UV-1800 Spectrophotometer with 1 mm precision cells made of Quartz SUPRASIL® (Kyoto, Japan).

One-way ANOVA was conducted using the XLSTAT extension for Microsoft Office Excel (Addinsoft, version 2023.1.1) in order to identify the effect of origin on colour coordinates, CI and TPI, considering the origin as a fixed factor. For significant effects ($p \leq 0.05$), a Fisher post hoc means comparison test was carried out to identify differences among the three regions.

2.3.3. Voltammetric Analysis

The measurements were recorded one hour after the bottles were opened with the use of Edel Therapeutics apparatus and Nomasense Polyscan disposable sensors. A new sensor was used for every measurement by placing two to three drops of wine sample on the disposable wine sensor until the sensor area was covered. Linear sweep voltammograms were acquired between 0 and 1200 mV potentials, as described in Ferreira et al. [21]. A total of 120 voltammetric signals (recorded every 10 mV) for each wine were recorded four times (recorded on two different days). Differences between replicated samples with an EDEL value higher than 0.1 were discarded as they were considered to be outliers. For reproducible measurements (i.e., differences in EDEL values lower than 0.1, usually between 3 and 4 measurements), averaged voltammograms were considered.

As in previous studies, the first-order derivative of the measured current was calculated to better illustrate and identify the voltammetric differences [20].

Principal component analysis (PCA) was calculated using the first derivative of the 120 measurements acquired for each of the 30 wines. The PCA was calculated using Varimax rotation to better interpret the signal variability among the three subregions.

One-way ANOVAs were conducted on the wine coordinates of the main PCs (eigenvalue ≥ 1) considering the region of origin as a fixed factor. A Fisher post hoc means comparison test was carried out in order to identify differences among the three regions. The significance of the results was considered at $p \leq 0.05$.

All statistics were performed using the XLSTAT extension for Microsoft Office Excel (Addinsoft, version 2023.1.1).

3. Results and Discussion

3.1. Sensory Differences among Rioja Subregions

3.1.1. Free Sorting Task

The free sorting task aimed at identifying the salient sensory dimensions differing among the wine sample sets based on their overall visual and flavour similarity. A three-dimensional MDS solution (Figure 1) was considered to be optimal (stress value = 0.157). The greater the distance between the objects (wine samples), the lower similarity that they exhibited, and vice versa.

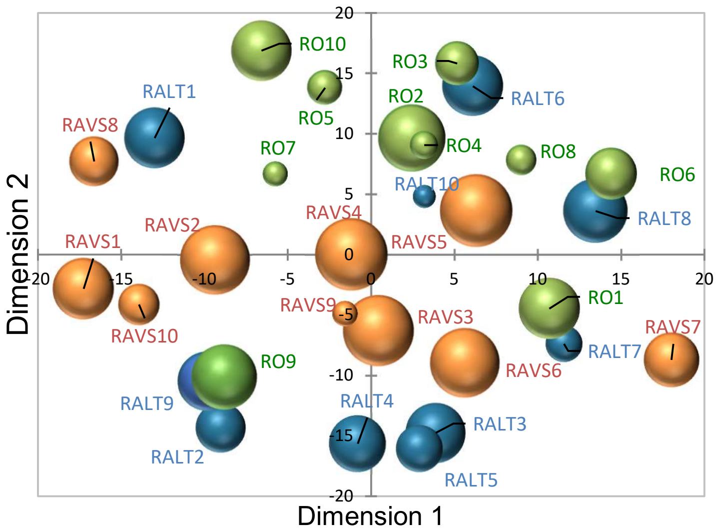

Figure 1. Three−dimensional MDS plot derived from the sorting task carried out using the 30 wine samples. The size of the bubbles represents the third dimension. Rioja Alta wines (RALT) are represented in blue, Rioja Alavesa wines (RAV) are represented in orange and Rioja Oriental wines (RO) are represented in green.

A significant effect of origin for Dimension 2 (F = 5.08; $p < 0.05$) was observed. This suggests that this sensory dimension differentiates among the regions of origin. The pairwise test shows that wines from RO (in green colour), with mainly positive scores on this dimension and thus plotted on the top part of Figure 1, are significantly different from RALT (in blue colour) and RAVS (in orange colour) samples. These two last wine regions show lower scores (low part of Figure 1) for Dimension 2 than wines from RO (upper part of Figure 1). These results confirm a clear regional effect and evidence salient sensory differences among these three regions. This effect can be easily explained in terms of regional proximity and the shared Atlantic climate of RALT and RAVS regions, which differs from the Mediterranean climate of the RO region. Even if no clear distinctiveness between RAVS and RALT wines was observed following this sensory strategy, more subtle differences between both regions could not be ruled out. The nature of this task meant that salient differences among the wines of the sample set were projected [24]. Thus, specific sensory differences between these two regions were further studied using the free description task. This second task shed light on the more subtle sensory differences among the sample set.

