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Sensory characterisation and consumer preference segmentation to meet the demand of changing trends in wine appreciation using minority grape varieties

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ABSTRACT

The aim of this study was to investigate consumer acceptance and sensory drivers of preference for wines produced from Portuguese minority grape varieties, using them as a case study to assess how wine involvement modulates intrinsic liking. A two-step approach combining expert sensory characterisation and consumer testing was applied. First, 12 white and 12 red wines made from minority varieties including one reference sample made from a blend of major commercial grape varieties for each category were selected. Each group of wines was first sensory evaluated conducting projective mapping followed by ultra-flash profiling by a panel of 21 wine professionals. A generalised procrustes analysis, followed by agglomerative hierarchical cluster analysis carried out on each wine category yielded four distinct sensory clusters, one of which contained the commercial sample. The most representative sample from each minority cluster was selected for subsequent consumer tasting. In the second step, three white (Donzelinho Branco, Callum, Rabo de Ovelha) and three red (Moreto, Tinta Francisca, Negra Mole) minority varieties together with the two commercial blends were scored for liking using a 10-point scale and described by rate-all-that-apply by 84 Portuguese wine consumers, who were stratified according to their level of wine involvement.

Overall, the liking scores were mostly neutral-to-positive. When the responses were averaged across all consumers, the commercial reference wines received higher mean liking scores than the minority-variety wines; however, preference segmentation revealed niche consumer groups showing comparable or higher appreciation for specific minority-variety profiles. For white wines, differences in preference among clusters were mainly associated with variations in perceived reductive notes and dried-fruit character, whereas for red wines, preference patterns were related to differences in perceived fruit character, woody/spicy notes, astringency, and colour-linked style perception. Wine involvement contributed to differences in preference patterns, particularly for white wines, but did not fully explain all consumer segments. These results highlight the usefulness of combining rapid expert mapping with consumer segmentation and involvement stratification to characterise sensory diversity and identify consumer niches with potential interest in wines from minority grape varieties.

KEYWORDS: grape varieties, consumer science, wine styles, sensory spaces, flavour profiles, niche segments, sensory perception

INTRODUCTION

The evolution of wine consumption trends is usually addressed independently of wine sensory features, such as packaging, production methods, e-commerce or market development (Bousquet, 2023). In parallel, structural changes in global viticulture worldwide have led to a progressive reduction in grape variety diversity, as vineyards increasingly converge on a limited number of internationally recognised cultivars (Anderson & Pinilla, 2021). The recovery of minority grape varieties therefore represents an opportunity to test whether consumers share the sensory orientations associated with these evolving market dynamics, particularly focusing on intrinsic properties.

Reports on the agronomic and winemaking potential of such varieties have been published over the last two decades (Martínez-Pinilla *et al.*, 2013; Balda *et al.*, 2014). The widespread cultivation of international and market-friendly varieties, such as Cabernet-Sauvignon, Merlot, or Chardonnay, has been primarily driven by their strong name recognition and commercial reliability, rather than by intrinsic oenological quality alone. They have been planted all over the world, mainly with the aim of obtaining commercially successful wines, even in countries with a pre-existing rich diversity of autochthonous grapes (Balda *et al.*, 2014) or whose climatic conditions are not suitable for proper ripening (Jones, 2012). These developments have led to a growing interest in conserving the somewhat neglected ancestral varieties to counteract the homogenisation driven by the world market (García-Muñoz *et al.*, 2011).

An increasing number of reports describing the sensory features of ancestral varieties has been published; these reports originate from traditional wine countries such as Spain (Sánchez-Palomo *et al.*, 2018), Italy (Vercesi *et al.*, 2024), or Greece (Miliordos *et al.*, 2021). Moreover, South American countries are also recovering their original grape varieties (Meneses *et al.*, 2024), while in Australia, using minority varieties is seen as a potential means of coping with climatic change (Mezei *et al.*, 2021); indeed, old grape varieties have been found to adapt well to climate (van Leeuwen & Destrac-Irvine, 2017). In addition, grape varieties with longer vegetative cycles allow more balanced wines to be obtained than those originating from overripe grapes (Augusto *et al.*, 2019; Vercesi *et al.*, 2024), which have been clearly distinguished by untrained consumers from their cooler climate counterparts (Loureiro *et al.*, 2016; Coste *et al.*, 2018; Souza-Coutinho *et al.*, 2020).

Portugal has a high diversity of grape varieties, with 34 main grape varieties (18 white and 16 red) covering about 87 % of the total vineyard area (Brazão *et al.*, 2023). Several reports have addressed the genetic or agronomic characteristics of the less cultivated Portuguese varieties (Alifragkis *et al.*, 2015; Barrias *et al.*, 2023; Sousa *et al.*, 2024), but their sensory profile has been relatively little studied (Piras *et al.*, 2020; Brazão *et al.*, 2023). The study of these varieties therefore offers a valuable framework to explore both sensory diversity and consumer response to non-dominant wine styles, while contributing to the preservation of viticultural biodiversity.

Consumer wine preferences have been widely studied, being dependent on both intrinsic (*i.e.*, sensory features) and extrinsic (*e.g.*, label, mode of production, origin, among others) factors (Francis & Williamson, 2015). Studies have established that consumers are not a homogenous group, their preferences being better understood under the concept of segmentation (Pickering *et al.*, 2014). This concept is based on grouping individuals according to common features that modulate product appreciation. In the field of wine appreciation, consumer segmentation has been achieved through the utilisation of demographic data, including age, gender, and geographical location, as well as lifestyle characteristics, personality traits, cultural background, and/or involvement with wine, among others (Johnson & Bastian, 2015; Pickering & Hayes, 2017; Sena-Esteves *et al.*, 2018; Rodrigues & Parr, 2019; Mora *et al.*, 2019).

Within this framework, consumer involvement has emerged as a key factor influencing wine appreciation. As demonstrated in the existing literature, the experience of wine consumption is influenced by sensory perception, emotional state, and cognitive processes. However, the extent to which these factors contribute to the overall experience is contingent on the individual's level of involvement with wine. Low-involved consumers tend to prioritise immediate sensory and emotional responses, while wine experts tend towards cognitive evaluation. Highly involved consumers are positioned between these two categories, utilising all three dimensions (Oyinseye *et al.*, 2022). These studies are based on experiments that considered both the extrinsic and intrinsic cues of wine, but less work is focused on understanding the role of the consumer's involvement in wine acceptance that is based exclusively on the intrinsic, and thus sensory, properties of wine.

Hopfer and Heymann (2014)'s study identified four distinct American consumer segments based on their preference for Cabernet-Sauvignon wines. However, the researchers did not find a common trait within these consumer clusters that could explain the differences in liking based on demographic information (*i.e.*, age, gender, and income), wine consumption, or wine expertise. It is interesting to note that these segments differed significantly from the scores given by the experts, who expressed a preference for fruity attributes (*e.g.*, red fruit, dark fruit) and oak, as well as sweet aromas. Conversely, they penalised marginally detectable vegetal-green, chemical, earthy, sulfur, and animal aromas. These results align with the findings of Sáenz-Navajas *et al.* (2015), who observed significant discrepancies in quality assessments provided by wine experts and consumers. Both groups exhibited a similar propensity to penalise sensory traits as reported by Hopfer and Heymann (2014). In relation to the attributes that enhance perceived quality, wine experts exhibited a higher valuation of fruity wines, while consumers demonstrated a preference for oaky red wines.

Despite these advances, the empirical evidence for how the level of involvement of non-expert consumers influences intrinsic wine preference is still limited. Therefore, the main

purpose of this work was to evaluate the consumer acceptance of wines produced with Portuguese minority varieties and to identify their main sensory drivers of preference. Minority grape varieties are used here in a case study to investigate how consumer involvement modulates hedonic responses to wines differing in sensory style when extrinsic cues have been removed. It was hypothesised that the consumers' level of wine involvement influences their preference patterns based on intrinsic sensory properties, and that specific consumer segments may show appreciation for sensory profiles associated with minority grape varieties, even if the majority still prefers the dominant commercial styles.

MATERIALS AND METHODS

1. Wine samples

Twenty-four Portuguese wines were selected, 12 of which were white and 12 red. The wine selection was performed by the research team in collaboration with producers, aiming to maximise sensory diversity while ensuring the inclusion of Portuguese minority grape varieties from different regions. The Blend_T_21 and Blend_D_19 samples were made from different grape varieties representing traditional Portuguese wines, while the remaining 22 were single varietals of minor varieties, each representing less than 2 % of the total Portuguese vineyard area (Table S1). Most of the samples were young wines in their first to third year (Table 1), that had been generously provided by the producers. The different wines were produced using simple winemaking methods. According to the winemakers, wines were designed to highlight the unique characteristics of each grape variety in its region.

Given the exploratory nature of this study and the availability of minority-variety wines, samples from different vintages were included. This is acknowledged as a limitation, particularly for the red commercial reference wine (2019 vintage) compared to the minority-variety wines (mainly 2021–2022), and is discussed in the "Discussion" section.

TABLE 1. White and red wine samples made from minority grape varieties, which were sensory characterised by a professional tasting panel using projective mapping (PM) and ultra-flash profiling (UFP).

