SENSORY CHARACTERISATION OF AGED WHITE WINE BY EXPERIENCED TASTERS

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« It takes the impact and the friendship - this is the key word - with someone to give us a look more true and complete for the reality and for ourselves »

L. Giussani

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Abstract

The present work aimed at the sensory analysis of aged dry white wines to understand which factors drive their quality evaluation by experienced tasters. Nine critics, seven oenologists and fourteen oenology students, aged between 22 and 72 years old, composed the tasting panel. The wines included 16 old white wines and two young white wines, one rosé and one red, used as distractors. Individuals were asked to freely describe the wines, evaluate several synthetic descriptors and characterise the sensory profile through a CATA methodology. In addition, participants reported their liking and predicted wine age.

In the free description, the three test panels showed a homogeneous characterisation of the wines consistent with their age and colour. According to the taster group, the quality evaluations were differently correlated with synthetic wine parameters. For critics overall quality scores were driven by wine power (r=0.87), persistence (r=0.90) and complexity (r=0.91). Oenologists influenced by the number of flavours (r=0.72), balance (r=0.87), persistence (r=0.88) and complexity (r=0.83). The quality assessment for students could only be related to wine balance (r=0.79). For critics and oenologists liking was closely related with the quality evaluation (r=0.98 and r=0.97, respectively), while students showed a lower correlation (r=0.78).

The influence of colour browning on quality evaluation was more evident in critics, followed by oenologists and students. Further, CATA analysis demonstrated that old white wines were globally described as having a "ripe/matured/evolved" aroma and an "austere" mouthfeel elicited by acidity, salinity, dryness and persistence. This consistent old white wine profile appeared to influence quality evaluation. Conversely, the distractor wines tended to be less scored by critics and oenologists given their young sensory profile and lower browning colour. Accordingly, these two cohorts devalued a white wine with ten years old characterised by low absorbance (0,111 at 420nm) and "fresh" flavours.

The age prediction showed that most tasters failed to guess the age wines with more than about 15 years old that can be understood as a sign of their high ageing potential.

In conclusion, experienced tasters consistently described and recognised the sensory profile of old white wines. However, the inference of overall quality from synthetic descriptors was relatively different, with critics being more sensitive to wine power while oenologists and students were more influenced by wine balance.

Keywords: Aged white wine, quality, aroma, flavour, colour.

Resumo

O presente trabalho teve como objetivo a análise sensorial de vinhos brancos secos envelhecidos para compreender quais os fatores que orientam a sua avaliação da qualidade por provadores experientes. Nove críticos, sete enólogos e catorze estudantes de enologia, com idades compreendidas entre os 22 e os 72 anos, compuseram o júri. Os vinhos incluíram 16 vinhos brancos velhos, dois vinhos brancos jovens, um rosé e um tinto, usados como distratores. Os indivíduos foram convidados a descrever livremente os vinhos, avaliar vários descritores sintéticos e caracterizar o perfil sensorial através de uma metodologia CATA. Além disso, os participantes relataram seu gosto e idade prevista do vinho.

Na descrição livre, os três painéis de ensaio mostraram uma caracterização homogênea dos vinhos compatível com sua idade e cor. De acordo com o grupo de provadores, as avaliações de qualidade foram diferentemente correlacionadas com os parâmetros sintéticos do vinho. Para os críticos, as pontuações gerais de qualidade foram determinadas pelo poder do vinho (r = 0,87), persistência (r = 0,90) e complexidade (r = 0,91). Os enólogos influenciam o número de sabores (r = 0,72), equilíbrio (r = 0,87), persistência (r = 0,88) e complexidade (r = 0,83). A avaliação da qualidade para os alunos só poderia ser relacionada ao equilíbrio do vinho (r = 0,79). Para críticos e enólogos, o gosto está intimamente relacionado com a avaliação da qualidade (r = 0,98 e = 0,97, respectivamente), enquanto os alunos apresentam menor correlação (r = 0,78).

A influência do escurecimento da cor na avaliação da qualidade foi mais evidente nos críticos, seguidos por enólogos e estudantes. Além disso, a análise CATA demonstrou que os vinhos brancos velhos foram globalmente descritos como tendo um aroma "maduro / maturado / evoluído" e uma sensação na boca "austera" induzida pela acidez, salinidade, secura e persistência. Este perfil consistente de vinho branco antigo pareceu influenciar a avaliação da qualidade. Por outro lado, os vinhos distratores tendem a ser menos pontuados por críticos e enólogos, devido ao seu perfil sensorial jovem e menor cor de escurecimento. Nesse sentido, os mesmos desvalorizaram um vinho branco com dez anos caracterizado por baixa absorbância (0,111 a 420nm) e sabores "frescos".

A previsão da idade mostrou que a maioria dos provadores não conseguiu adivinhar a idade dos vinhos com mais de 15 anos, o que pode ser entendido como um sinal do seu elevado potencial de envelhecimento.

Em conclusão, provadores experientes descreveram e reconheceram de forma consistente o perfil sensorial dos vinhos brancos velhos. No entanto, a inferência da qualidade geral dos descritores sintéticos foi relativamente diferente, com os críticos sendo mais sensíveis ao poder do vinho, enquanto os enólogos e estudantes foram mais influenciados pelo equilíbrio do vinho.

Palavras-chave: Vinho branco velho, qualidade, aroma, flavour, cor.

Resumo alargado

O presente trabalho teve como objetivo a análise sensorial de vinhos brancos envelhecidos através de provadores experientes para principalmente compreender como a cor e o psicológico podem influenciar na qualidade e na avaliação do vinho.

Em particular, os objetivos do estudo centram-se:

- Na diferença entre os painéis e dentro dos painéis, percebendo se existe homogeneidade ou não;
- Na distinção do gosto pessoal com a qualidade dos vinhos;
- Análise da qualidade perante a cor dos vinhos, de maneira a entender se os provadores são influenciados;
- Entender quais os aromas que caracterizam os vinhos mais e menos classificados
- E, por último, entender se os provadores entendem a idade dos vinhos, consoante o aspeto, aroma e boca que apresentavam.

O painel de provadores foi composto por nove críticos, sete enólogos e quatorze alunos de enologia, com idades compreendidas entre os 22 e os 72 anos. A prova era composta por 16 vinhos brancos velhos, 2 vinhos brancos jovens, um rosé e um tinto.

Na descrição livre, os três painéis de prova não se destacaram em relação uns aos outros. O discurso foi homogéneo e com noção de conhecimento de vinhos.

Os painéis foram analisados com testes estatísticos de Kruskal-Wallis e Dwass-Steel-Critchlow-Fligner pairwise comparison de maneira a encontrar diferenças significativas (α = 0.05).

Compreendeu-se que os estudantes são os que apresentam mais homogeneidade dentro do painel, seguindo-se os enólogos e depois os críticos. Esta análise foi feita inicialmente apenas com recurso a médias mas, posteriormente, foi realizada uma análise estatística que o comprovou.

Na análise de diferenças entre os painéis, os estudantes são os que diferem mais com o painel dos críticos e enólogos, demonstrando que avaliam de uma maneira diferente.

A complexidade é dos fatores que mais pode influenciar na avaliação de um vinho. Como tal, realizou-se correlações entre a complexidade e os restantes descritores sintéticos. Os críticos definem a complexidade através do número de aromas, comprimento, potência, gosto e qualidade do vinho em boca. Os enólogos focam-se mais no comprimento, gosto e qualidade do vinho em boca. Enquanto que os estudantes não têm nenhuma correlação forte com nenhum dos descritores.

Para painéis de provadores experientes, é importante diferenciar a qualidade do gosto pessoal. No entanto, a correlação entre estes dois descritores sintéticos é bastante elevada. Os estudantes foram o painel que mais se destacou nesta diferença, com 0.778 de correlação.

O acastanhamento influencia a perceção de qualidade. Com análise de correlações e gráficos de linearidade, entendeu-se que vinhos demasiado castanhos e os vinhos jovens têm uma influência mais negativa na perceção da qualidade. Enquanto que os vinhos mais equilibrados em relação à cor têm notas mais elevadas.

O painel que apresentou maior correlação entre a cor e a qualidade foi dos críticos, ou seja, baseiam a sua avaliação na cor dos vinhos.

Na análise de aroma e sensações de boca, os vinhos foram descritos globalmente como tendo um perfil aromático “maduro/ amadurecido/ evoluído” e “austeros” na boca, com acidez, salinidade, secos e persistentes, consistentes com as características sensoriais de brancos com idade.

Dois vinhos postos a prova destacaram-se entre os restantes. O vinho 650 foi avaliado por dois painéis, enólogos e estudantes, como sendo dos melhores vinhos. Enquanto que o vinho 923 foi avaliado pelos três painéis como sendo dos piores vinhos.

O vinho 923, apesar de ter 10 anos, pela maneira como é descrito no CATA, é considerado um vinho jovem, com características mais cítricas, com fruta fresca e floral. Ou seja, a qualidade do vinho foi posta em causa unicamente pelo facto de este ter sidoconfundido por um distrator.

Através de gráficos aranha é possível verificar que os vinhos mais e menos classificados por cada painel, apresentam uma caracterização bastante semelhante. Esta caracterização demonstra que o significado de qualidade para os provadores é relativamente parecido, o que difere são os vinhos.

A idade foi prevista pelos provadores. Na maior parte dos vinhos os provadores deram uma inferior ao que seria suposto. Deve-se ao facto de os vinhos estarem bem preservados e apresentarem características bastante jovens.

Nas correlações da idade real com a idade prevista, os estudantes foram os que se aproximaram mais, com r=0.6806.