3.1.2. Free Description Task

The initial list derived from the description of the 30 wines by 29 wine professionals yielded a total of 3629 terms. After the removal of non-descriptive terms and lemmatisation, 938 terms were recorded: 545 describing wine aroma, 270 describing taste and mouthfeel and 123 describing visual characteristics. These terms were submitted to a categorisation step in order to identify categories of terms with a similar meaning. This refining fused the terms, yielding 64 for aroma, 71 for taste and mouthfeel and 13 for visual categories. Out of these 212 terms, 52 were cited by at least 15% of the participants were considered to facilitate data interpretation [25]. These terms were further considered for the understanding of the sorting task dimensions and the description of the core attributes describing the global Rioja category and the subregions.

3.1.3. Linkage between Sorting Task and Free Description Task

In order to understand the salient dimensions derived from the sorting task, the wine coordinates on the three MDS dimensions were correlated with the frequency of citation of terms derived from the free description task. Spearman correlation coefficients revealed that Dimension 2, which drives differences between RO Tempranillo wines and the other two regions, is highly linked to the visual attribute "colour intensity" ($r = -0.70$; $p < 0.0001$), followed by the mouthfeel− and aroma−related terms "body and structure" ($r = -0.47$; $p < 0.01$) and "liquorice" ($r = -0.42$; $p < 0.05$). These results show that RAVS and RALT wines are overall described as having higher colour intensity, structure and body and liquorice aromas than the wines from the RO samples. It is widely accepted that grapes ripened under elevated temperatures such as those from RO region can show lower phenolic content, including lower anthocyanin concentration [26,27], which could affect wine colour intensity and the body and structure of RO wines. Regarding the differences in the liquorice aroma among the regions, it was shown to be more evident in the Tempranillo Tinto genotypes producing small berry grapes [28]. Differences in berry size are attributed to climate conditions; thus, lower rainfall and higher temperature induce the production of smaller berries [29]. However, this is not the case in our study, because under this assumption, RO grapes, exposed to higher temperatures and lower rainfall than the other northern regions, would have shown smaller grapes and thus higher liquorice aroma, but the opposite effect was observed. Other authors have also suggested that minimal pruning [30] could induce the production of smaller berries (and thus higher liquorice aroma) than conventional hand pruning. While the differences in the phenolic composition can be explained due to higher temperatures in the RO region, the specific presence of the liquorice aroma in cooler Rioja regions (RALT and RAVS) deserves to be studied in more depth in the future.

Besides this salient sensory difference observed among the sample set, there are two other dimensions (Dim. 1 and Dim. 3) that are not linked to wine origin, but that are also considered by experts to be important sensory cues differentiating between the 30 samples. Dim. 1 can be explained in terms of "balsamic/mint" ($r = -0.47$; $p < 0.01$) aromas. Thus, samples projected on the left side of the plot (Figure 1), and thus with negative scores for Dim. 1, present higher intensity for this attribute. This aroma, which is probably also a chemesthetic sensation, is attributed to certain sesquiterpenes. Among them, the cyclic terpenes 1,4-cineole and 1,8-cineole are reported to be possible contributors to balsamic aromas, but their origin is still controversial because they are demonstrated to increase during ageing and to appear in grapes cultivated close to eucalyptus trees [31,32]. However, this is not the case for our wines, because they were all young wines with similar time ageing, and they were not close to eucalyptus. The presence of other plants close to the vineyards transmitting such balsamic aromas to final wines or other woody-related treatments during winemaking could explain this difference in the balsamic properties of young Tempranillo Tinto Rioja wines. Regarding Dim. 3, it confronted samples with "violet colour", "fresh fruit", "lactic" aroma and "high aroma intensity" (negative scores for this dimension, and thus smaller bubbles in the plot), to wines (positive scores for Dim. 3, and thus bigger bubbles) showing "garnet" (r = −0.76; $p < 0.0001$), "roasted-smoky" (r = −0.67; $p < 0.0001$), "spicy" (r = −0.60; $p < 0.001$), "woody" (r = −0.59; $p < 0.01$), "cherry in alcohol" (r = −0.55; $p < 0.01$) and "dried fruit" (r = −0.54; $p < 0.01$) aromas. This difference between wooded and non-wooded wines has been repeatedly observed in the study of red wines [33] and confirms the importance given by winemakers to this sensory dimension when differentiating between wines.