Wine colour	Wine code	Grape variety	Denomination	Vintage
White	Blend_T_21[1]	Fernão Pires and Verdelho	Tejo DOC	2021
	Vital_L_22	Vital	Alenquer DOC	2022
	Jampal_L_21	Jampal	IG Lisboa	2021
	Folga_D_22	Folgasão	Douro DOC	2022
	Carac_M_23	Caracol	Madeirense DOP	2023
	RabOve_A_232	Rabo de Ovelha	Alentejo IGP	2023
	Ramis_PS_22	Ramisco	IG Península de Setúbal	2022
	Moscat_D_22	Moscatel Galego	Douro DOC	2022
	Donzel_D_182	Donzelinho Branco	Douro DOC	2018
	Callum_BI_222	Callum	Beira Interior DOC	2022
	FontCal_BI_22	Fonte Cal	Beira Interior DOC	2022
	Sarig_A_223	Sarigo	IG Península de Setúbal	2022
Red	Blend_D_191	Old vines	Douro DOC	2019
	NegMol_Al_222	Negra Mole	Algarve IGP	2022
	TintCar_A_21	Tinta Carvalha	Alentejo DOC	2021
	Moret_A_222	Moreto	Alentejo DOC	2022
	TintMiu_A_21	Tinta Miúda	IG Alentejano	2021
	Ramis_PS_20	Ramisco	IG Península de Setúbal	2020
	TintFran_D_222	Tinta Francisca	Douro DOC	2022
	Cascul_D_19	Casculho	Douro	Several
	TintCao_D_16	Tinto Cão	Douro DOC	2016
	Rufet_BI_21	Rufete	Beira Interior DOC	2021
	Bastar_D_22	Bastardo	Douro DOC	2022
	Maruf_D_21	Marufo	Douro DOC	2021

[1] Reference samples used in PM and rate-all-that-apply (RATA) studies carried out by wine experts; [2] Wines selected for the consumer trial; [3] Tank sample, wine not yet on the market, new brand.

2. Wine sensory description by a panel of wine experts

2.1. Participants

For the sensory characterisation carried out using the PM methodology, 21 expert tasters were selected (4 females and 17 males). The group was composed of wine professionals (oenologists, journalists, wine critics) aged between 25 and 65 (the average age being 45 years old) and with more than five years of professional experience. They had all signed a declaration in accordance with the Declaration of Helsinki, and the faculty Ethic Committee had provided a formal acceptance of the research (report 2/2025). Accordingly, the tasters were informed at the start of the experiment that they would remain anonymous and that the data they provided would only be reported in aggregate. They had to sign a consent form in order to take part. Participants could request more detailed information. They could withdraw from the research if they requested access to their personal data, their rectification and deletion, restriction of their processing and portability, or any other right, and they could withdraw their consent at any time by contacting the experimenters. To take part in the study, they had to be over 18, free from certain health problems, not drink alcohol, not be pregnant and have no involvement with the research. They were not paid for their participation.

2.2. Procedure

The tasting sessions were held on two separate days (3 and 17 June 2024). Each participant attended two sessions on the same day, which were separated by a 30-minute break. The first session comprised the evaluation of white wine samples, and the second the evaluation of red wine samples. The wines were placed on the table in front of each expert in a different, randomised order following a Williams squares design created by RedJade software (version 6.2.3).

Each session consisted of two parts. In the first part, participants were asked to distribute the samples on a white sheet of paper according to their similarities and dissimilarities following the PM strategy (Valentin *et al.*, 2018). All the wines had to be placed on the 60 × 40 cm white sheet in such a way that two wines were placed close together if they were perceived as similar, and further apart if they were perceived as different. In the second part, once the wines had been arranged, they were asked to write a maximum of three descriptors that characterised each sample on the sheet next to each wine (*i.e.*, UFP).

The tasting took place in a laboratory of the Instituto Superior de Agronomia, at 22 °C and, with adequate lighting and ventilation. Thirty mL of wine was served in black Schott Zwiesel Sensus glasses, each marked with a unique three-digit code. The white wines were served at a temperature of 12 °C and the red wines at 18 °C. After serving, plastic Petri dishes were used to cover the glasses. Each professional evaluated each wine and was given water and unsalted crackers to cleanse the palate if necessary.

2.3. Data analysis

For each participant, the position of the samples on the sheet was measured. Therefore, the x and y coordinates (the bottom left part of the sheet representing the origin (0,0)) for each sample and participant were registered. A final wine × assessor matrix was obtained and submitted to Generalised Procrustes Analysis (GPA) (Findlay, 2023) to obtain a two-dimensional consensual map of samples. Further, the consensual coordinates derived from GPA were submitted to Agglomerative Hierarchical Cluster Analysis (AHCA). For AHCA, Ward's linkage method and Euclidean distances were used. The number of clusters was determined by inspecting the dendrogram and selecting the cut-off at the level showing the largest increase in linkage distance between successive agglomeration steps (*i.e.*, the largest vertical jump in the dendrogram), which indicates a marked decrease in within-cluster similarity when additional merges are forced.

The method described by Ballester *et al.* (2024) was utilised to process the data derived from UF; therefore a multi-stage approach was adopted. To prevent redundancy, the initial step involved compiling a list of every attribute that the tasters had mentioned and eliminating any duplicate terms. The next step was lemmatisation, which consisted of grouping terms with the same root into a single representative term (for example, "complexity" and "complex" were combined to form "complex"). Then, three researchers separately conducted a triangulation process on the data by grouping terms belonging to the same semantic universe. After comparing the groups formed by the experimenters, a final, consolidated list of terms was determined by consensus.

Finally, a matrix containing the frequency of citations for each attribute was constructed, with the consensual terms in columns and wines in rows. For each attribute, the average of the citation frequency of between the wines belonging to the same cluster derived from the GPA-AHCA was calculated to obtain a raw description of the clusters. To identify any differences between the four clusters in the citation of attributes, chi-square was calculated, and for significant attributes ($p < 0.1$) the Marascuilo post-hoc test was applied.

The responses were compiled for the 12 white and 12 red wines separately. The final list of descriptors contained 32 terms for white wines and 25 terms for red wines. Attributes cited by at least 10 % of the panellists were considered, an arbitrary threshold used to ensure a minimum level of agreement.

3. Consumer liking and wine characterisation

3.1. Participant selection

Participants were recruited through emailed invitations and social media. Recruitment was limited to participants who lived and had spent most of their lives in Lisbon to ensure consistency in terms of the region of origin effect and familiarity. They completed an online questionnaire on demographic information and their level of involvement (10 items) in wine consumption; inspired by the questionnaire

developed by Bruwer and Buller (2013), our questionnaire was adapted to Portuguese consumers, taking into account the results of previous work involving Spanish consumers (Oyinseye *et al.*, 2022) (see Table S2). Participants were asked to rate their agreement with statements using a 5-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree). The survey was conducted for a period of two weeks.

A final number of 84 consumers (out of the 95 that performed the demographic and involvement questionnaire) qualified for and participated in the sensory sessions (Table S3). The requirements to participate were: (i) drink wine at least once a month; (ii) reside in the Lisbon metropolitan area for a minimum of 10 years; and (iii) not work in the wine industry.

Regarding the expert panel, all its members had been informed about the objective of the study and had signed a consent form in accordance with the Declaration of Helsinki.

At recruitment, consumers and expert panel participants were informed that they would take part in a sensory study involving wine tasting. At the beginning of the sessions, they were not informed about the nature of the samples (minority *vs* commercial wines) nor about the specific hypotheses tested, in order to minimise expectation bias.

3.2. Procedure

The tasting sessions took place on different days. Each participant attended two sessions (each lasting a maximum of 30 minutes) on the same day with a 30-minute break between sessions.

The first session was devoted to the evaluation of four white wines and the second to four red wines. Wines were selected based on the results from the PM reported in a previous selection and aiming at having wines with maximal sensory variability. Specifically, one wine located near the centroid of each expert-derived sensory cluster was selected in order to represent the typical sensory profile of each cluster.

In each session, the wines were randomised according to a Williams square design. The tastings took place at the Instituto Superior de Agronomia, in a room at a temperature of 22 °C and with adequate lighting and ventilation. Twenty-five mL of each wine was served in transparent glasses (Schott Zwiesel, model Ivento, Bavaria, Germany) that were coded with three-digit numbers. White wines were poured at 10 °C and red wines at 16 °C. The glasses were covered with plastic Petri dishes. Each taster evaluated each wine individually, and they were provided with water and unsalted crackers to cleanse the palate when necessary. The participants were not informed of the nature of the samples or the purpose of the study.

For each wine, participants were asked to first rate wine liking on a structured 10-point scale (0 = 'I don't like it at all'; 5 = 'I don't like it or I dislike it'; 10 = 'I like it very much') based on visual, olfactory and gustatory appreciation. A 10-point scale was chosen to provide sufficient discrimination for segmentation analyses while maintaining simplicity for consumers. Then, sensory profiling was undertaken following the RATA methodology (Danner *et al.*, 2017; Nguyen *et al.*, 2020).