Os provadores ao saberem que a prova era dirigida a vinhos brancos velhos, com alguns distratores, levou a que os avaliassem dessa mesma maneira. Os vinhos mais jovens acabaram por ser mais prejudicados. No entanto, os vinhos brancos velhos com características mais jovens devido ao seu elevado poder de conservação, acabaram por ser igualmente prejudicados.

Os estudantes foram os que mais surpreenderam pela positiva porque estava-se à espera que fossem influenciados pela cor e pelo facto de nunca terem tido experiência com vinhos brancos tão velhos.

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Glossary

IVV - Institute of Vine and Wine

TDN - 1,1,6-trimethyl-1,2-dihydronaphthalene

CATA – Check-All-That-Apply

CEV – Centro de Estudos Vitivinícolas

ISA – Instituto Superior de Agronomia

ISO - International Organization for Standardisation

1. Introduction

According to the Institute of Vine and Wine, wine is the "product obtained by the vinification/alcoholic fermentation, total or partial of fresh grapes, from various types of grape varieties (*Vitis Vinifera*), whose berries are crushed, pressed or processed by other technological processes permitted by law" (IVV, 2021). Its composition is mostly water, ethyl alcohol, sugar, acids and salts. Its aroma molecules can elicit fruity, fragrant and several other descriptors.

In wine, the term ageing is seen as a positive or negative. The meaning of ageing presupposes a wine's evolution process that alters its chemical and aromatic composition (Linsenmeier *et al*., 2010). When ageing negatively connotes a wine, it has a defect. However, when it has a positive development in its ageing (improves the quality of the wine), it is said to have 'matured'. The aroma of aged wines is associated with developing molecules that enable new aromatic compounds and the degradation of fruity and flowery aromas (Linsenmeier *et al*., 2010).

Several studies focused on the psychological part, with or without taster experience. For example, Spence (2020) described how environment, day, mood and many other factors could influence tasting wine. It is also known that the visual aspect has a substantial weight in aromas and flavour. Wine consumers, without any experience in the wine sector, are greatly influenced by the visual aspect, and when tasting, for example, older white wines with more evolved colour, they end up focusing on browning, thinking that wine itself may be spoiled (Spence, 2020).

The question addressed in this work was related to experienced panels' behaviour regarding old white wines. Thus, the present work was aimed at the sensory analysis of aged white wines through experienced tasters. A tasting was carried out with three experienced panels (critics, oenologists and oenology students) to verify whether the degree of experience can also influence how wines are evaluated.

In particular, our research was aimed at answering the following questions:

a) Does the browning of wines have any relationship with the overall evaluation of wines?

b) Do the three panels have different global quality ratings? Do they have the same ratings on some wines?

c) Are there differences in the analysis of the quality of a wine?

d) Do they know how to separate quality judgements from liking?

2. The wine flavour perception

2.1. First steps within the brain

There is a sequence of essential steps concerning what the brain begins to assimilate when tasting wines. Shepherd (2015) analysed and summarised all the essential steps listed in table 2.1. To begin with, there is the cephalic phase, entirely linked to the taster's head, where vision and imagination are the main points, thus giving anticipation to the tasting and an inspection that influences the expected taste. Then smell is the sense that will accompany the initial wine evaluation, thus exposing the senses. Subsequently, the following steps will be followed: ingestion, initial analysis, formation of the perception of the wine's image, the appearance of the object aroma, swallowing, and its powder. Later, we will talk about the orthonasal and retronasal associated with these stages.

Table 2.1. Brain and biomechanics stages in wine tasting (Shepherd, 2015).

Brain systems	**Biomechanics**
Cephalic phase (vision)	
Preliminary analysis (vision)	Orthonasal smell
Ingestion	Tongue, exhalation, retronasal smell
Initial analysis	Tongue, exhalation, retronasal smell
Forming the wine perceptual image	Tongue, exhalation, retronasal smell
Forming the wine flavour object	Tongue, exhalation, retronasal smell
Swallowing	Automatic motor action
Post-swallowing	Exhalation, retronasal smell

2.2. Visual sensations

Colour is the first perception of a taster, it influences the aroma, taste, and flavour (Spence, 2020), and it is one of the most critical factors in visual sensations. There are two essential factors to evaluate the colour of the wine: hue and intensity. Both features can give a runway about the process of vinification like grape maturity, duration of skin contact, fermentation, and wine age, although the assessment is different. The hue is responsible for the shade or tint, where intensity is accountable for the expressiveness of the colour and brightness (Jackson, 2009). To analyse the gradation of the wine's depths, the glass is tilted against a white

background, thus giving a range of tones and density attributes. Often, the age of the wine is therefore analysed in the tasting (Jackson, 2009).

2.2.1. Emotional colour

Emotions are present in our daily lives, and they tend to justify all the actions we take, even in a wine tasting where we must be as less emotional as possible. Although there are expectations associated with the colour or odour of wines in a tasting, these expectations are often associated with a memory (Malfeito-Ferreira, 2021). When our mind has already established a perception of what wine will be like by its colour/odour, all subsequent judgments will already reference what was initially thought. Parr (2019) states that forming a prototype mental representation can often evaluate the test experience.

As already mentioned, vision is the predominant sense in the tasting, strongly influencing the association of flavours to specific colours, creating expectations. Ballester *et al*. (2009) revealed an interesting relationship between the description of the wine and its colour. Descriptors associated with yellow/light objects (honey, lemon, hazelnut, butter) refer to white wines, while red wines tend to be associated with red/dark things with descriptors such as blackcurrant, cherry, violet.

2.2.2. Mechanisms of colour generation of white wines

The colour change in white wines starts right at the winemaking stage, due to enzymatic reactions, through the interception of hydroxycinnamic esters, in the active oxidase of polyphenol. The brownish colour progressively appears due to non-enzymatic oxidation. White wines have several compounds in their constitution that participate in specific reactions. In the case of oxidation reactions, hydroxycinnamates and flavonols play an essential role. Kanavouras *et al*. (2020) also state that the formation of brownish-yellow compounds originates from the oxidation of compounds such as hydroxycinnamic acids due to the polymerisation of ortho-quinones.

Del Caro *et al*. (2014) also state that brownish-yellow macromolecules result from the oxidation and polymerisation of phenols and quinones. SO2 and ascorbic acid, when added to wine, also play a significant role in the oxidation of polyphenols, reducing ortho-quinones. Dry inactive yeasts in wine release polysaccharides that positively affect wine colour, this type of

protection are due to the interaction of polysaccharides with phenolic compounds that oxidise (Kanavouras *et al*., 2020).

Other factors influence wine colours, such as pH and temperature. When the pH and temperature increase, the darkening of the wine also increases. This is because the concentration of ions concerning the phenol increases the oxidation rates. However, temperature, oxygen, pH and light during the storage of wine are also involved in the oxidation of white wines (Kanavouras *et al*., 2020).

However, several problems can occur in a wine that presents with little colour: extracting few phenolic compounds and reduced varietal flavour (by removing the juice from the films without maceration), grape varieties with the bit of excess colour of sulfur dioxide from the wine. As a result, most aged white wines darken over time. However, the opposite can happen due to the winemaking technique, resulting from the precipitation of melanoid pigments (Jackson, 2009).

2.3. Orthonasal odour

The smell is one of the most developed systems through structures, connections, and functions linked to the nervous system (Sarnat *et al*., 2017). Parr (2019) stated that highly emotional and distinct olfactory experiences are not forgotten or do not change. On the contrary, they are remembered very well and, when one is not aware, they affect through the presence of the odour. This type of event can influence how it proves, having the inhibition to articulate or identify the influences.

To expose the volatile and aromatic senses of the wine, the tasters smell the wine before shaking it, assessing the development of the wine throughout the tasting, activating the orthonasal route (Jackson, 2009). Vision comes into play with smell, and aroma (bouquet) is the first encounter between the two. The initial idea of the wine being tasted begins to structure even better (Shepherd, 2015).

Then, there is agitation. One of the essential phases of the olfactory evaluation is the agitation of the wine, where it is possible to obtain the release of aromatic compounds through the air/wine interface, restoring the superficial layer of aromas (Jackson, 2009). The aroma (bouquet) is the first encounter while sight and smell come into play (Shepherd, 2015).

The perception of the quality of an odour is only possible through olfactory receptors located in the olfactory mucosa. After inhalation of the odour molecules, a combinatorial coding is

obtained in which the odorant in question interacts with the active olfactory receptors. The image of smell is formed through electrical signals to the olfactory bulb; subsequently, the different signals are sent to areas of the brain that adjust cognition, emotion, memory and behaviour. Although both activate the same receptors, the orthonasal pathway is quite different from the retronasal pathway (Malfeito-Ferreira, 2021).

Much of the sensory information stored comes from smell. Our brain reverts to memories of stored scents and aromas during the most tasting time. Odour memories are made through complex perceptions to detect different sensations (Jackson, 2009).

There are often specific difficulties in verbalising one's emotion when tasting wine, which can even be compared to the test in expressing feelings and emotions in our day-to-day. However, training in sensory analysis and a knowledge base makes it possible to improve this expression (Malfeito-Ferreira, 2021).

2.4. Flavour

Malfeito-Ferreira (2021), reviewing several authors, used the definition of flavour as a multimodal neural construction, like a new sense resulting from other senses. The brain is an essential source for the very definition of taste, and it interprets the molecules providing the proper meaning. The entire interpretation is derived from gustatory, oral somatosensory and retronasal olfactory signals defining their perception when tasting drinks (or foods) (Cherubino *et al*., 2018). With this, the individual's response to a flavouring such as odour or odorant results from the sensory property of the flavour itself (Malfeito-Ferreira, 2021).