3.1.4. Core and Specific Sensory Profiles of Rioja Wines

Among the terms obtained in the free description task, the descriptor "fresh fruit" was the most frequently used to describe the overall sample set (average of 63% of citations among the 30 young red wines). This term did not show significant differences in citation ($X^2 = 2.63$, $p = 0.268$) among the wines of the three regions. The next, more cited term shows an average citation that is two times lower. This was the visual-related term "violet−purple", with an average citation of 30% among all of the wines, followed by "dry" (29%) and "high aroma intensity" (27%). This first result suggests that the "fresh fruit" characteristic is a core characteristic of young Tempranillo Tinto Rioja wines in the region overall. This category included specific attributes such as white fruits (pear, apple, quince, grape), citrus, black fruit (blueberry, blackberry), red fruit (cherry, strawberry, raspberry) and stone fruit (plum, peach).

In an attempt to further evaluate specific sensory differences among the three regions, Correspondence Analysis was calculated with the frequency of citations of the 52 attributes across the 30 wines, and the regions were considered as supplementary variables (Figure 2).

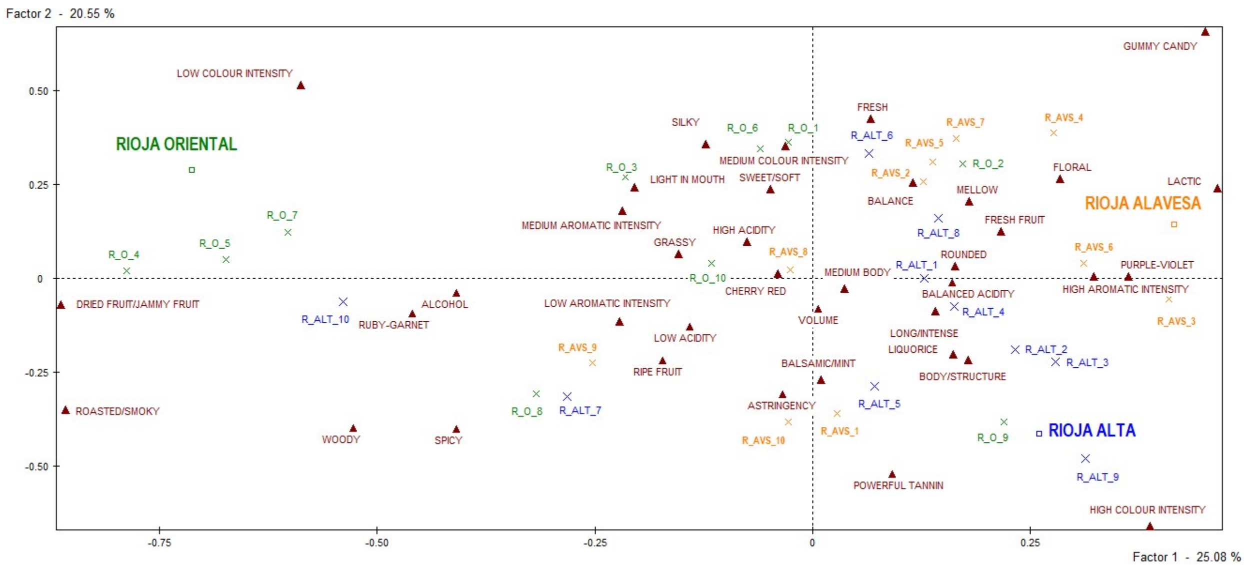

Figure 2. Projection of visual and flavour descriptors (in brown) and wines (Rioja Alta wines—RALT—in blue, Rioja Alavesa—RAVS—in orange and Rioja Oriental—RO—in green) on the CA space. The regions are illustrative variables.