Participants had to select from a list of 10 attributes referring to flavour (for white wines: citrus/tropical fruit, dried fruit, floral, herbaceous, neutral, oxidation, reduction, yellow/white fruit, woody/spicy; and for reds: animal, defective, dried fruit, fresh fruit, neutral, oxidation, red/black fruit, woody/spicy), taste (for whites: acid), mouthfeel (for reds: astringency), and multidimensional (for reds: complexity) attributes. The assessed sensory attributes had been extracted from the description of the initial 24 wines described in the previous session by the panel of wine experts. The attributes were selected based on their frequency of citation and their relevance to differentiate sensory clusters, while keeping the list short and understandable for consumers. To facilitate the interpretation of potentially ambiguous technical terms, brief associated descriptors were provided in parentheses for the purposes of comprehension and their consistent use, especially by low-involved consumers; for instance, "boiled potato, honey, overripe apple" for *oxidation* and "rotten eggs, sewer, garbage" for *reduction*. Each consumer was required to only rate the intensity of attributes they perceived in the wine (*i.e.*, only those that apply) on a 7-point scale, where 1 = 'extremely low' and 7 = 'extremely high'.

3.3. Data analysis

Participant selection. A first Principal Component Analysis (PCA) was carried out on the participants' answers to the involvement questionnaire to identify the questions with the greatest impact on consumer involvement. This analysis showed that 8 out of 10 questions were most strongly correlated (Table S2 of supplementary data). The standardised Cronbach's α was calculated. This is a reliability coefficient that ranges from 0 to 1. Higher values of Cronbach's α indicate higher internal consistency. Cronbach's α values higher than 0.75 were considered acceptable, otherwise the non-related items were identified and removed and Cronbach's α recalculated. An average level of involvement score was calculated with the selected eight items (Cronbach's $\alpha > 0.75$) by assigning scores of 1–5 to responses ranging from totally disagree: 1, to totally agree: 5.

To define two contrasting involvement groups, participants with scores below the 33rd percentile and above the 67th percentile were classified as low- and high-involved, respectively, while intermediate scores were excluded from the tasting sessions to minimise overlap between involvement levels (Oyinseye *et al.*, 2022).

Consumer liking and wine characterisation. First, the preference scores of all the 8 wines evaluated and the 84 respondents were subjected to a PCA considering consumers as variables to determine the consensus among the responses. Then, an AHCA was run to group the wines according to the similarity of their preference scores.

To identify significant differences between wines in terms of their sensory descriptions, two-way ANOVA with all the scores of RATA attributes were calculated, considering the 84 consumers as random factors and the wine as fixed factors.

Consumer segmentation was carried out by calculating an AHCA on the preference scores. Then, two-way ANOVA was calculated using the preference scores and considering the clusters of consumers derived from the AHCA and the wine, and their interaction as fixed factors. In addition, a one-way ANOVA on the involvement scores and considering the cluster as a fixed factor was calculated to evaluate the effect of the level of involvement on consumer segments. For significant effects, Student–Newman–Keuls post-hoc pairwise comparison (95 %) test was calculated.

Finally, to relate sensory profile and preference scores, a PCA for each wine set was performed, considering the significant RATA attributes as active variables, and the averaged preference score (considering all the consumers together) as well as the average preference scores for each cluster as supplementary variables. These analyses were performed with the XLSTAT software (version 2023.1.1) and the free online statistical software Jamovi (version 2.3.28).

RESULTS

1. Wine sensory description by a panel of wine experts

The results of the AHCA calculated on the data derived from the PM task showed the presence of four distinct clusters for both the white and red wines (Figure 1). The two-dimensional consensual configuration obtained by GPA is presented in Figure S1.

Overall, the white wine clusters significantly differed in their aroma intensity and fruity profile, covering a broad sensory space. The wines in Cluster III showed the most intense and the fruitiest profiles in contrast to the samples in Clusters IV and I (see Table S4 for the average of citation of terms for each cluster and their significance). The studied white wine set thus occupied a distinct sensory space, with profiles ranging from intense and fruity to neutral and subtle.

Cluster I contains the reference sample Blend_T_21, as well as the samples Ramis_PS_22, and Jampal_L_21. Even if there were no significant differences in terms of the attribute citations, most wines in this cluster displayed the highest frequency of citation for the terms “neutral” and “structured”. Cluster II brings together the wines Folga_D_22, Donzel_D_18, Vital_L_22, and Carac_M_23, showing the highest frequency of citation for the terms woody/spicy and yellow/white fruit. Cluster III contains the Sarig_A_22, Callum_BI_22, and FontCal_BI_22 wines. Their highest intensity and fruity character is related to the highest citation for yellow/white and citrus/tropical fruit. This cluster also showed higher citation frequency for acid taste and fine character. Finally, Cluster IV included the RabOve_A_23 and Moscat_D_22 wines, with higher frequency for the terms “neutral” and “reduced profile”, which could explain their significant least intense and fruity character.

For the reds, only the term “animal” showed significant differences between the clusters, which was significantly higher for the wines in Cluster I (Table S4). This group of wines contains the wines Moret_A_22 and Ramis_PS_20, which also showed a higher frequency of citation for neutral and oxidised attributes, indicating a less fruity sensory style that is associated with notes of ageing or evolution. Cluster II consists of the wines TintCao_D_16, Rufet_BI_21, TintFran_D_22, Bastar_D_22, and Maruf_D_21, which showed a higher frequency of citations for the woody/spicy and complex terms. Cluster III contains the wines Cascul_D_19, NegMol_Al_22, and TintCar_A_21 wines, which were defined by their red/black fruit descriptors, with the presence of fresh fruit, albeit neutral, and showing a younger profile. On the other hand, Cluster IV group together the reference sample, Blend_D_19 and TintMiu_A_21,

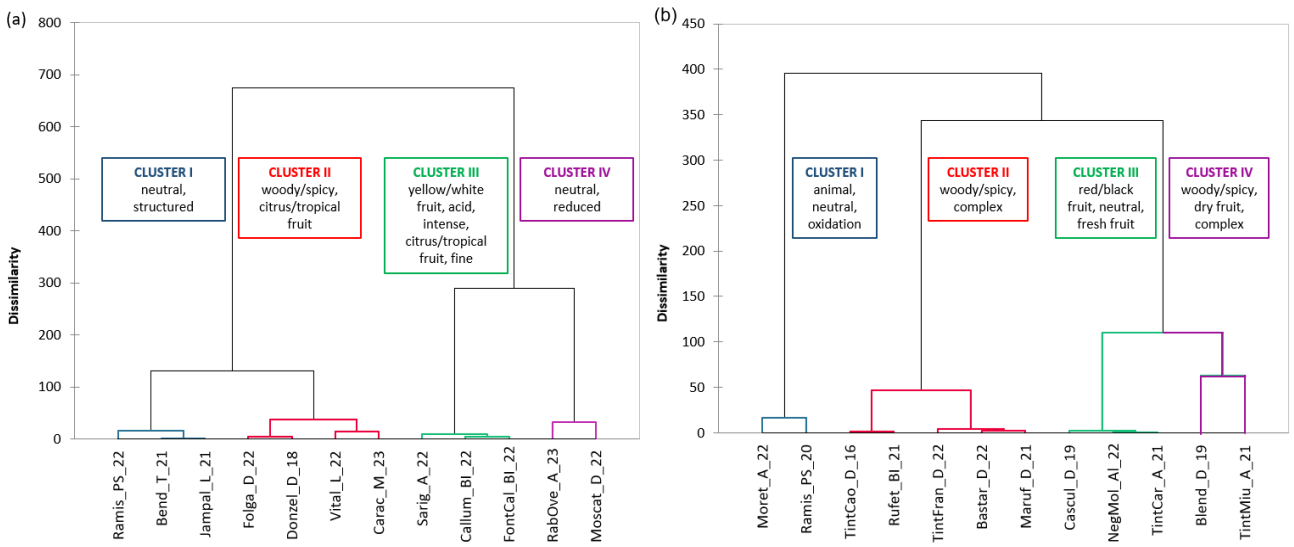


FIGURE 1. Dendrogram resulting from agglomerative hierarchical clustering of a) white wines and b) red wines based on sensory dissimilarity.

which are characterised by the presence of wood and spices, combined with the descriptors of dried fruit and complexity, suggesting wines with more structure. These groups show a remarkable sensory diversity among the red wines analysed, due to differences in style, ageing, and aromatic profile.

The dendrogram analysis revealed multiple clusters, each representing wines with distinct sensory profiles (Figure 1). Within a cluster, the wines positioned closest to the average centre are those that most effectively capture the representative characteristics of the group. Therefore, selecting one of these central wines ensures the choice of a sample that best embodies the typical profile of its cluster. Accordingly, for the consumer test, the selected white wine samples were Blend_T_21, Donzel_D_18, Callum_BI_22, and RabOve_A_23, and the red wine samples were Blend_D_19, Moret_A_22, TintFran_D_22, and NegMol_Al_22.

2. Overall wine liking

Significant differences in wine liking were observed between the wines. Most wines were scored with values of 4 to 8 (on a 0-10 scale), indicating a neutral to positive liking (Figure S2). Computing all wines, the average scores were higher for white (5.09 ± 2.36) than for red wines (4.41 ± 2.39) ($F = 13.779$; $p < 0.001$), driven by the number of 0 scores for red wines (31 responses). These null scores were distributed among all wines, the highest number being given to NegMol_Al_22 by 12 consumers.

Furthermore, in both cases, the reference commercial wine (*i.e.*, blend wine) received significantly higher preference scores compared to the minor varieties (Table 2). However, since one commercial reference wine was included per colour category, these results should be interpreted as comparisons with the selected reference style, rather than as a general statement about commercial wine preference.