Many factors are analysed in a tasting, and the most striking ones are synthetic like quality, intensity and temporal and spatial patterns. Quality is the mouthfeel that defines acidity, sweetness, bitterness, saltiness, and astringency. However, power is characterised by the strength associated with the wine. These two factors are strongly associated with the time pattern, being evaluated for its persistence, while the spatial pattern is defined by localised sensations in the tongue, taste, throat, and cheeks, being more related to quality (Jackson, 2009).

Figure 2.1 shows how the time-intensity curve and spatial pattern are essential in evaluating qualitative attributes (Jackson, 2009).

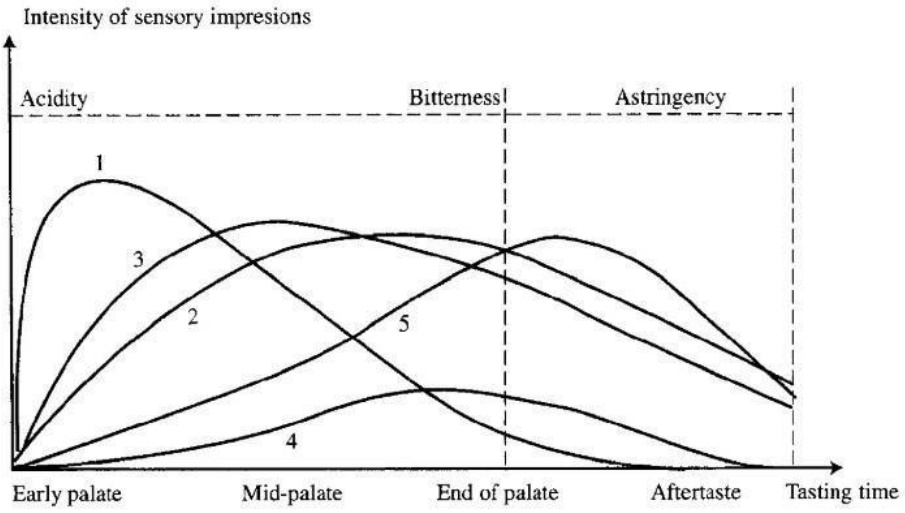

Figure 2.1. Influence of flavonoid polymerisation on sensory attributes: 1, catechins and simple procyanidins; 2, oligomeric procyanidins; 3, procyanidin polymers; 4, anthocyanins; 5, stalk tannins (Jackson, 2009).

When tasting a wine, stirring the wine in the mouth allows the wine to contact all regions of the oral cavity (Jackson, 2009). Therefore, the initial analysis must have the touch in the mouth so that there is maximum exposure of the senses, such as touch and mouth sensation. As the taste of wine is an active perception like food, it forms its sensory image, being conscious and illusive through the connection of the olfactory part to the link of the mouth (Shepherd, 2015).

Sweetness and acidity are the first recognised taste sensations because they are perceived in the first regions of the tongue. In terms of duration, the acidity stands out more than the sweet. As shown in Figure 2.1, bitterness is detected later, and its perception may coincide with the decline in the perception of sweetness, which can be emphasised more. However, for the bitterness to reach its peak, it can take more than 15 seconds; this is one of the reasons why wine should be kept in the mouth longer (Jackson, 2009).

Some images are formed due to external sensory stimuli; as the sensory pathways process continues, these images are transformed into objects in the brain's language. Shepherd (2015) states that there are central behavioural systems involved in the recognition process in a test; for example, recognition is done through memory systems, and dynamic systems deal with feelings; this allows the language system to create categories and formulate communication.

The retronasal smell originates much of the flavour that each person feels; that is, when exhaling when tasting the wine, the volatiles is transported from the mouth to the nasal cavity (Malfeito-Ferreira, 2021).

The wine must be aspirated in the mouth to make the most of the retronasal experience, flooding the olfactory receptors with volatiles from the wine into the mouth (Shepherd, 2015). The procedure is simple, but it takes some practice. First, the jaws are tightened. Consequently, the cheek muscles contract and the air are slowly sucked in by the wine; this allows the transfer of aromas in the mouth and nasal cavity through the back of the throat (Jackson, 2009).

The sense of smell does not detect some aromas as they are not present at values above the detection thresholds, and it is possible to see them via the retronasal route. Other factors intrinsic to the taster enhance certain perceptions, such as the increase in mouth temperature, which modifies the volatilisation and action of enzymes present in saliva and mucous membranes. The nose is compressed when the wine is tasted in the mouth to understand the importance of retronasal odour, limiting aroma access to the nasal passages (Jackson, 2009).

2.5. The wine flavour active molecules

The aroma of wine is composed of several complex interactions of specific compounds. Several studies investigate the sensory interactions of chemical compounds in different concentrations, and the conclusions are different due to several extrinsic factors that induce changes in the compounds (Coetzee *et al*., 2015).

Several sensory interactions between groups of aroma compounds, such as esters, thiols, terpenes, alcohols, allow obtaining a relatively large range of aroma compounds (Coetzee *et al*., 2015).

The formation or degradation of aromatic compounds causes the loss or creation of fruity and floral aromas in younger wines. As a result, the aroma of the wine is intense and complex (Linsenmeier *et al*., 2010).

For example, it is enough that the wort does not have enough oxygen to create a reducing environment that allows the formation of different compounds in wine, compared to a wort that has had contact with the right amount of oxygen. Another example, during oxidation, in white wine, compounds such as sotolon, methional, phenylacetaldehyde can be formed, altering the

aromatic composition of the wine. The compounds mentioned above are responsible for developing the oxidation character of white wines (Coetzee *et al*., 2015).

As previously described, each compound has its importance and one of the essential factors that condition its perception is the odour perception threshold, which consists of the lowest concentration/threshold that the sense of smell can detect (Gómez-Míguez *et al*., 2007).

In several articles, it is possible to find a value described as IVV (Institute of Vine and Wine) that explains the odour activity value in the concentration/threshold ratio, allowing to estimate the contribution of a specific compound to the wine's aroma. However, it should be noted that not all volatile compounds that make up a wine are found at concentrations below or close to their sensory limits (Gómez-Míguez *et al*., 2007).

2.5.1. Off-flavours

Some phenomena play essential roles throughout the winemaking process, such as oxidation/reduction, better known as redox. These processes cause significant changes in the composition of the wine, changes that influence the final result of the wine, such as its colour and aroma. Ferreira *et al*. (2003) and other articles explain that, through technological parameters, oxidative degradation is associated with low pH, very high storage temperatures and high oxygen content.

In wine ageing, oxidation is irreplaceable, but it has to be controlled. When oxidation is not adequately controlled, it defects the wine, especially the aroma. This is explained by the fact that oxidation is related to the rapid loss of the sensory characteristics of the wine and the formation of aldehydes, damaging the floral and fruity notes with the construction of new atypical aromas (Silva-Ferreira *et al*., 2003).

Sotolon (3-hydroxy-4,5-dimethyl-2[5H]-furanone) is a volatile compound known as an intensive odour, generally described as spicy/curry, fenugreek, old honey (Gabrielli *et al*., 2021), notes od cane sugar, coffee and nutty (Blank *et al*., 1996). This compound is usually indicated in oxidised aged wines like Porto, Vin Jauen, Vins Doux Naturels, Madeira, Sherry, botrytised and barrel-aged white wines. Each wine has a different threshold associated, as demonstrated in table 2.2 (Gabrielli *et al*., 2021).

Table 2.2. Sotolon aroma threshold associated with different wines by Gabrielli *et al*., 2021.

	Porto	**Vin Jauen**	**Vins Doux Naturels**	**Madeira**	**Sherry**	**Botrytised**	**Barrel-aged white wines**
Threshold (µg/L)	5-958	120-268	0-26	0-2000	0-500	5-20	0-140

Despite the differences in the thresholds, sotolon is considered a key odorant on some fortified wines. Instead, however, afford a dry white wine providing loss in character in flower, fruit, and freshness (Gabrielli *et al*., 2021).

In many studies, the authors demonstrate that methional and phenylacetaldehyde are responsible for the typical aroma of oxidative spoiled white wine. Both have a specific aromatic note (Bueno *et al*., 2010) honey-like, boiled-potato/vegetable, wet soil and straw. However, the threshold values are pretty different, to methional is 0,5 µg/L and to phenylacetaldehyde is 25 µg/L (Silva-Ferreira *et al*., 2007).

High temperatures and high oxygen concentration levels are responsible for the formation of α-dicarbonyl compounds (reactants in the Strecker reaction – Strecker aldehydes) (Linsenmeier *et al*., 2010), leading to the appearance of methional and phenylacetaldehyde (Bueno *et al*., 2010). Compared with the parent amino acid, Strecker aldehydes contain one less carbon and, for example, methional from methionine and phenylacetaldehyde is from phenylalanine (Silva-Ferreira *et al*., 2007). Thus, these molecules can be used as chemical indicators in a wine (Bueno *et al*., 2010).

TDN, is the compound responsible for the typical aroma of Riesling wines, the aroma of kerosene and gasoline (Ross *et al*., 2014) and is a grape-derived C13 norisoprenoid (Sacks *et al*., 2012).

One of the factors that influence the appearance of TDN in the ageing of white wine is the lower pH, the increase in the age of the bottle, oxidation. TDN is mainly absent from grape berries and juices (Sacks *et al*., 2012), so it is formed through the hydrolysis of multiple glycosylated precursors with posterior rearrangement during winemaking (Linsenmeier *et al*., 2010); the same can continue during storage (Ross *et al*., 2014).

Ross *et al*. (2014) explain that in warmer regions and with a higher rate of sun exposure in the vineyard, higher concentrations of TDN are associated, especially before maturing, but quantitative data to explain this observation are not available, and quantitative measurements of TDN in wines other than Riesling are almost absent from the literature (Sacks *et al*., 2012).

Several varieties have TDN values. However, the highest values are found in the Riesling variety (Ross *et al*., 2014).