The results of the CA (Figure 2) confirmed the origin effect, clearly differentiating RO from the other two regions regarding the first factor (which explains 25% of the original variance). This result is well in line with the results of the sorting task. Moreover, the similarity between the two sensory spaces generated under the two sensory tasks (sorting task and free description task) is confirmed, as the RV coefficient is highly significant (RV = 0.663; $p < 0.0001$). RO wines, plotted on the left part of the CA, exhibit ruby−garnet colour and lower colour intensity, as well as more spicy and ripe fruit aromas than wines from the other two regions (with purple−violet colour and higher colour and aromatic intensities). While there is overall similarity in the results derived from the two tasks, the free description task is able to differentiate between the sensory profiles of RALT and RAVS in terms of the second factor. RALT wines (with negative scores for factor 2) exhibit higher colour intensity and powerful tannins, while those from RAVS (positive scores for factor 2) are mainly characterised by their gummy/candy and lactic aromas.

While clear (between RO and the other two regions) and subtle (between RALT and RAVS) differences among the three wines from the three regions are observed, it cannot be neglected that within the regions there are diverse sensory profiles. In order to clarify this point, CA factors were submitted to cluster analysis. Table 2 shows the five clusters of wines with different sensory profiles identified. The three subregions of DOCa have different sensory profiles, with some shared with other subregions (clusters 1 and 3) and some being more specific (clusters 2, 4 and 5). Cluster 1 is formed by wines from RALT and RAVS, and is characterised by high colour intensity, purple-violet colour, fresh fruit and lactic aromas, with high aromatic intensity and high acidity. In contrast, Cluster 3 significantly includes wines from RO and RAVS described with low colour intensity, medium aromatic intensity, grassy aromas, and fresh powerful tannin and low acidity in the mouth. Besides these commonalities between the three regions, clear regional specificities are observed. Thus, Cluster 2, mainly including RALT wines, is linked to high colour intensity, ripe fruit, spicy and balsamic/mint aromas and powerful tannins perceived in the mouth. Cluster 4, attributed to specificities of RAVS wines, is characterised by medium colour intensity and gummy candy, fresh fruit, lactic and floral aromas, with silky, soft and mellow sensations in the mouth, in line with previous results [34]. Finally, RO wines (Cluster 5) are described with lower colour intensity than the other two regions, with a specific ruby-garnet colour, jammy fruit and spicy aromas and a light feeling in the mouth.

Table 2. Cluster, description and significant subregion/s for each cluster.

Cluster	Description	Significant Subregions (Test-Value; Significance)
1	high colour intensity; purple-violet fresh fruit; lactic high aromatic intensity high acidity	RALT (test-value = 18.73; $p < 0.001$) RAVS (test-value = 6.80; $p < 0.001$)
2	high colour intensity ripe fruit; spicy; balsamic/mint powerful tannin	RALT (test-value = 5.86; $p < 0.001$)
3	low colour intensity medium aromatic intensity grassy; fresh powerful tannin; low acidity	RO (test-value = 17.54; $p < 0.001$) RAVS (test-value = 3.04; $p < 0.01$)
4	medium colour intensity gummy candy; fresh fruit; lactic; floral silky; balance; sweet/soft; mellow	RAVS (test-value = 7.09; $p < 0.01$)
5	low colour intensity; ruby-garnet dried fruit/jammy fruit; spicy light in mouth	RO (test-value = 21.26; $p < 0.001$)

3.2. Effect of Region on Conventional Oenological Parameters and Colour Coordinates

Table 3 shows that among the 14 chemical parameters, 3 significantly vary among the three regions. RO wines present lower pH values and lactic acid levels and higher luminosity (L_{10}*) overall than the other two regions. While differences in pH values are difficult to explain, the lower lactic acid levels could be the result of a lower transformation of malic acid into lactic acid by lactic bacteria given the lower synthesis of the first in warm climates [26], such as the RO region with a Mediterranean climate. The fact that RO wines do not present lower total acidity overall, despite lower levels of malic acid being expected, can be explained because the addition of tartaric acid to final wine is an authorised practice in the Rioja region and probably performed in wines from the warmest RO region, where a lower synthesis of total acids is expected. Similarly, the higher luminosity of RO wines also observed and highlighted in the sensory tasks (i.e., lower colour intensity), could be explained in terms of climate conditions, as warmer temperatures hinder the production of phenolic compounds [27].

Table 3. Averaged conventional oenological and colour parameters (±standard deviation) for the three regions and significance for regional effect according to one-way ANOVA (ns: not significant). For significant effects (marked in bold) for a given parameter, different letters among subregions indicate significant differences ($p < 0.05$) according to post hoc Fisher pairwise test.