3. Liking distribution among consumers

Figure 2a shows the projection of the preference scores of participants on the first two axes of the PCA. The first and second principal components (F1, F2) explains almost 50 % of the total variance of the data. The dissemination of consumers along the quadrants of the plot demonstrates that there was not a homogenous distribution of liking scores, since each vector is a measure of correlation among the scores given to each wine. The projection of the samples is presented in Figure 2b, in which a contrast can be seen between the lower scored red wines in the left-hand quadrants and the higher scores given to the white wines in the right-hand quadrants. The AHCA in Figure 2c shows a clear separation between the appreciation of white and red wines. These results provided statistical justification for the separate analysis of the results from the white and red wines respectively.

The results shown in Figure 2a highlight the absence of homogenous appreciation among the consumers, thus justifying looking for segments with a higher consensus on white and red wines. Therefore, in the next step, a consumer segmentation based on preference scores was applied.

4. Cluster segmentation based on preference scores

4.1. White wines

The consumer preferences for all white wines were subjected to AHCA (Figure S3) showing a separation into three clusters of consumers (demographic characteristics shown in Table S5). Interestingly, a significant effect of the level of involvement of consumers among clusters was observed, with significantly higher scores for Cluster I (average = 3.68) than for both Cluster II (average = 3.20) and Cluster III (average = 3.30) ($F = 5.905$; $p < 0.01$), which confirms our initial hypothesis (Table 3). The significant interaction between cluster and sample ($F = 17.228$; $p < 0.0001$) shows that the preference for samples depends on the cluster to which each judge belong. The average liking score for each cluster is shown in Table 3, together with a summarised description of the sensory preference styles.

Regarding the consumer description, six significant attributes significantly varied among the white wines; these were citrus/tropical fruit, reduced, dried fruit, acid, oxidation, and neutral (Table 4). The mean liking scores and the sensory characterisation of the white wines were subjected to a PCA (Figure 3); they are listed in Table S6.

TABLE 2. Mean preference scores of the studied wines (mean ± standard error).

Wine colour	Sample	All consumers[1]
White	Blend_T_21	6.04 ± 0.22 a
	Donzel_D_18	5.06 ± 0.24 b
	Callum_BI_22	4.81 ± 0.24 b
	RabOve_A_23	4.48 ± 0.30 b
Red	Blend_D_19	5.39 ± 0.26 a
	Moret_A_22	4.06 ± 0.25 b
	TintFran_D_22	4.15 ± 0.24 b
	NegMol_Al_22	4.05 ± 0.27 b

[1] Different letter for the same wine colour, indicate significant differences in the column ($p < 0.05$).

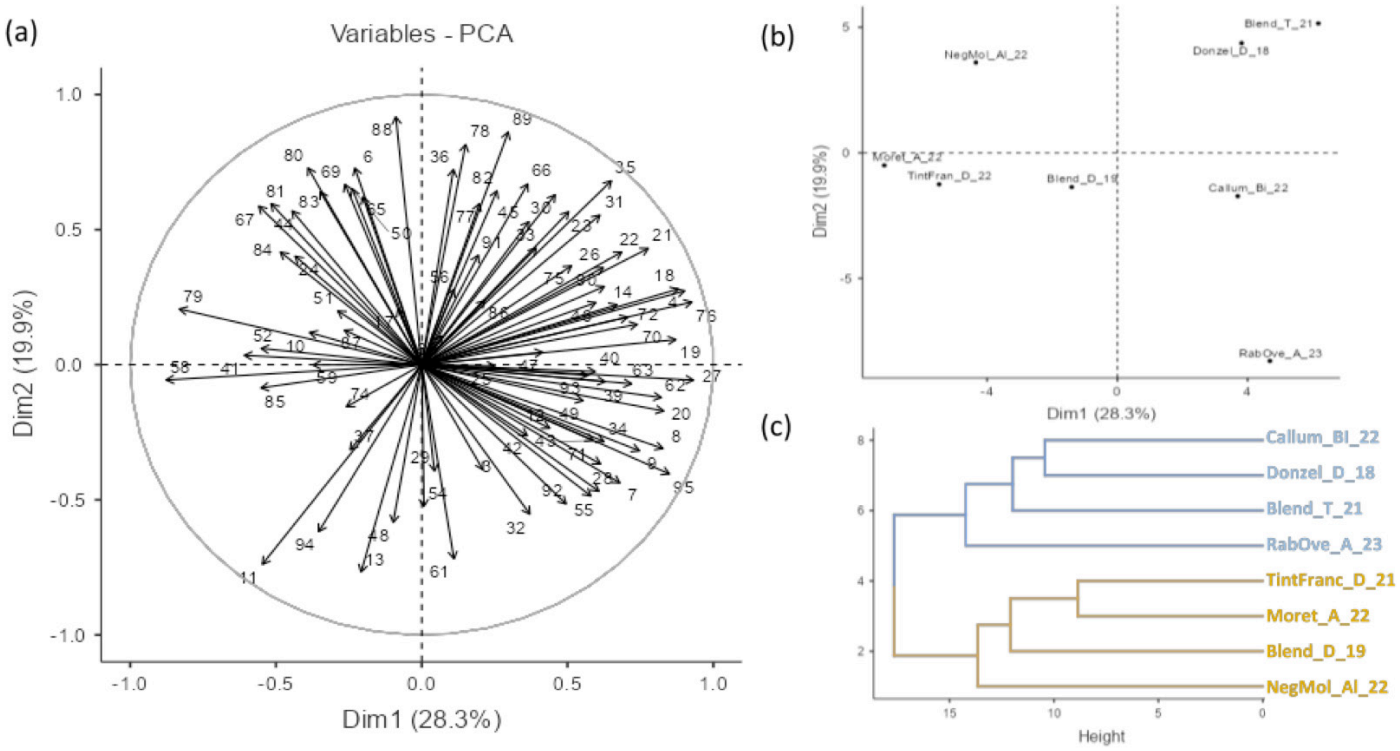


FIGURE 2. PCA showing a) the distribution of individual preference scores, b) the projection of white and red wines on the PCA plot, and c) the respective cluster dendrogram (wine codes are listed in Table 1).

TABLE 3. Mean preference scores according to the different preference clusters.

Cluster (number of tasters)	Involvement level[1]	Blend_T_21[2]	Donzel_D_18	Callum_Bl_22	RabOve_A_23	Preference styles
I (34)	3.68 a	6.65 def	4.79 bc	5.85 cde	7.03 ef	Intense freshness wine likers, insensitive to reduction
II (12)	3.20 b	6.42 def	7.75 f	7.33 f	3.17 a	Mellowed wine likers, reduction dislikers
III (38)	3.30 b	5.37 bcd	4.45 b	3.08 a	2.61 a	Mild fruitiness wine likers, reduction dislikers

[1] Different letters indicate significant differences in the column ($p < 0.01$).

[2] Different letters indicate significant differences in the column and in the line ($p < 0.05$).

TABLE 4. ANOVA results (*F*, *p*, and significance) of the sensory attributes of white wines rated by consumers (consumers as random and wine as fixed factors).

Attributes	*F*	*p*	Significance
Citrus/tropical fruit	8.264	<0.0001	***
Reduced	8.117	<0.0001	***
Dried fruit	5.622	0.001	**
Acid	4.999	0.002	**
Oxidation	4.337	0.005	**
Neutral	2.896	0.036	*
Yellow/white fruit	1.427	0.235	ns
Floral	1.352	0.258	ns
Woody/spicy	0.739	0.53	ns
Herbaceous	0.093	0.964	ns

* <0.05; ** <0.01; *** <0.001; ns, not significant.

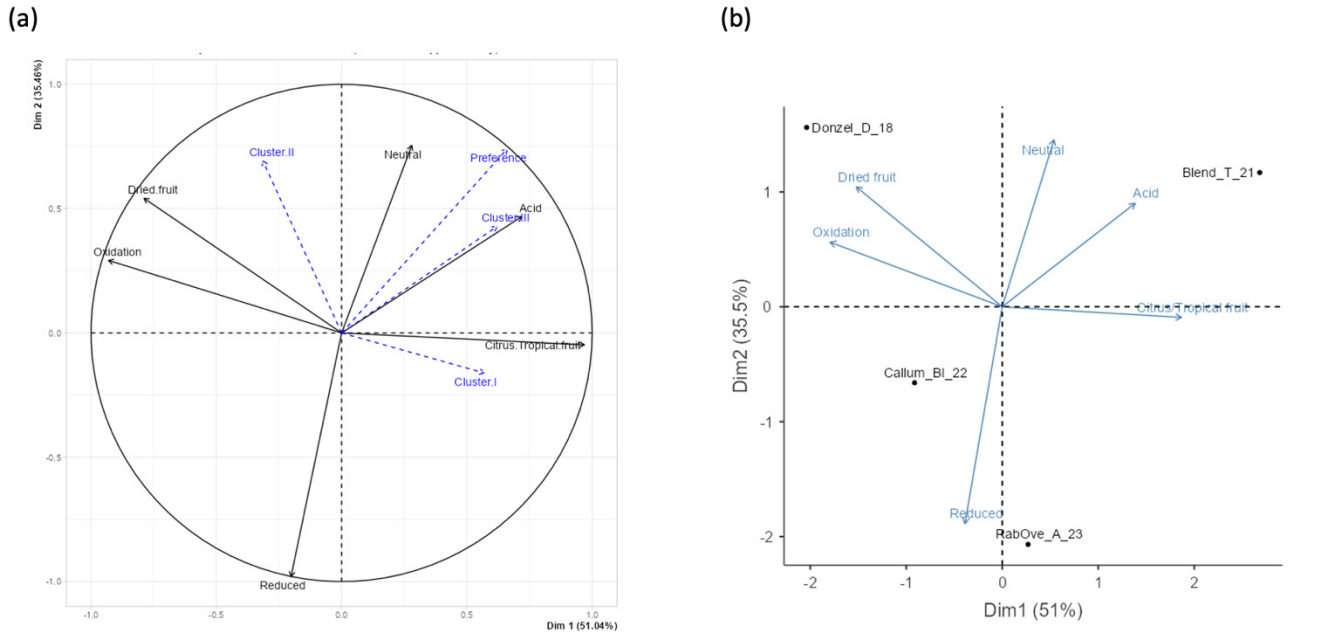


FIGURE 3. PCA biplots of a) the significant sensory attributes of white wines and preference for the consumer clusters, and b) the sensory attributes and wine samples. Preference given by all consumers (Preference) and by each cluster (Clusters I, II, and III) were plotted as illustrative variables (dashed blue lines).