Sacks *et al*. (2012) indicate the limit values of detection for different grape varieties, with wines between one and three years old, and the Riesling variety, as explained above, presents significantly higher values, such as 6.4 ± 3.8 µg/L. The remaining grape varieties (Cabernet Franc, Chardonnay, Cabernet Sauvignon, Gewurztraminer, Merlot, Pinot Gris, Pinot noir and Sauvignon blanc), present values below 1.3 ± 0.8 µg/L, subsequently indicates that it has a sensory limit of 20 µg/L. Riesling wines aged ten years can present TDN concentrations up to 42 µg / L, with a sensory limit well above the detection limit (Sacks *et al*., 2012).

2.6. Sensory Analysis

Sensory analysis of wine was one of the first achievements of sensory analysis. One of the objectives of sensory analysis is to obtain wine evaluations in a less biased way, using objective and analytical perception protocols, mitigating the psychological and physiological factors that may affect the tasters' responses. Sensory analyses began to grow and were used as analysis tools to understand consumer preferences (Lesschaeve & Noble, 2010).

2.6.1. Free description

The free description method can be analysed in several ways. Each taster can be asked to describe the wine as they wish, without giving any instructions (Lawrence *et al*., 2013), or you can say precisely what you want by saying: "Describe the visual/olfactory/taste characteristics of the wine" (Mahieu *et al*., 2020). Data analysis can be performed through a software system in order to organise the speech and discover keywords to make a citation frequency table (Mahieu *et al*., 2021), or it can serve to verify the speech of each taster, realising if each panel has homogeneity in the way describes the wine.

2.6.2. The scale of wine evaluation

The personal preference scale can be used with several features. The complexity questionnaire as a wine rating scale is used to understand how tasters understand the complexity of a wine (Parr *et al*., 2020a). The complexity can be understood in different ways, such as assessing harmony, the ease or difficulty of finding aromas and mouthfeel, and the persistence of wine Wang *et al*. (2021). With this type of assessment, it is also possible to understand whether the taster understands or not what he is trying to prove.

2.6.3. CATA

CATA consists of a list of sensory attributes that tasters indicate depending on the presence or absence of the descriptor. This method is considered for rapid sensory profiling (Phetxumphou *et al*., 2020). A previously chosen list is presented for tasters of sensory descriptors (Rinaldi *et al*., 2021). Wines are considered complex products, and when we evaluate one, it becomes even more complex. For this reason, more and more studies are choosing to use CATA instead of intensity scales, as they are considered more difficult to assess (Nanou *et al*., 2020).

3. Materials and Methods

3.1. Wine Samples

Sixteen commercial aged white wines and four commercial red, rosé and white wines, used as distractors, from different wineries were used for this study. Table 3.1 shows the origin of each wine sample and its absorbance characteristics. All the aged white wines had between 5 and 47 years old, and the distractors had 47 (red), 15 (rosé), 3 (oak-aged white) and 1 (fruity young white) years old. The producers kindly supplied the wine samples. Before sensory analysis, the wines were opened and tasted to check occasional flaws by three experienced tasters of the laboratory staff.

Table 3.1. Wine samples included in the study, along with their absorbance.

Brand	Company	Region	Year	Code	Absorbance	
					420nm	520nm
Catarina	Bacalhôa	Península de Setúbal	2000	102	0,484	-
Casa de Santar	Sociedade Agrícola de Santar	Dão	2003	147	0,286	-
Dom Rafael	Herdade do Mouchão	Alentejo	2011	381	0,266	-
Alvarinho	Quinta do Soalheiro	Melgaço	2012	839	0,322	-
Fraga da Galhofa (Rosé)	Vinilourenço	Douro	2006	692	0,591	0,332
Branco Dão	CEV Nelas	Dão	1974	710	0,201	-
Cartuxa	Fundação Eugénio de Almeida	Alentejo	2010	774	0,221	-
Alvarinho	Palácio da Brejoeira	Monção	2016	748	0,151	-
Mau Feitio	Vinilourenço	Douro	2013	015	0,197	-
Fraga da Galhofa (Muscat of Alessandria)	Vinilourenço	Douro	2020	297	0,091	-
Pasmados	José Maria da Fonseca	Península de Setúbal	2008	583	0,695	-
Quinta Vale do Ruivo	José Madeira Afonso	Beira Interior	2011	923	0,111	-
Alvarinho	Palácio da Brejoeira	Monção	2012	256	0,181	-
Sericaia	Ares Alentejanos	Alentejo	2015	561	0,143	-
Periquita (Red)	José Maria da Fonseca	Península de Setúbal	1974	429	4,939	3,343
Vinhas Velhas	Luís Pato	Bairrada	1991	201	0,782	-
Quinta dos Termos DOC	Quinta dos Termos	Beira Interior	2003	338	0,284	-
Alvarinho	Quinta do Soalheiro	Melgaço	2011	650	0,379	-
Pedra Cancela	Lusovini	Dão	2012	477	0,172	-
Quinta do Monte d'Oiro	Quinta do Monte D'Oiro	Lisboa	2018	365	0,092	-

3.2. Tasting panels

The study used three different experienced tasting panels. The first panel consisted of nine wine trade critics (professionals and sommeliers) aged between 42 and 72 years old. The second panel consisted of seven oenologists and oenology scholars aged between 28 and 61 years old. Both participants had more than six years of professional experience in wine. The third panel consisted of fourteen oenology students from the Vitis Vinifera Master of Viticulture and Oenology Engineering held in ISA faculty, aged 22 and 40 years. The participants were not paid for their participation.

Three sensory analysis sessions were held at the Microbiology laboratory of the Instituto Superior de Agronomia, Ajuda, Lisbon. The professional first and second sensory analyses were performed on June 14, 2021 (photographs in Annex I) (one in the morning and one in the afternoon). The third and last sensory analysis was carried out only with students on July 9, 2021.

3.3. Wine Evaluation

The tasting was divided into two parts. Each part had the presence of 10 wines, combined with a brief rest break. The wine bottles were opened 30 minutes before and were used transparent glasses (ISO 3591:1977) covered by glass Petri dishes.

All samples were kept at a temperature of 19 ± 1ºC, and the room had windows open for ventilation. Panellists were presented with a test sheet divided into three parts. The first part consisted of a free description and the second part consisted of a score sheet for synthetic descriptors as described by Parr *et al*. (2020). The third part corresponded to the aroma and flavour description using a CATA methodology. The attributes chosen for the CATA assessment were selected from a previous online survey (Sequeira, 2021). After the CATA list, respondents were asked to rate the quality and liking by drawing a line on a 9 cm scale. Finally, the questionnaire ended with a question about the age of the wine, as shown in Annex II.

3.4. Data Analysis

For the analysis of free description, no statistical test was applied. Only the speech and words used with the complement of scientific articles were analysed.

The analysis of panels and wines from the taste scales focused on the differences between each one. Initially, an ANOVA was planned to test mean differences. However, as the sample size was minimal, the variables were not continuous and had a lack of homogeneity, it was necessary to use a non-parametric alternative.

As such, the Kruskal-Wallis test with Dwass-Steel-Critchlow-Fligner pairwise comparisons was performed, according to Cassi *et al*. (2021) and Wojtkowska *et al*. (2021). The analyses were performed with the free online statistical software Jamovi version 1.8. The α significance level was set as 0.05, with test *p*-values < 0.05 indicating significant differences.

For better understanding, correlation values between descriptors were used.

For statistical analysis of the CATA results, Chi-square (χ^2) tests were applied, but the data violated the test assumptions (i.e., no more than 20% of the expected counts were less than five and all the individual expected counts are one or greater). Furthermore, given the small sample, both χ^2 and alternatives tests had the lower statistical power to detect statistically significant differences. Therefore, radar charts were created to describe the differences of the panels more efficiently qualitatively.

Finally, a correlation between wine age and predicted age was analysed to investigate panels' ability to distinguish and assess the age of wines.

4. Results and discussion

4.1. Free description

The free descriptions were analysed in order to find reproducible and comparable answers. We thought about evaluating the free description to categorise the test panels to complete the test form. However, it was thought that critics would use more elaborate words, oenologists would use more technical words, and students would always use more prosaic words. However, after a detailed analysis of each panel, it was found that all tasting panels presented a very homogeneous discourse among themselves. Usually, panels composed of experienced people tend to have a much more comprehensive and assertive vocabulary to distinguish sensory attributes (Phetxumphou *et al*., 2020).

4.2. Wine quality scores

The different panels tasted 20 wines, and the respective quality evaluations are listed in table 4.1. When the statistical analysis was applied to the results, mean scores for all wines were not different, considering the three panels together or separately. The extensive range of scores assigned to each wine by the different tasters may explain this output. According to the results presented in table 4.1, the values with differences above one in the range are represented by bold. It appears that students are the only panel that did not overcome this difference. This observation indicates that the panel scores more homogeneously. As we will see later in table 4.7, the homogeneity of the panel may be evidenced by statistical analysis.

Table 4.1. Wines' average quality scores of white wine degrees of expertise. Bold numbers indicate a range above 1.