Parameter	RALT	RAVS	RO	Significance
pH	**3.77 ± 0.08 [a]**	**3.74 ± 0.07 [a]**	**3.64 ± 0.08 [b]**	**<0.01**
volatile acidity (g L^{-1}) [a]	0.34 ± 0.08	0.3 ± 0.07	0.32 ± 0.09	ns
total acidity (g L^{-1}) [b]	2.89 ± 0.35	2.91 ± 0.30	2.98 ± 0.31	ns
reducing sugars (g L^{-1})	1.6 ± 0.52	1.62 ± 0.48	2.01 ± 0.47	ns
malic acid (g L^{-1})	0.03 ± 0.22	0.06 ± 0.09	0.10 ± 0.17	ns
lactic acid (g L^{-1})	**1.29 ± 0.53 [a]**	**1.13 ± 0.25 [ab]**	**0.83 ± 0.26 [b]**	**<0.05**
alcohol content (%, v/v)	13.61 ± 0.39	13.61 ± 0.48	13.55 ± 0.38	ns
TPI (a.u.)	55.06 ± 7.56	53.85 ± 5.94	49.03 ± 8.76	ns
colour intensity (a.u.)	11.16 ± 2.12	11.36 ± 2.26	9.32 ± 1.75	ns
a_{10}^*	52.64 ± 7.72	53.13 ± 6.84	46.67 ± 4.15	ns
b_{10}^*	6.94 ± 2.62	6.20 ± 3.56	5.81 ± 3.74	ns
L_{10}^*	**50.02 ± 6.90 [b]**	**48.74 ± 6.04 [b]**	**55.81 ± 5.73 [a]**	**<0.05**
C*	53.17 ± 7.59	53.63 ± 6.56	47.18 ± 3.99	ns
H*	7.65 ± 3.38	6.92 ± 4.43	7.24 ± 4.75	ns

[a] Expressed as g L^{-1} of acetic acid; [b] expressed as g L^{-1} of tartaric acid.

3.3. Effect of Region on Voltammetric Signals

The average of voltammetric signals (represented as the first derivative) of wines for each of the three regions is shown in Figure 3. The voltammograms show the three main regions, with the first two representing anodic waves with maximal intensity (120 and 100 nA/mV) around 330 mV and 660 mV, respectively, and separated by a minimum between 500 and 530 mV. The third region, between 850 and 1200 mV, shows the lowest derivative current reaching values six times lower than the first anodic wave. Lower potentials correspond to rapidly oxidable compounds involved in oxidative reactions such as anthocyanins, ortho-diphenols and triphenols of gallic acids, while less readily oxidisable compounds, such as vanillic or coumaric acids, meta-diphenols such as catechin, SO_2, certain amino acids and brown pigments, are responsible for curves at higher potentials [20,35]. In order to identify voltammetric regions showing independent tendencies, a PCA with Varimax rotation was conducted. Six dimensions representing independent and non-correlated voltammetric regions were identified (Figure 3). On the first anodic wave, Dimensions 1 and 6 are contributed by two (126–365 and 425–542 mV, in blue in Figure 3) and one (375–413 mV, in black) regions. Dimension 3 (in green) and 5 (in red) belong to the second anodic wave and correspond to the regions at 552–691 mV and 710–810 mV, respectively. Finally, Dimensions 2 (in yellow) and 4 (in grey) belong to the third region in the 800–1040 mV and 1107–1194 mV regions. In order to further identify the voltammetric regions (linked to PCA dimensions) showing differences among the three regions, one-way ANOVA, with the origin as a fixed factor, was calculated. Out of the six dimensions, only one region of the second anodic wave plotted between 710 mV and 810 mV (i.e., Dimension 5, in red in Figure 3) was significant ($F = 4.986$, $p < 0.05$). The pairwise post hoc test showed that for this voltammetric region, RO wines showed significantly higher derivative current than RAVS and RALT wines, suggesting that wines from the RO subregion show significantly higher levels of less readily oxidisable compounds than the wines from the other two regions. This result also suggests that voltammetric signals are able to identify major and salient differences among the three regions as those identified via the sorting task. However, this chemical approach is not able to identify subtle differences revealed by more specific sensory strategies such as the free description task. Thus, voltammetry seems to be an adequate tool when major differences among wines are sought, while strategies that are more sensitive are required when more subtle differences need to be identified.