The ANOVA of RATA scores, with consumers clusters and wine as fixed factors, showed that reduction was the only attribute significantly influenced by the consumer cluster ($F = 2.95$; $p < 0.01$). This suggests that the characterisation of wines with this attribute depends on the consumer cluster, with RabOve_A_23 receiving the highest reduction scores from Cluster II, and similar scores being given by Cluster III to both RabOve_A_23 and Callum_BI_22 (Table S6).

Consumers in Cluster I had a higher level of involvement and they preferred all white wines to Donzel_D_18, although the latter's score was not significantly different from that of Callum_BI_22. This cluster preferred wines dominated by citrus/tropical fruit, such as Blend_T_21 and RabOve_A_23, both of which had higher acidity and lower reduction perception. Donzel_D_18 was slightly penalised due to its lower citrus/tropical fruit perception and higher dried fruit and oxidation notes. Callum_BI_22 was the most neutral wine with lower acidity. Despite this, the consumers in Cluster I showed relatively high appreciation of all the white wines, as the reduction of RabOve_A_23 was low and equal to the other wines in this cluster. As a result, the consumers in this cluster are referred to as intense freshness wine likers who are insensitive to reduction (see Table 3).

Cluster II showed a preference for most wines, except RabOve_A_23. Donzel_D_18, dominated by dried fruits, had lower acidity but was not penalised by oxidation. Callum_BI_22 shared similar characteristics, albeit with lower intensity. Blend_T_21 was also equally liked, likely due to a mild perception of citrus/tropical fruit. In contrast, RabOve_A_23 was the least liked, as its reductive flavours overwhelmed its other sensory attributes, leading to a low neutral score. The consumers in this cluster are referred to as mellowed wine likers and reduction dislikers.

Cluster III was the largest group and its preferences mirrored the overall consumer responses (Figure 3a). Blend_T_21, with its citrus/tropical fruit and acidity, and Donzel_D_18, with its dried fruit and oxidation notes, were the most liked. The difference from Cluster I was related to the lower preference given to RabOve_A_23 and Callum_BI_22, which tended to have higher reductive flavours (Table S6). As Blend_T_21 tended to have higher neutral scores, the consumers in this cluster were referred to as mild fruit likers and reduction dislikers.

4.2. Red wines

The preference scores for red wines were subjected to AHCA, with four different clusters being identified (Figure S5, demographic characteristics shown in Table S5). A relative consensus was observed in the responses of three out of the four clusters, while some of the responses of Cluster II were scattered across the plot (Figure S6). A highly significant interaction between consumer cluster and sample ($F = 13.306$; $p < 0.0001$) was observed for red wines, indicating that preference for each sample depended on the cluster to which the judge belonged.

A significant effect of the level of involvement was observed among the clusters ($F = 4.397$; $p < 0.01$), with consumers in Cluster IV showing a significantly higher level of involvement compared to the other three clusters (Table 5). This observation is consistent with the involvement effect observed in the white wine set. This difference can be attributed to the higher proportion of high-involved subjects in Cluster IV (Table S5). Unlike white wines, the ANOVA of RATA scores, considering cluster and wine as fixed factors and their interaction, showed no significant effect of cluster on any of the sensory descriptors. The average preference scores for each cluster are shown in Table 5, along with a brief

description of the preferred styles. Regarding the description of wines, Table 6 presents the significant attributes that differ among the red wines, including woody/spicy, astringency, neutral, animal, complex, and red/black fruit.

Figure 4 illustrates the PCA with the projection of the significant sensory descriptors, cluster preferences, and the associated wines. Overall, the higher perception of wood/spicy, red/black fruits, astringency, and complexity explains the preference for the commercial blend. By contrast, the animal aroma predominantly characterised Moret_A_22, which was negatively related to preference. TintFran_D_22 was the most neutral wine. NegMol_Al_22 is located in the quadrant opposite the blend and lying between the animal notes of Moret_A_22 and the neutral character of TintFran_D_22. The mean liking scores and the sensory characterisation of red wines are summarised in Table S7.

Cluster I consists of consumers who significantly favoured only the commercial blend wine (bold oaky red wine likers). Consumers in Cluster II gave low scores to all red wines (red wine dislikers). The consumers in Cluster III enjoyed all reds except for the light-coloured NegMol_Al_22, suggesting that colour-linked style perception may have influenced preference. By contrast, the consumers in Cluster IV, composed of a higher proportion (68 %) of high-involved consumers, strongly preferred NegMol_Al_22 and liked Moret_A_22 and TintFran_D_22 less. The high score given to Blend_D_19 indicates that this cluster's liking was not restricted to a single wine style, contrasting with the preferences of Cluster I (full and light red wine likers).

DISCUSSION

The distribution of the liking scores was qualitatively similar to that in other studies, in which wines were rated by a high number of tasters (Bodington & Malfeito-Ferreira, 2019). The most relevant difference was the assignment of a high number of zeros to red wines, with a concomitant average score lower than that of the whites. Highly reputed wines tend to receive lower ratings when tasted blind (Vecchio *et al.*, 2019; Yang & Lee, 2021; Angelini *et al.*, 2023). In the present study, the overall higher liking scores for white wines compared to red wines may reflect differences in sensory style perception under blind conditions and should not be interpreted as evidence of a broader market trend.

Segmentation according to wine involvement has been described in academic literature using self-reported questionnaires without tasting (Johnson & Bastian, 2015; Pomarici, 2016). In this work, the assignment of wine preferences to the outputs of an involvement questionnaire was followed by wine sample tasting. The findings corroborate our initial hypothesis that wine preferences, based exclusively on intrinsic properties (*i.e.*, sensory

TABLE 5. Mean preference scores according to the different preference clusters.

Cluster (number of tasters)	Involvement level[1]	Blend_D_19[2]	Moret_A_22	TintFran_D_22	NegMol_Al_22	Preference styles
I (25)	3.33 b	6.08 e	3.56 bcd	3.24 bcd	2.52 abc	Bold oaky red wine likers
II (18)	3.34 b	2.11 ab	1.67 a	2.22 ab	3.56 bcd	Red wine dislikers
III (22)	3.31 b	6.97 e	6.27 e	6.36 e	3.77 cd	Full colour wine likers
IV (19)	3.83 a	5.79 e	4.42 d	4.63 d	7.05 e	Full and light red wine likers

[1] Different letters indicate significant differences in the column ($p < 0.01$).
[2] Different letters indicate significant differences in the column and in the line ($p < 0.1$).

TABLE 6. ANOVA results (*F*, *p* and significance) of the sensory attributes of red wines.

Attributes	*F*	*p*	Significance
Woody/spicy	12.791	<0.0001	**
Astringency	9.108	<0.0001	**
Neutral	6.928	0.000	**
Animal	5.937	0.001	**
Complex	5.341	0.001	**
Red/black fruit	3.902	0.009	**
Dried fruit	2.084	0.103	ns
Oxidation	2.060	0.106	ns
Fresh fruit	1.564	0.199	ns
Defective	1.151	0.329	ns

* <0.05; ** <0.01; *** <0.001; ns, not significant.