Wine	Overall	Critics		Oenologists		Students	
	Average	Average	Range	Average	Range	Average	Range
102	5.81	6.12	0.31	5.91	0.10	5.41	0.40
147	4.93	4.99	0.06	4.75	0.18	5.05	0.12
381	5.73	5.29	0.44	6.50	0.77	5.40	0.33
839	6.17	5.49	0.68	7.83	**1.13**	5.20	0.97
710	5.19	5.15	0.04	6.23	**1.04**	4.20	0.99
774	5.70	6.20	0.50	6.01	0.31	4.89	0.81
748	4.79	3.63	**1.16**	5.53	0.74	5.22	0.43
015	5.27	4.32	**1.07**	5.72	0.45	5.78	0.51
297	4.32	3.39	0.93	4.59	0.27	4.98	0.66
583	6.33	6.24	0.09	7.31	0.98	5.43	0.90
923	4.33	2.99	**1.34**	5.50	**1.17**	4.49	0.16
256	5.54	4.91	0.63	6.20	0.66	5.52	0.02
561	5.07	4.26	0.81	5.56	0.49	5.40	0.33
201	5.87	6.31	0.44	5.69	0.18	5.62	0.25
338	5.77	5.68	0.09	6.79	**1.02**	4.83	0.94
650	5.81	4.18	**1.63**	7.31	**1.50**	5.95	0.14
477	5.24	3.76	**1.54**	7.01	**1.77**	4.96	0.28
365	4.70	3.38	**1.32**	4.54	0.16	5.17	0.47

The young white distractor wines (297 and 365) tended to be scored with lower values regarding the lower scores. Interestingly, wine 923 (2011 vintage) was also in the lower range of values. The rosé and red distracting wines were scored within the range given to the white wines but tended to the lower classifications (Table 4.2). The *p*-values are not significantly different to 692 and 429 wines, so differences are not observed in how the three tasting panels evaluate quality. However, the *p*-value associated with wine 429 is moderately different, showing that it could have been some heterogenous with the three tasting panels.

Table 4.2. Wines' average quality scores of rosé and red distracting wines. Kruskal-Wallis test comparing quality evaluations by critics, oenologists, and students ($\alpha = 0.05$). χ^2: Test statistic.

Wines	Overall	Critics	Oenologists	Students	$X^2_{(2)}$	*p*-value
692	3.78	3.19	4.07	4.08	1.03	0.597
429	4.07	3.58	3.08	5.55	5.09	0.078

This behaviour indicated that tasters declassified wines that were not young or white by previously being aware of the purpose of the tasting. Although wine 923 may be explained by

its sensory features, the tasters assume it is new and judge it worse as it does not fit in with the old white wines. In addition, there seems to be a difference in the assessment given by the different panels as observed regarding the scores given to the white or red distractors.

It is interesting to analyse that the three panels assess rosé wine (692) more closely than red wine (429). Once again, as the wines are not old white wines, the quality assessment is impaired. Students are the ones who give the highest marks. They do not prejudicate the distractors wines.

4.3. Effect of experience on wine scores

The differences in assessment across degrees of expertise are shown in table 4.3. *P*-values less than 0.05 indicate statistically significant differences between panels. Those who present the differences will be studied in more detail to understand that panels stand out in these differences. According to table 4.3, it is possible to verify that the quality of wines 938, 583, 650, 477 and 365 differs across panels.

Table 4.3. Kruskal-Wallis test comparing quality evaluations by critics, oenologists, and students ($\alpha = 0.05$). Bold numbers indicate statistically significant values. χ^2: Test statistic.

Wines	$\chi^2_{(2)}$	*p*-value
102	0.6732	0.714
147	0.5127	0.774
381	1.2233	0.542
839	7.1355	**0.028**
710	1.3900	0.499
774	2.5855	0.275
748	1.9311	0.381
015	3.2187	0.200
297	3.5868	0.166
583	6.3679	**0.041**
923	4.5865	0.101
256	2.2081	0.332
561	2.7330	0.255
201	0.3398	0.844
338	4.5535	0.103
650	13.7711	**0.001**
477	12.4648	**0.002**
365	6.9853	**0.030**

The difference in quality scores given by the different panels was evaluated by Dwass-Steel-Critchlow-Fligner pairwise comparisons test. Table 4.4 shows that only one wine (477) is repeated between two panels with significant differences ($\alpha < 0.05$).

Table 4.4. Quality evaluation by the critics, oenologists, and students. Average and *p*-value (α=0.05) associated with Dwass-Steel-Critchlow-Fligner pairwise comparisons test. Bold numbers indicate statistically significant values.

Wines	Average			*p*-value[a]		
	Critics	**Oenologists**	**Students**	**Cr|En**	**Cr|St**	**En|St**
839	5.49	7.83	5.20	0.086	0.924	**0.030**
583	6.24	7.31	5.43	0.169	0.821	**0.036**
650	4.18	7.31	5.95	**0.002**	0.060	0.054
477	3.76	7.01	4.96	**0.010**	0.316	**0.007**
365	3.38	4.54	5.17	0.251	**0.031**	0.572

[a] Cr, critics; En, enologists; St, students.

The panels of critics and oenologists differ significantly for the 650 and 477 wines. It could mean that the critics rated the wine as a non-standard wine for old white wines (despite being 10 and 9 years old, respectively), while the oenologists managed to understand that it was a wine with some age.

It should also be noted that there are some wines with moderately significant differences, that is, with a *p*-value between 0.05 and 0.10. The 650 stands out with differences between all the panels, having evaluated in a heterogeneous way. The 839 wine also stands out moderately but at the limit for critics and oenologists.

The oenologists have very high values in the first four wines (table 4.4) and have differentiated themselves from the other panels.

The various classifications can then be related to the CATA differences and check whether the sensory profiles could explain the observed different quality scores.

4.4. Quality prediction

4.4.1. Differences among the panels assessing synthetic descriptors

The different wine synthetic descriptors were averaged among each panel, and the results are shown in Table 4.5. For a better understanding of the evaluations of each panel and analysis of the differences, three boxplots are shown in figures 4.1, 4.2 and 4.3.

Table 4.5 and figures 4.1, 4.2 and 4.3 show that oenologists were the ones who evaluated with the highest scores, on average, and the associated standard deviation was the most minor compared to the other tasting panels.

The results presented in table 4.5, with the statistics associated with the panels, allow us to verify that, although the oenologists have a minor standard deviation, they are the ones who, together with the critics, that present a relatively significant difference in the evaluations of the descriptors within the panel. However, the critics are the ones who presented the most significant difference between the evaluations of the descriptors within the panel. In total, they represent a minor difference in the standard deviation compared to the students.

It can be concluded that students have higher standard deviations due to sporadic tasters who assess more out of the box, but the rest are more homogeneous in their evaluation.

Table 4.5. Averages and standard deviations from the descriptors with the twenty wines by the three tasting panels.

Descriptors	Critics		Oenologists		Students	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Familiarity	5.67	2.20	6.86	1.57	4.26	2.29
Flavour number	4.81	2.47	5.65	1.79	4.07	2.15
Flavour Identification	5.95	2.18	6.06	1.46	4.24	2.18
Harmonious	4.94	2.13	6.06	1.39	5.03	2.22
Balance	5.00	2.22	5.87	1.53	5.01	2.32
Linger	4.59	2.31	5.96	1.73	4.87	2.21
Power	4.53	2.26	5.97	1.47	5.04	2.04
Complexity	4.07	1.98	5.64	1.41	4.88	2.06
Like	4.67	2.13	5.56	1.69	5.08	2.18
Quality	4.65	1.94	5.81	1.57	5.16	1.94

According to figure 4.1, 4.2, 4.3 and table 4.5, it can be seen that oenologists attribute a higher value of complexity to wines. The averages of the test panel of critics are at the same level or below the averages of students, demonstrating the significant difference in the way critics and students assess.

Knowing that complexity is linked to the number of flavours or the easy way to identify aromas or the wine's length in the mouth, it is possible to define how each panel tastes and assesses complexity.

Although, on average, critics assess the complexity with 4.07, considering that the maximum value is nine and its half is 4.50, it is possible to verify that the panel have a lower value about complexity, with 4.07.

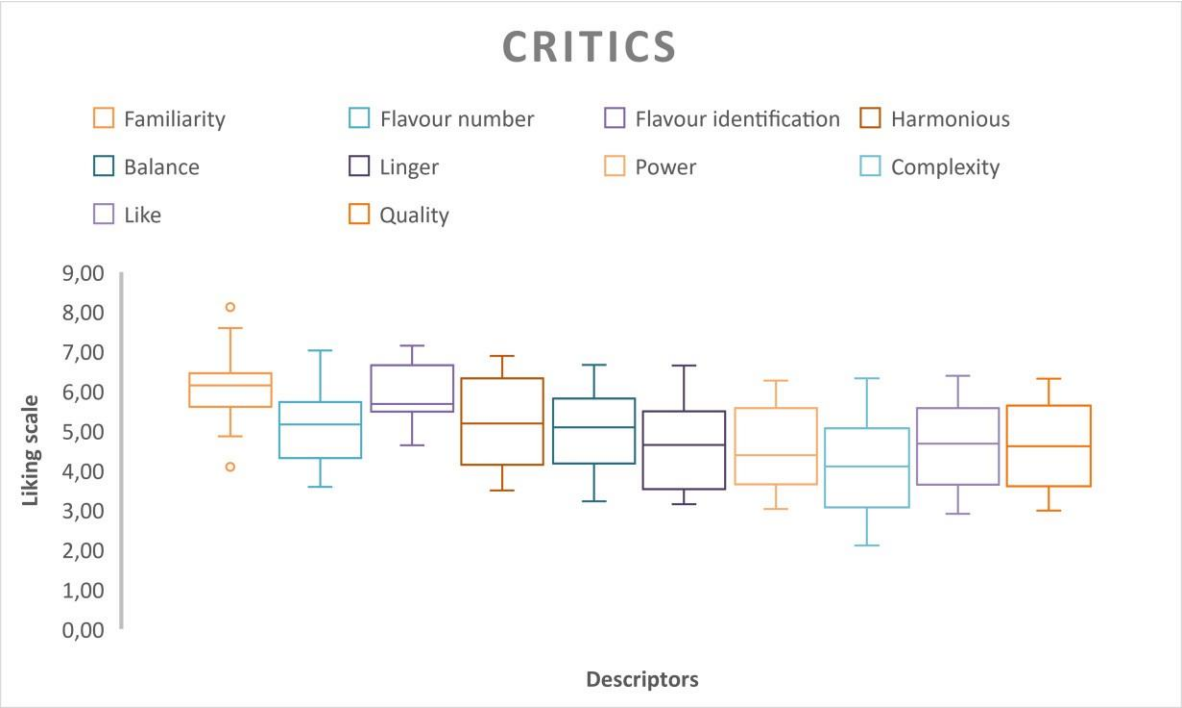

Figure 4.1. Boxplot with the scales of the descriptors by critics.