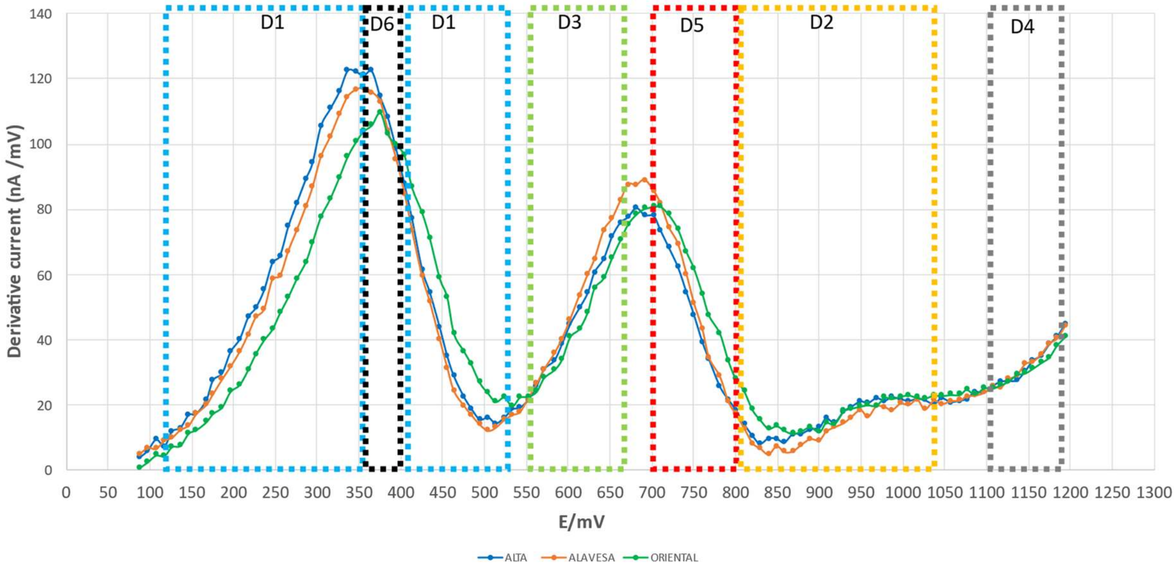

Figure 3. First-derivative voltammograms for the wines (averaged within a region) for three Rioja subregions. Rioja Alta wines (RALT) are represented in blue, Rioja Alavesa wines (RAV) are represented in orange and Rioja Oriental wines (RO) are represented in green. The six voltammetric regions corresponding to independent dimensions derived from the PCA with Varimax rotation are marked with dotted squares.

4. Conclusions

This is the first time that the regional typicality of Tempranillo Tinto Rioja wines has been scientifically approached, as sensory differences among the three subregions have been anecdotic up until now. This exploratory study has employed a combination of nonverbal (free sorting task) and verbal (free description task) tasks, which have allowed us to demonstrate that young Tempranillo Tinto Rioja wines share a common fresh fruit characteristic driving the typicality of the overall region. In summary, salient sensory differences among RO and the other two regions (RALT and RAVS) have been identified. RALT and RAVS young red wines show higher colour intensity, liquorice aroma and body/structure than their RO counterparts. This major differential sensory characteristic can be easily measured via voltammetric signals (in the 710–810 mV region) using disposable sensors. Further specific and more subtle differences between RALT and RAVS young Tempranillo wines could be identified using the free description task. Together with the perceived colour intensity differences clearly identified in the sorting task, differences in aroma profile as well as mouthfeel sensations drive the subregional typicality. The specific RALT wine profile is linked to ripe fruit, spicy and balsamic/mint aromas and powerful tannins, while RAVS wines show typical gummy candy, fresh fruit, lactic and floral aromas, with silky, soft and mellow sensations in the mouth. Finally, RO wines are described as having jammy fruit and spicy aromas and light mouthfeel.

This study contributes to increasing the understanding of Rioja wine typicality and lays the foundations for further work investigating the complex concept of regional typicality in wines. The main limitation of the study is the exploratory nature of the voltammetric analysis and the low resolution of its signals which are only able to identify salient regional differences. A higher number of wines would be necessary to prove the validity of regional classification based on this electrochemical technique. Additionally, the identification of more sensitive, yet cheap and easy-to-implement, tools in the wine industry is necessary when more subtle differences among regions are to be identified. Further, the limited number of wines (10 by region) could also hinder the generalisation of the results; thus, a study with a higher number of samples would help to validate the results of the present study.

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