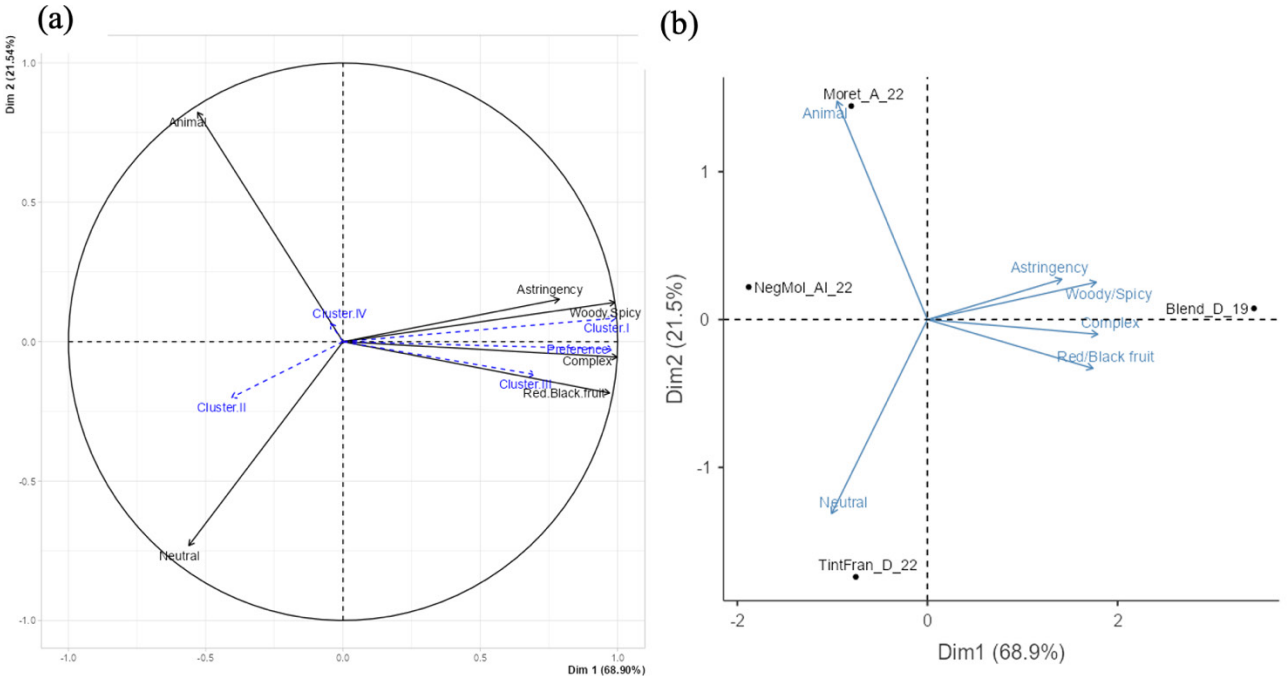


FIGURE 4. PCA biplots of a) the sensory attributes and preference for the clusters of red wines, and b) the sensory attributes and wine samples. Preference given by all consumers (Preference) and by each cluster (Clusters I, II, III, and IV) were plotted as illustrative variables (dashed blue lines).

profile), are modulated by the level of involvement of the consumer. To our knowledge, these results provide additional empirical evidence for the role of wine involvement in modulating intrinsic preference patterns.

Beyond the specific case study of Portuguese minority grape varieties, the present work also highlights the methodological value of combining rapid expert sensory mapping (PM + UFP) with consumer liking, RATA profiling, and involvement-based segmentation, as a cost-effective strategy to identify sensory drivers of preference and potential niche consumer segments.

The consumers gave consistent wine descriptions, which confirms the fact that consumers can provide wine descriptions comparable to those of trained tasters (Valentin *et al.*, 2012; Varela & Ares, 2012). These responses enabled us to show that most consumers yielded responses consistent with those reported from international wine challenges. The citrus/tropical fruits of white wines are known to elicit the highest appreciation, while for red wines, the red/black fruit, oaky and astringent mouthfeel are typical of the Grand Gold medals (Malfeito-Ferreira *et al.*, 2019).

The lower scores given to the minority wines by the consumers might be a result of their lower familiarity with their sensory features, since preference is affected by degree of familiarity (Yang & Lee, 2020). Nevertheless, the wines from Ramisco, Jampal, and Tinta Miúda might have a commercial advantage, since the descriptions they gave were similar to those of the blends (Long *et al.*, 2023). However, it should be noted that only one commercial reference wine was included per colour category; therefore, conclusions regarding "commercial wines" should be interpreted as comparisons with the selected reference style rather than as a general statement.

In addition, the diversity of vintages included in the initial wine set represents a limitation of the study, particularly regarding the red wines whose commercial reference (2019) differed in age from most of the minority-variety wines (mainly 2021–2022). Wine age and vintage conditions can influence sensory profiles and perceived liking; this should be considered when interpreting the proximity between the samples in the expert-derived clusters, as well as the consumer preference patterns.

Regarding the sensory drivers of preference, in white wines, the contrasting responses were mainly due to the perception of reduction and, to a lower extent, to dried fruits (highly correlated with oxidation). Cluster I, comprising 65 % of high-involved consumers and a higher proportion of older and more frequent consumption individuals (see Table S5), yielded lower reduction scores for RabOve_A_23 than the other clusters. According to Franco-Luesma *et al.* (2016) and Bekker *et al.* (2020), the presence of reductive aromas masks fruity and floral aromas, resulting in a more neutral profile. Therefore, the majority of the consumers in Cluster I may have been insensitive to reduction (Lytra *et al.*, 2014). However, reduction can also be perceived under the concept of the so-called mineral character of highly reputed white wines (Rodrigues *et al.*, 2015) explaining the high preference given to RabOve_A_23 (see Table 3). Interestingly, professionals had also recognised a reduction in this wine but with low citation frequency during the PM evaluation. The duality of the concept, where some individuals recognise its high qualitative significance associated with minerality while others associate it with spoilage, may explain the observed conflicting behaviours (Malfeito-Ferreira, 2022). Moreover, reduction may also convey a positive connotation when associated with organic wines (Romano *et al.*, 2020).

Oxidation has been shown to differentiate non-faulty and faulty wines, with few perceptual differences between experts and novices (Franco-Luesma *et al.*, 2019). Accordingly, the white wine that was described using the terms dried fruits and oxidised was from 2018 (Donzel_D_18) and was most appreciated by Cluster II, with an equivalent number of individuals from both involvement levels and a lower frequency of consumption. Indeed, Cluster II only comprised 12 persons, who could be referred to as "oxidation fans" – a term that was applied by Franco-Luesma *et al.* (2019) to a small group of novices. Nevertheless, wine professionals now adequately recognise the quality of "oxidised" aged white wines, as recently documented by Esteves *et al.* (2024). For many consumers in the present study, however, the term "oxidation" may have had negative connotations, which could have been minimised if the term "mellowed by age" had been used, as proposed by Marasà *et al.* (2024) when dealing with proper ageing.

Overall, the sensory discrimination of white wines appears to mainly have been due to dried fruits/oxidation and reduction (see Figure 3) with different quality inferences. In the absence of these attributes, appreciation could not be fully explained by differences in the intensity perception of the consensual flavours of citrus/tropical fruit or acidity. These findings suggest that consumer acceptance of minority-variety white wines may depend not only on conventional fruit-driven freshness cues but also on how consumers interpret sensory notes that can be perceived either positively (*e.g.*, minerality, aged character) or negatively (*e.g.*, reductive/oxidative deviations), depending on involvement and prior experience.

In reds, the main source of conflicting consumer responses was probably wine colour, since the wines were tasted in transparent glasses and no particular attribute could be associated with the different perceptions of each cluster, in contrast to reduction in white wines. The perception of animal aroma might explain the occasional lower preferences, but the behaviour was not so evident as reduction was in the white wines. As a tendency, astringency probably explains the responses of Cluster II (red wine dislikers), in which Blend_D_19 received the highest score for astringency, suggesting that it may have been the penalising factor. The low red colour intensity of the variety Negra Mole elicited higher preference by some individuals, who were clearly outnumbered by those preferring bolder and more aromatically intense wines. Nevertheless, this preference for a light-coloured red, as would be expected for a Burgundian Pinot noir (Valentin *et al.*, 2015), has been mostly associated with high-involved subjects, with a high percentage of women who have high consumption frequency, demonstrating that there are niches that prefer these wines (Yang & Lee, 2021). These results are particularly relevant for minority varieties, as they support the existence of targeted market segments for less conventional red wine styles.

The acceptance or rejection of certain flavours was accompanied by the saliency of their perception, which is an idiosyncratic feature (Barwich, 2017). The fact that liking/disliking could be anticipated, in certain cases, by the magnitude of the sensory response can be linked to olfaction being an emotional sense (Yeshurun & Sobel, 2010). Even before perception and flavour identification, the brain produces an emotional reaction that modulates the flavour perception (Schulze *et al.*, 2017). This was particularly evident with the high intensity grades given to dried fruits and reduction in the most and least liked white wine, respectively, in Cluster II (Donzel_D_18, RabOve_A_23), suggesting that the high variations in preference scores are the result of emotional reactions of affection or distaste. This behaviour was not so clearly observed in red wines for any of the flavours. It may have been possible to associate the animal descriptor with the "horse sweat" off-flavour (Malfeito-Ferreira, 2018), but the red wines were not so markedly affected by this flavour as the white wines by reduction.

The utilisation by the professionals of a sensory attribute with an aesthetic value (complexity) was only valid for reds, being highly correlated with red/black fruit and woody/spicy. The consumer results showed a high positive correlation between complexity and preference, which was expected since neither experts nor non-experts are able to separate enjoyment from aesthetic evaluation (Sackris, 2018).

CONCLUSION

Preference for the commercial style, which was represented by the control samples, was still dominant for most of the consumers after the responses had been averaged across the full consumer sample. However, given that only one commercial reference wine was included per colour category, these results should be interpreted as a comparison with the selected reference style rather than as a general conclusion regarding commercial wine preference.

Preference patterns were mainly driven by intrinsic sensory cues associated with familiar and widely appreciated profiles, such as fruit-forward character in white wines and red/black fruit combined with woody/spicy notes in red wines.