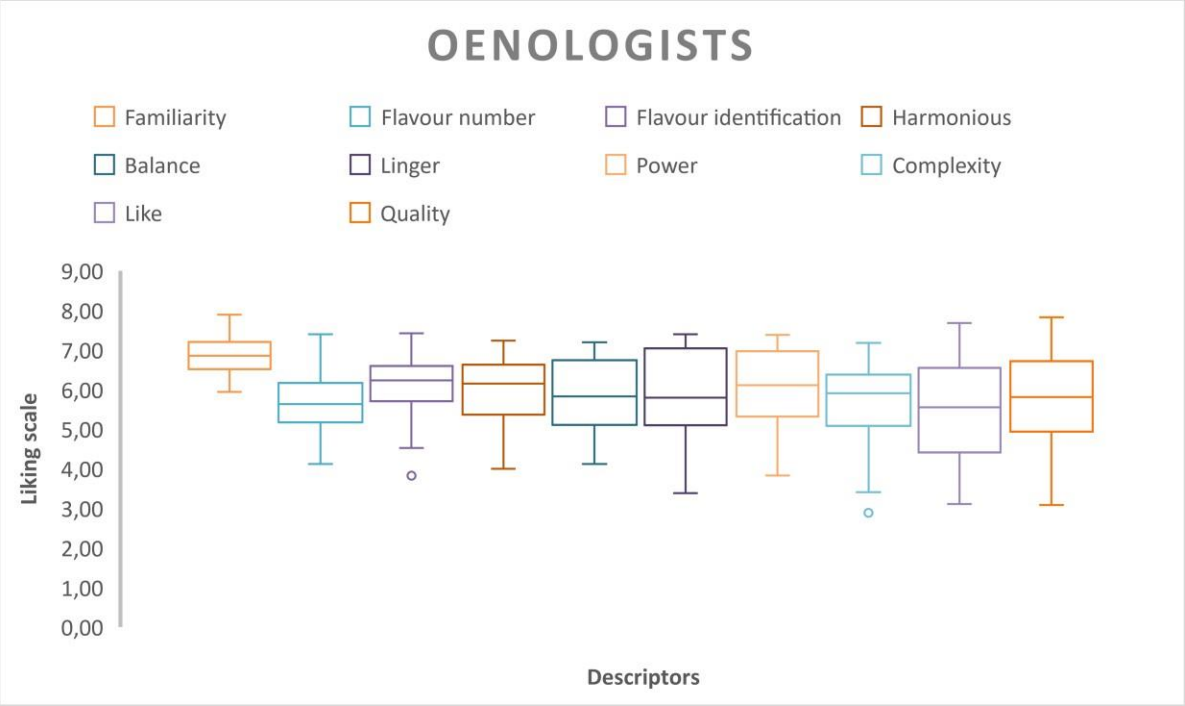

Figure 4.2. Boxplot with the scales of descriptors by oenologists.

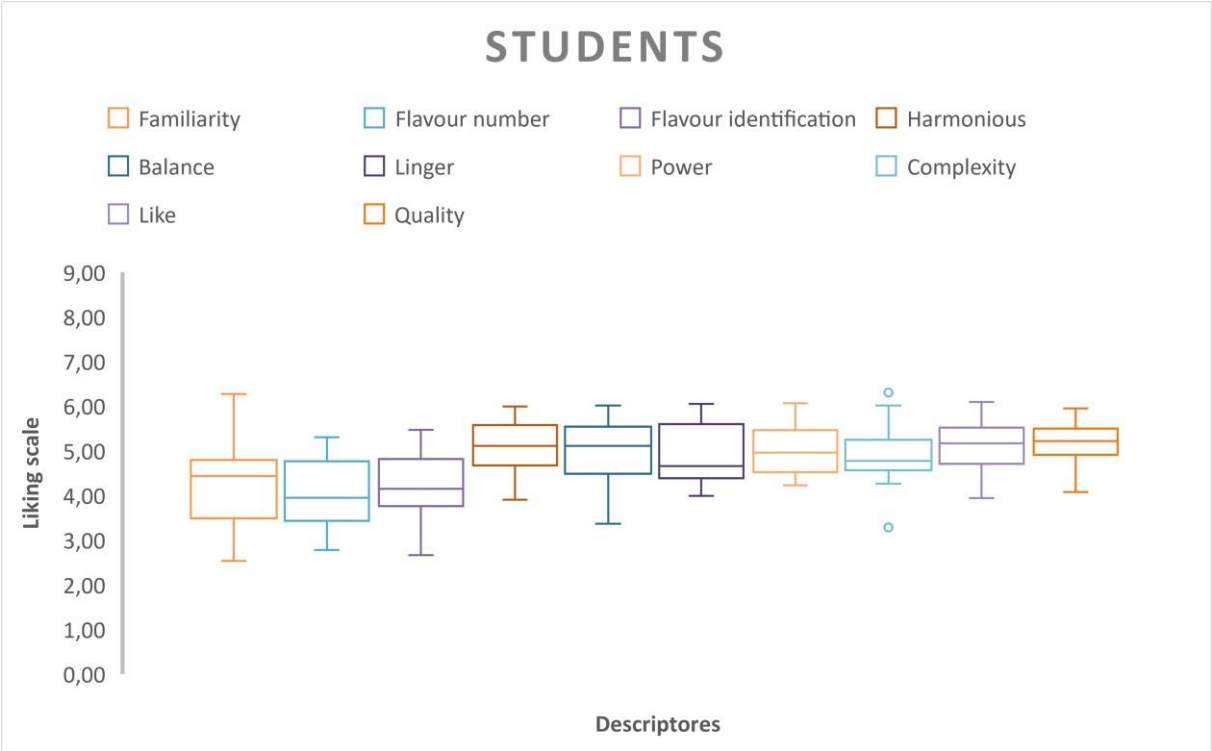

Figure 4.3. Boxplot with the scales of the descriptors by students.

On the other hand, the oenologists evaluated the complexity with an average value of 5.64, relatively close to the values of flavours, knowing how to identify them, and the linger in the mouth. It can be explained by the panel's ability to assess complexity differently as the values are relatively similar. This can be explained by the panel's ability to assess complexity differently, as the values are relatively similar.

For a better understanding of the complexity with the descriptors, an analysis of the correlation between the variables was performed, shown in table 4.6. Critics are the ones who evaluate complexity with a high number of descriptors (with five), then oenologists with two, and the students do not have a strong correlation with complexity and any descriptor.

So, according to table 4.6, critics evaluate complexity based on the flavour number, linger, power, like and quality. Oenologists evaluate only with linger, like and quality.

Table 4.6. Correlation (r) between complexity and the rest of the synthetic descriptors and liking. Bold numbers indicate strong correlations (above 0.7).

Tasting Panels	Familiarity	Flavour number	Flavour identification	Harmonious	Balance	Linger	Power	Like	Quality
Overall	0.364	0.470	0.313	0.382	0.570	**0.750**	0.584	**0.700**	**0.726**
Critics	0.233	**0.821**	0.495	0.595	0.678	**0.836**	**0.784**	**0.933**	**0.908**
Oenologists	0.443	0.587	0.089	0.340	0.644	**0.765**	0.385	**0.848**	**0.827**
Students	0.417	0.002	0.355	0.210	0.388	0.650	0.583	0.318	0.443

4.4.2. Differences within the panels

The participants were grouped a *priori* according to their professional status, assuming that there should be some homogeneity in quality evaluation. However, the variation shown in Table 4.7 suggests that there may be considerable heterogeneity In the responses. Homogeneity tests are presented in table 4.5 (p-values <0.05), indicating statistically significant differences in homogeneity regarding several synthetic descriptors.

According to table 4.7, only the student group showed homogeneity in response to the quality descriptors. However, they constantly evaluate the same way, proving that they do not create idiosyncratic quality standards.

The other two tasting panels evaluated wines differently for several of the descriptors.

Table 4.7. Kruskal-Wallis test comparing descriptors evaluations by critics, oenologists and students (α = 0.05). Bold numbers indicate statistically significant values. χ^2: Test statistic.

Descriptor	Critics		Oenologists		Students	
	$\chi^2_{(15)}$	*p*-value	$\chi^2_{(15)}$	*p*-value	$\chi^2_{(15)}$	*p*-value
Familiarity	11.2	0.740	10.3	0.1004	19.5	0.0872
Flavour number	19.8	0.181	18.2	0.250	19.3	0.202
Flavour identification	17.0	0.317	15.5	0.417	19.5	0,191
Harmonious	27.9	**0.022**	26.8	**0.030**	12.1	0.670
Balance	21.4	0.124	26.4	**0.034**	16.4	0.356
Linger	25.4	**0.045**	27.3	**0.026**	20.5	0.154
Strong and powerful	25.9	**0.039**	20.1	0.168	14.4	0.497
Complexity	35.5	**0.002**	21.4	0.125	12.9	0.608
Like	26.8	**0.030**	33.2	**0.004**	14.0	0.522
Quality	30.3	**0.011**	25.3	**0.046**	12.2	0.664

Subsequently, the descriptors represented by bold *p*-values in table 4.7 were subjected to pairwise comparisons with the Dwass-Steel-Critchlow-Fligner test to see significant differences inside the panel.