This behaviour is not surprising, since the pleasantness of the wines dominated by fruit-associated sensory cues – expressed as fresh fruitiness in the white control or red/black fruit and oak in the red control – is often associated with high consumer intrinsic liking.

By contrast, when sensory profiles deviate from these dominant styles – such as wines perceived as being more evolved or lighter in colour – consumers may need to be more familiar with them and have more experience in order to positively interpret them.

The results clearly show that consumers are not a homogenous entity. They demonstrate that the level of involvement of consumers with wine constitutes a determining factor in the modulation of wine preferences based on intrinsic properties. In addition, the preference segmentation revealed the existence of niche consumer groups who show comparable or higher appreciation for specific wines made from minority grape varieties.

These findings highlight the potential of using minority grape varieties to address differentiated market segments and support the usefulness of combining rapid expert sensory mapping with consumer segmentation and involvement stratification to identify sensory drivers of liking. From an applied perspective, targeted communication, and consumer education initiatives may help contextualise and explain less familiar sensory profiles, facilitating a broader acceptance of wines produced from minority grape varieties. Finally, future studies should be carried out to confirm these findings, using a larger consumer sample and a broader set of commercial reference wines, ideally matched by vintage, to better disentangle the effects of wine style, wine age, and seasonal variability on consumer segmentation and sensory drivers of preference.

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REFERENCES

Alifragkis, A., Cunha, J., Pereira, J., Fevereiro, P., & Eiras Dias, J. (2015). Identity, synonymies and homonynies of minor grapevine cultivars maintained in the portuguese ampelographic collection. *Ciência e Técnica Vitivinícola*, *30*, 43-52. https://doi.org/10.1051/ctv/20153001043

Anderson, K., & Pinilla, V. (2021). Wine's belated globalization, 1845–2025. *Applied Economic Perspectives and Policy*, *44*(2), 742–765. https://doi.org/10.1002/aepp.13174

Angelini, F., Castellani, M., & Ventrucci, M. (2023). Cumulative information on quality and willingness to pay: a study on wine evaluation. *Journal of Foodservice Business Research*, 1–39. https://doi.org/10.1080/15378020.2023.2259315

Augusto, D., Oliveira, A., Falco, V., & Castro, I. (2019). Uncovering Northeast Portugal grapevine's varietal legacy. *Vitis*, *58*(5), 89-93. https://doi.org/10.5073/vitis.2019.58.special-issue.89-93

Balda, P., Ibáñez, J., Sancha, J., & de Toda, F. M. (2014). Characterization and identification of minority red grape varieties recovered in Rioja, Spain. *American Journal of Enology and Viticulture*, *65*, 148-152. https://doi.org/10.5344/ajev.2013.13050

Ballester, J., Belascoin, M., Gonzalez-Hernandez, M., Parga-Dans, E., González, P. A., & Saenz-Navajas, M. (2024). Sensory attributes and quality perception of red natural wines: a comparative study in Spain and France. *OENO One*, *58*(1). https://doi.org/10.20870/oeno-one.2024.58.1.7737

Barrias, S., Pereira, L., Rocha, S., de Sousa, T. A., Ibáñez, J., & Martins-Lopes, P. (2023). Identification of Portuguese traditional grapevines using molecular marker-based strategies. *Sciencia Horticulturae*, *311*, 111826. https://doi.org/10.1016/j.scienta.2023.111826

Barwich, A. S. (2017). Up the nose of the beholder? Aesthetic perception in olfaction as a decision-making process. *New Ideas in Psychology*, *47*, 157–165. https://doi.org/10.1016/j.newideapsych.2017.03.013

Bekker, M., Nandorfy, D. E., Kulcsar, A., Faucon, A., Bindon, K., & Smith, P. (2020). Comparison of remediation strategies for decreasing 'reductive' characters in Shiraz wines. *Australian Journal of Grape and Wine Research*, *27*(1), 52–65. https://doi.org/10.1111/ajgw.12459

Bodington, J., & Malfeito-Ferreira, M. (2019). Should ties be broken in commercial wine competitions? When yes, what method is practical and defensible? *Journal of Wine Economics*, *14*, 298-308. https://doi.org/10.1017/jwe.2019.35

Bousquet, J. (2023). Marketing challenges and trends influencing wine producers and consumers. *Journal of Business and Management Studies*, *5*, 155–160. https://doi.org/10.32996/jbms.2023.5.3.16

Brazão, J., Sun, B., Caldeira, I., Baeta, F., Amaral, J., & Eiras-Dias, J. (2023). Wines' characterisation of eight minority Portuguese grapevine varieties (in Portuguese). *Ciência e Técnica Vitivinícola*, *38*, 21-34. https://doi.org/10.1051/ctv/ctv20233801021

Bruwer, J., & Buller, C. (2013). Product involvement, brand loyalty, and country-of-origin brand preferences of Japanese wine consumers. *Journal of Wine Research*, *24*, 38–58. https://doi.org/10.1080/09571264.2012.717221

Coste, A., Sousa, P., & Malfeito-Ferreira, M. (2018). Wine tasting based on emotional responses: An expedite approach to distinguish between warm and cool climate dry red wine styles. *Food Research International*, *106*, 11-21. https://doi.org/10.1016/j.foodres.2017.12.039

Danner, L., Crump, A. M., Croker, A., Gambetta, J. M., Johnson, T. E., & Bastian, S. E. (2017). Comparison of Rate-All-That-Apply and Descriptive Analysis for the Sensory Profiling of Wine. *American Journal of Enology and Viticulture*, *69*(1), 12–21. https://doi.org/10.5344/ajev.2017.17052

Esteves, M., Sequeira, M., & Malfeito-Ferreira, M. (2024). Definition of the sensory and aesthetic spaces of dry white wines with aging ability by experienced tasters. *Beverages*, *10*(2), 44. https://doi.org/10.3390/beverages10020044

Findlay, C. (2023). A perspective on the evolution of descriptive methods. In J. Delarue & J. B. Lawlor (Eds.), *Rapid Sensory Profiling Techniques* (pp. 131–138). Elsevier eBooks. https://doi.org/10.1016/b978-0-12-821936-2.00018-2

Francis, I. L., & Williamson, P. O. (2015). Application of consumer sensory science in wine research. *Australian Journal of Grape and Wine Research*, *21*, 554–567. https://doi.org/10.1111/ajgw.12169

Franco-Luesma, E., Honoré-Chedozeau, C., Ballester, J., & Valentin, D. (2019). Oxidation in wine: Does expertise influence the perception? *LWT*, *116*, 108511. https://doi.org/10.1016/j.lwt.2019.108511

Franco-Luesma, E., Sáenz-Navajas, M., Valentin, D., Ballester, J., Rodrigues, H., & Ferreira, V. (2016). Study of the effect of H_2S, MeSH and DMS on the sensory profile of wine model solutions by Rate-All-That-Apply (RATA). *Food Research International*, *87*, 152–160. https://doi.org/10.1016/j.foodres.2016.07.004

García-Muñoz, S., Asproudi, A., Cabello, F., & Borsa, D. (2011). Aromatic characterization and enological potential of 21 minor varieties (*Vitis vinifera* L.). *European Food Research and Technology*, *233*, 473. https://doi.org/10.1007/s00217-011-1538-1

Hopfer, H., & Heymann, H. (2014). Judging wine quality: Do we need experts, consumers or trained panelists? *Food Quality and Preference*, *32*, Part C, 221-233. https://doi.org/10.1016/j.foodqual.2013.10.004

Johnson, T. E., & Bastian, S. E. (2015). A fine wine instrument – an alternative for segmenting the Australian wine market. *International Journal of Wine Business Research*, *27*(3), 182–202. https://doi.org/10.1108/IJWBR-04-2014-0020

Jones, G. V. (2012). Climate, grapes, and wine: structure and suitability in a changing climate. *Acta Horticulturae*, *931*, 19-28. https://doi.org/10.17660/ActaHortic.2012.931.1

Long, J., Mezei, L. V., Souza-Gonzaga, L., Johnson, T. E., Corsi, A., & Bastian, S. E. P. (2023). Australian red wines made from non-traditional, emerging red grape varieties: distinguishing sensory profiles and consumer perceptions. *OENO One*, *57*(4). https://doi.org/10.20870/oeno-one.2023.57.4.7323

Loureiro, V., Brasil, R., & Malfeito-Ferreira, M. (2016). A new wine tasting approach based on emotional responses to rapidly recognize classic European wine styles. *Beverages*, *2*(1), 6. https://doi.org/10.3390/beverages2010006

Lytra, G., Tempere, S., Zhang, S., Marchand, S., de Revel, G., & Barbe, J.-C. (2014). Olfactory impact of dimethyl sulfide on red wine fruity esters aroma expression in model solution. *OENO One*, *48*, 75–85. https://doi.org/10.20870/oeno-one.2014.48.1.1660

Malfeito-Ferreira, M. (2018). Two decades of "horse sweat" taint and *brettanomyces* yeasts in wine: where do we stand now? *Beverages*, *4*, 32. https://doi.org/10.3390/beverages4020032

Malfeito-Ferreira, M. (2022). Wine minerality and funkiness: blending the two tales of the same story. *Fermentation*, *8*, 745. https://doi.org/10.3390/fermentation8120745