Of all the descriptors that showed overall significant differences, only one, in the statistical analysis, presented with a significant *p*-value (complexity with *p*=0.002). The wine that caused that difference was wine 923. The significant difference associated with the *p*-value of 0.002 indicates that critics assess complexity with more nuances. The rest only presented low *p*-values but no value below 0.05. As such, only the Complexity descriptor was studied within the scope of the critics.

Wang *et al*. (2021) have an interesting point of view on the complexity of the wine. They say that complexity has many different ways to be defined, and two of them can be related to other descriptors used in the tasting. For example, when a single element expresses complexity, the number of flavours and complexity can be directly proportional. Alternatively, complexity can be explained by a single dynamic element, such as the duration of lingering flavours in the mouth. Furthermore, another interesting correlation can be described by the degree of difficulty in identifying (with the lower limit being difficult and the upper limit being easy) with the complexity.

4.4.3. Quality prediction

The correlation of each synthetic parameter on the quality prediction. Through a correlation between quality and the other descriptors divided by the three panels of evidence, it is possible to identify which descriptors the panels associate with quality. Like has a strong correlation with quality and will be discussed more further.

When all panels' responses are blended, the best quality predictors are balance, linger, and complexity. However, this does not show how the different cohorts evaluate quality. Indeed, there was a clear difference in the inferences elicited by the three panels.

According to table 4.8, critics associate that quality is described through the lingering, power, and complexity of the wine in the mouth. They do not care about harmony but potency. Oenologists associate quality, almost in the same way as critics, with the difference that the balance and flavours of the wine are more important than the power of the same in the mouth. While students rate it differently, there is only a strong correlation with balance, but harmony also stands out.

Table 4.8. Correlation (r) between quality and the rest of the synthetic descriptors and liking. Bold numbers indicate strong correlations (above 0.7).

Tasting Panels	Familiarity	Flavour number	Flavour identification	Harmonious	Balance	Linger	Power	Complexity	Like
Overall	0.057	0.559	0.192	0.608	**0.748**	**0.700**	0.493	**0.726**	**0.907**
Critics	0.001	0.643	0.266	0.468	0.591	**0.897**	**0.870**	**0.908**	**0.977**
Oenologists	0.157	**0.718**	0.179	0.673	**0.868**	**0.879**	0.588	**0.827**	**0.965**
Students	0.014	0.317	0.130	0.682	**0.786**	0.323	0.022	0.443	**0.778**

4.4.4. The relation between quality and liking

Is there a relationship between quality and liking? It is a fundamental question to see if the tasting panels can distinguish the quality of the wine from their preferences. Unfortunately, it is a highly complex exercise because most people confuse and let their preference interfere with the quality of a wine.

The results presented in Table 4.8 are illustrated in Figure 4.4. It is possible to verify that, in table 4.8 and figure 4.4, the three test panels cannot distinguish quality from personal taste,

and students are the ones with the lowest correlation. That is, they are the ones that better distinguish the two descriptors. For students, regarding their evaluations, the wines that stand out less for their correlation between quality and like were 365 (with the lowest correlation), followed by 015 and 748.

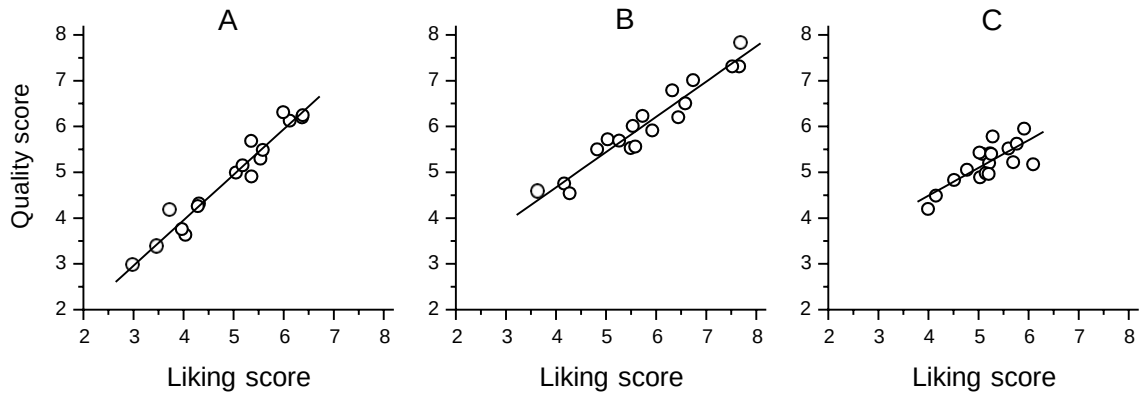

Figure 4.4. Correlation between quality and liking with the three panels: A-critics, B-oenologists and C-students.

It is also possible to notice, in figure 4.4, that the scale of the grades given by the students is very concentrated on the scale of 4 to 6. Thus, it leads to suppose that they either do not notice the wines' differences or use a smaller range in the scale.

4.4.5. The influence of colour on quality

Browning is a factor that can influence the quality perception of a wine. The quality scores as a function of wine absorbance are shown in Figure. 4.5.

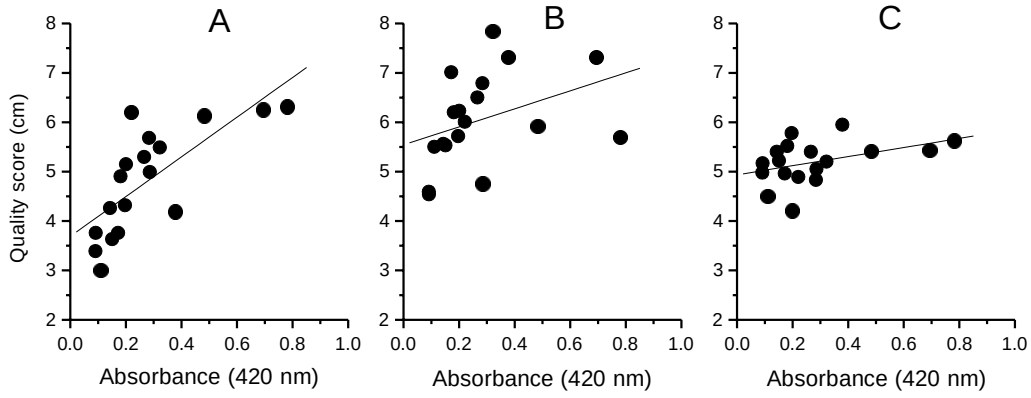

Figure 4.5. Correlation between quality and absorbance with the three panels: A, critics; B, oenologists and C, students.

In figure 4.5, it is possible to verify a positive relationship with browning. The tasters already knew the test's purpose, so browning would be part of the visual aspect of the wines. Indeed, light yellow wines are considered young, so they were less rated. Few brownish wines were rated less than 4, such as 923, 297, 748 and 365 (distractor) wines. Although browning was valued, exaggerated values were negative, synonyms for over-oxidation, like the 102, 201 and 583 wines.

The wines evaluated with lower quality were considered young wines due to their colour. Thus, the same logic evaluated distractor white wines 692 and 365 and rosé and red wines (692 and 429, respectively).

Table 4.9. Correlation between quality and absorbance

	Critics	**Oenologists**	**Students**
Correlation (r)	0.736	0.377	0.414

According to table 4.9, oenologists and students understood the difference between quality and absorbance. With a very positive correlation, critics associated lesser quality to wines with a not very strong colour, such as young wines.

Despite being the tasting panel with the lowest correlation, Oenologists observed that wines with a young colour and wines with strong colour are the most affected. In contrast, wines with more balanced browning have a better-quality assessment. According to figure 4.5 and table 4.9, the students show no correlation in quality and colour. It may have been based on obtaining quality in other descriptors.

4.5. CATA

To analyse the data in more detail, it was chosen to make radar charts by wine and separate the three panels' responses.

The radar charts were made through a table of citation frequencies with values between 0 and 1. It allows us to understand which descriptors were most mentioned by the tasters and understand the evaluation of wines more figuratively.

Spider graphics make it possible to verify that the most and least classified wines by each panel have a very similar characterisation. This characterisation demonstrates that the meaning of quality for tasters is relatively similar; the wines differ.

A boxplot chart was applied to each panel to perform the radar charts to determine hip one (25%) for wines classified as lower quality and hip four (75%) for wines classified as higher quality, according to the three tests panels.

Table 4.10. The best and worst wines are classified according to the tasting panels, using boxplot data. Bold numbers indicate significant repetition.

Tasting panels			**75%**			**25%**		
Critics	102	774	**583**	**201**	748	**923**	650	477
Oenologists	839	**583**	**650**	477	147	748	**923**	561
Students	015	256	**201**	**650**	710	774	**923**	338

It can be seen, in table 4.10, that wines 583, 201 and 650 were considered the best wines by two tasting panels. However, on the other hand, the 923 wine is considered by the three panels the one with lower quality because, despite the wine being ten years old, it is still young, very well preserved, influencing the three panels.

4.5.1. Aroma descriptors

In figures 4.6, 4.7, 4.8 and 4.9, critics and oenologists assess wines that present aromas of dried fruit, honey and beeswax, all characteristic aromas of old white wines, with more outstanding quality. In contrast, they evaluate lower quality wines with aromas characteristic of young white wines, such as fresh fruit, floral, citrus, with exceptions.