Malfeito-Ferreira, M., Diako, C., & Ross, C. (2019). Sensory and chemical characteristics of 'dry' wines awarded gold medals in an international wine competition. *Journal of Wine Research*, *30*, 204-219. https://doi.org/10.1080/09571264.2019.1652154

Marasà, G., Ferreira, J., Mota, M., & Malfeito-Ferreira, M. (2024). Understanding the mellowing effect of bottle aging on the sensory perceptions of varietal dry white wines. *Beverages*, *10*(3), 78. https://doi.org/10.3390/beverages10030078

Martínez-Pinilla, O., Guadalupe, Z., Ayestarán, B., Pérez-Magariño, S., & Ortega-Heras, M. (2013). Characterization of volatile compounds and olfactory profile of red minority varietal wines from La Rioja. *Journal of Science of Food and Agriculture*, *93*, 3720-3729. https://doi.org/10.1002/jsfa.6211

Meneses, M., Castro, M., & Hinrichsen, P. (2024). Genetic characterization of Criolla and European grapevines recently found in Chile: A Key Step for Their Rescue and Conservation. *Australian Journal of Grape and Wine Research*, *4817877*, 1-21. https://doi.org/10.1155/2024/4817877

Mezei, L. V., Johnson, T. E., Goodman, S., Collins, C., & Bastian, S. E. P. (2021). Meeting the demands of climate change: Australian consumer acceptance and sensory profiling of red wines produced from non-traditional red grape varieties. *OENO One*, *55*(2), 29–46. https://doi.org/10.20870/oeno-one.2021.55.2.4571

Miliordos, D. E., Merkouropoulos, G., Kogkou, C., Arseniou, S., Alatzas, A., Proxenia, N., Hatzopoulos, P., & Kotseridis, Y. (2021). Explore the rare–molecular identification and wine evaluation of two autochthonous Greek varieties: "Karnachalades" and "Bogialamades". *Plants*, *10*, 1556. https://doi.org/10.3390/plants10081556

Mora, M., Urdaneta, E., & Chaya, C. (2019). Effect of personality on the emotional response elicited by wines. *Food Quality and Preference*., *76*, 39–46. https://doi.org/10.1016/j.foodqual.2019.03.015

Nguyen, A. N., Johnson, T. E., Jeffery, D. W., Capone, D. L., Danner, L., & Bastian, S. E. (2020). Sensory and Chemical Drivers of Wine Consumers' Preference for a New Shiraz Wine Product Containing *Ganoderma lucidum* Extract as a Novel Ingredient. *Foods*, *9*, 224. https://doi.org/10.3390/foods9020224

Oyinseye, P., Suárez, A., Saldaña, E., Fernández-Zurbano, P., Valentin, D., & Sáenz-Navajas, M.-P. (2022). Multidimensional representation of wine drinking experience: Effects of the level of consumers' expertise and involvement. *Food Quality and Preference*, *98*, 104536. https://doi.org/10.1016/j.foodqual.2022.104536

Pickering, G. J., & Hayes, J. E. (2017). Influence of biological, experiential and psychological factors in wine preference segmentation. *Australian Journal of Grape and Wine Research*, *23*, 154–161. https://doi.org/10.1111/ajgw.12266

Pickering, G. J., Jain, A. K., & Bezawada, R. (2014). Segmentation and drivers of wine liking and consumption in US wine consumers. *International. Journal of Wine Research*, *6*, 9–19. https://doi.org/10.2147/IJWR.S70958

Piras, S., Brazão, J., Ricardo da Silva, J. M., Anjos, O., & Caldeira, I. (2020). Volatile and sensory characterization of white wines from three minority Portuguese grapevine varieties. *Ciência e Técnica Vitivinícola*, *35*, 49-62. https://doi.org/10.1051/ctv/20203501049

Pomarici, E. (2016). Recent trends in the international wine market and arising research questions. *Wine Economics and Policy*, *5*(1), 1–3. https://doi.org/10.1016/j.wep.2016.06.001

Rodrigues, H., Ballester, J., Sáenz-Navajas, M. P., & Valentin, D. (2015). Structural approach of social representation: Application to the concept of wine minerality in experts and consumers. *Food Quality and Preference*, *46*, 166-172. https://doi.org/10.1016/j.foodqual.2015.07.019

Rodrigues, H., & Parr, W. V. (2019). Contribution of cross-cultural studies to understanding wine appreciation: A review. *Food Research International*, *115*, 251–258. https://doi.org/10.1016/j.foodres.2018.09.008

Romano, M., Chandra, M., Harutunyan, M., Savian, T., Villegas, C., Minim, V., & Malfeito-Ferreira, M. (2020). Off-flavours and unpleasantness are cues for the recognition and valorization of organic wines by experienced tasters. *Foods*, *9*(1), 105. https://doi.org/10.3390/foods9010105

Sackris, D. C. (2018). What Jancis Robinson Didn't Know May Have Helped Her. *Erkenntnis*, *84*(4), 805–822. https://doi.org/10.1007/s10670-018-9981-z

Sáenz-Navajas, M. P., Avizcuri, J. M., Ballester, J., Fernández-Zurbano, P., Ferreira, V., Peyron, D., & Valentin, D. (2015). Sensory-active compounds influencing wine experts' and consumers' perception of red wine intrinsic quality. *LWT – Food Science and Technology*, *60*, 400-411. https://doi.org/10.1016/j.lwt.2014.09.026

Sánchez-Palomo, E., Cañas, P. M. I., Delgado, J. A., & Viñas, M. A. G. (2018). Sensory characterization of wines obtained by blending Cencibel grapes and minority grape varieties cultivated in La Mancha region. *Journal of Food Quality*, *2832095*, 1–8. https://doi.org/10.1155/2018/2832095

Schulze, P., Bestgen, A. K., Lech, R. K., Kuchinke, L., & Suchan, B. (2017). Preprocessing of emotional visual information in the human piriform cortex. *Scientific Reports*, *7*, 9191. https://doi.org/10.1038/s41598-017-09295-x

Sena-Esteves, M. M., Mota, M., & Malfeito-Ferreira, M. (2018). Patterns of sweetness preference in red wine according to consumer characterisation. *Food Research International*, *106*, 38–44. https://doi.org/10.1016/j.foodres.2017.12.043

Sousa, B., Araújo, S. de S., Sales, H., Pontes, R., & Nunes, J. (2024). Douro vineyards: A perspective for the valorisation and conservation of grapevine genetic resources. *Agronomy*, *14*, 245. https://doi.org/10.3390/agronomy14020245

Souza-Coutinho, M., Brasil, R., Souza, C., Sousa, P., & Malfeito-Ferreira, M. (2020). Consumers associate high-quality (fine) wines with complexity, persistence, and unpleasant emotional responses. *Foods*, *9*, 452. https://doi.org/10.3390/foods9040452

Valentin, D., Chollet, S., Lelièvre, M., & Abdi, H. (2012). Quick and dirty but still pretty good: a review of new descriptive methods in food science. *International Journal of Food Science & Technology*, *47*, 1563-1578. https://doi.org/10.1111/j.1365-2621.2012.03022.x

Valentin, D., Chollet, S., Nestrud, M., & Abdi, H. (2018). Projective mapping & sorting tasks. In S. E. Kemp, J. Hort, & T. Hollowood (Eds.), *Descriptive Analysis in Sensory Evaluation* (chapter 15, pp. 535-559). John Wiley & Sons Ltd. https://doi.org/10.1002/9781118991657.ch15

Valentin, D., Parr, W. V., Peyron, D., Grose, C., & Ballester, J. (2015). Colour as a driver of Pinot noir wine quality judgments: An investigation involving French and New Zealand wine professionals. *Food Quality and Preference*, *48*, 251–261. https://doi.org/10.1016/j.foodqual.2015.10.003

van Leeuwen, C., & Destrac-Irvine, A. (2017). Modified grape composition under climate change conditions requires adaptations in the vineyard. *OENO One*, *51*(2), 147–154. https://doi.org/10.20870/oeno-one.2017.51.2.1647

Varela, P., & Ares, G. (2012). Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization. *Food Research International*, *48*, 893–908. https://doi.org/10.1016/j.foodres.2012.06.037

Vecchio, R., Rinaldi, A., & Moio, L. (2019). Does the denomination taste better than the wine? *British Food Journal*, *121*, 3293–3306. https://doi.org/10.1108/BFJ-04-2019-0294

Vercesi, A., Gatti, M., Garavani, A., Pelusi, F., & Poni, S. (2024). Autochthonous red varieties in the Oltrepò Pavese wine district: an effective tool for adaptation to climate change. *Horticulturae*, *10*, 658. https://doi.org/10.3390/horticulturae10060658

Yang, J., & Lee, J. (2020). Current research related to wine sensory perception since 2010. *Beverages*, *6*, 47. https://doi.org/10.3390/beverages6030047

Yang, J., & Lee, J. (2021). Consumer perception of red wine by the degree of familiarity using consumer-based methodology. *Foods*, *10*, 749. https://doi.org/10.3390/foods10040749

Yeshurun, Y., & Sobel, N. (2010). An odor is not worth a thousand words: From multidimensional odors to unidimensional odor objects. *Annual Review in Psychology*, *61*, 219–241. https://doi.org/10.1146/annurev.psych.60.110707.163639