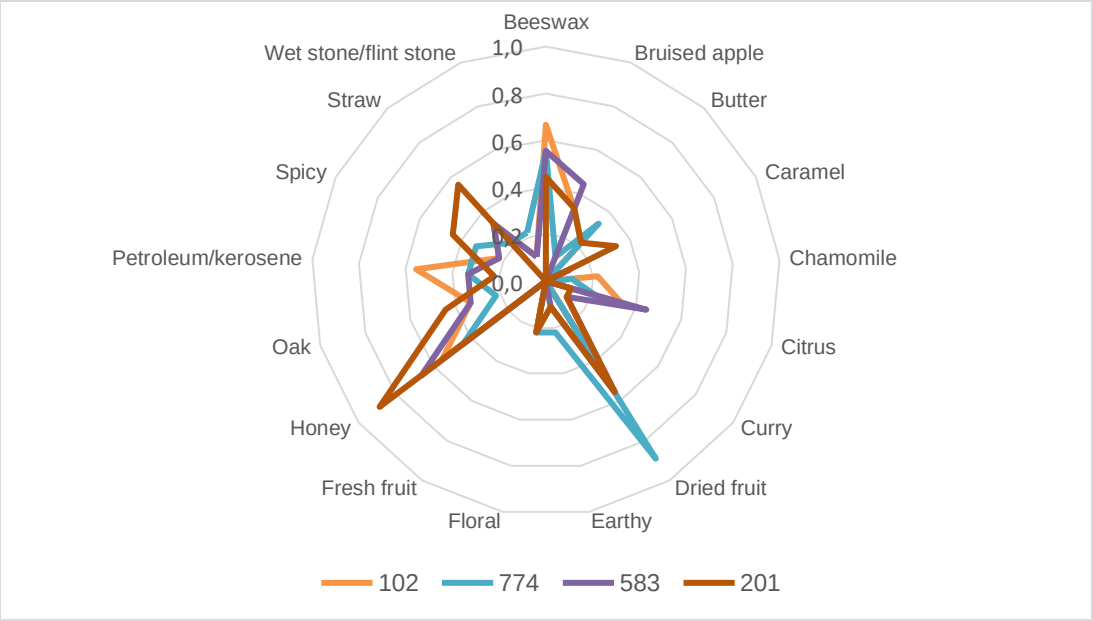

Figure 4.6. Spider diagram with the aroma attributes cited from CATA for the high-quality wines, according to critics

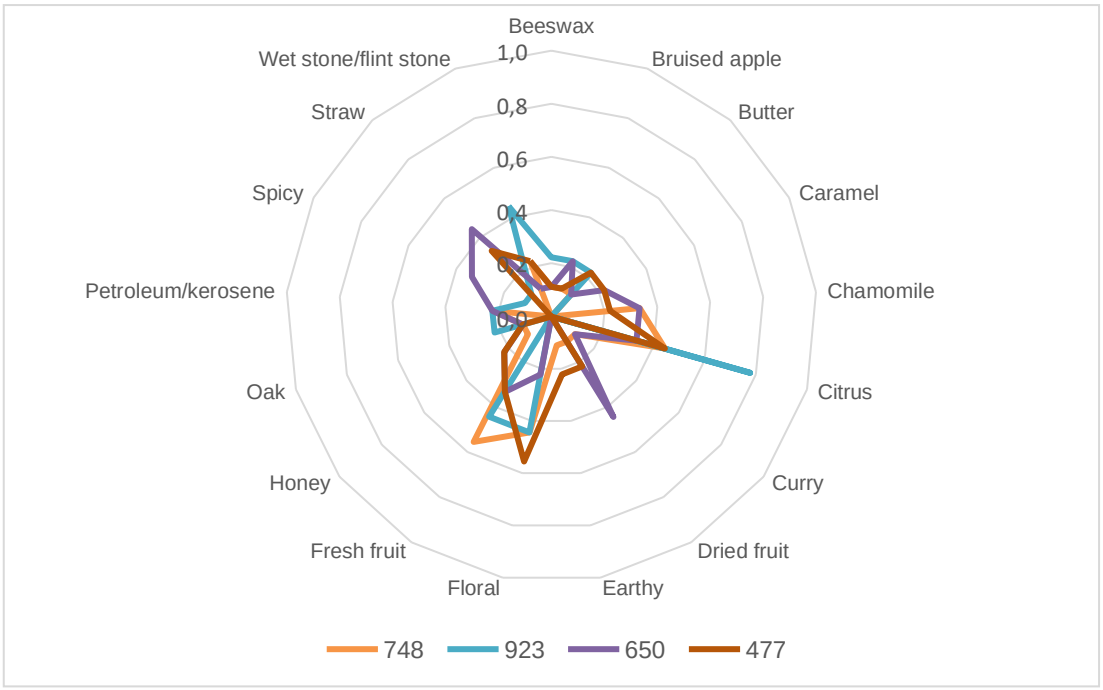

Figure 4.7. Spider diagram with the aroma attributes cited from CATA for the low-quality wines, according to critics

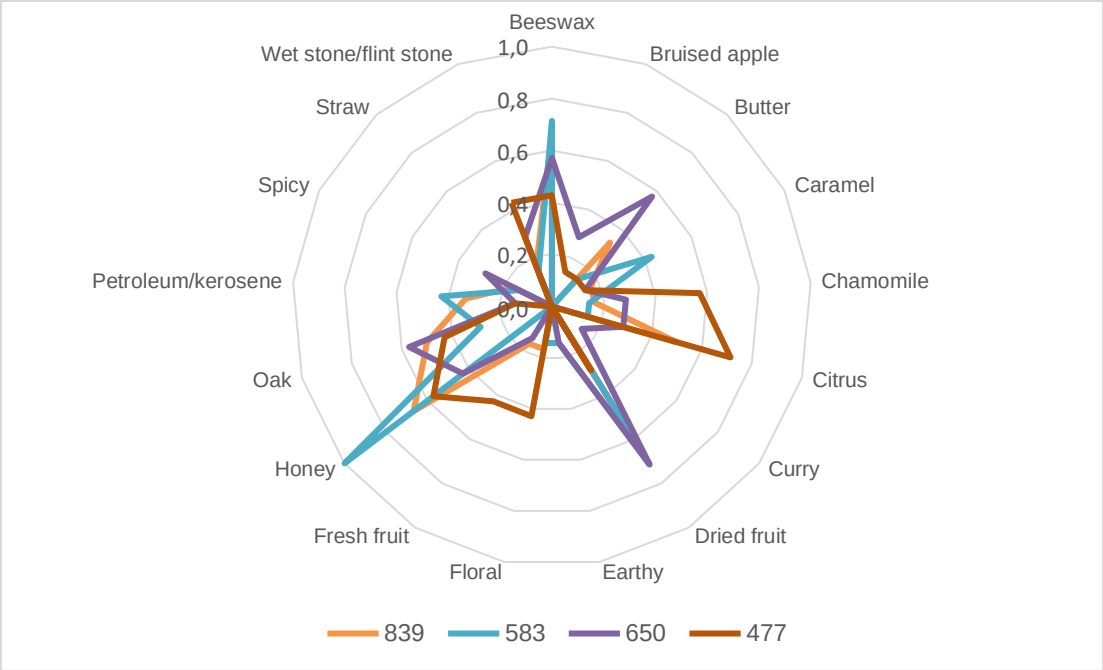

Figure 4.8. Spider diagram with the aroma attributes cited from CATA for the high-quality wines, according to oenologists.

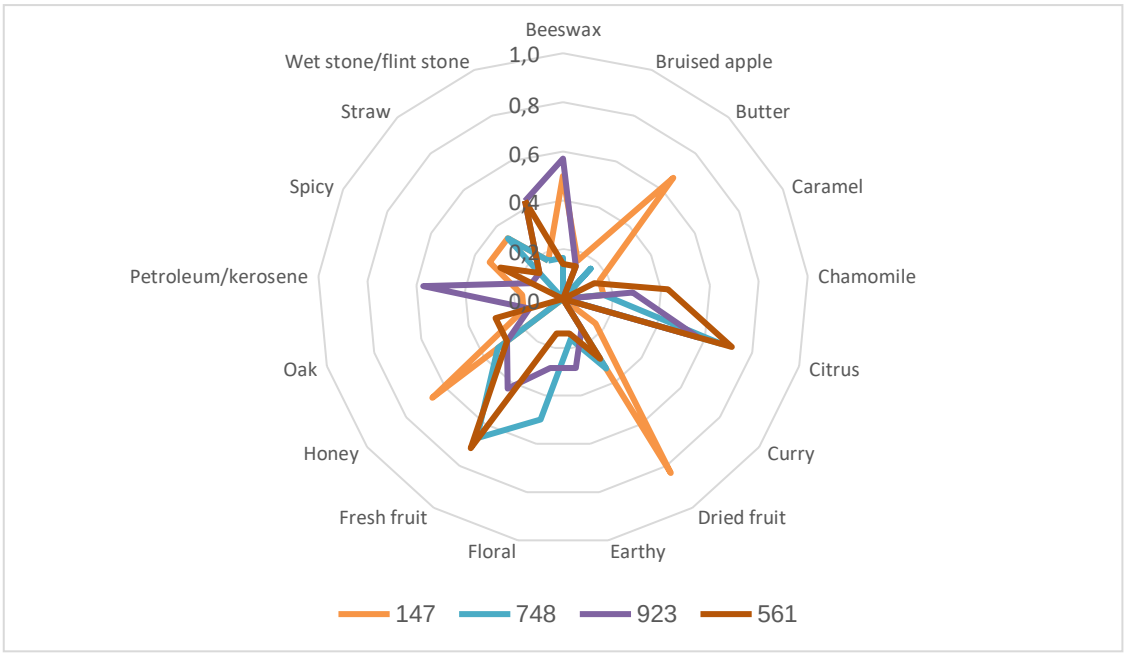

Figure 4.9. Spider diagram with the aroma attributes cited from CATA for the low-quality wines, according to oenologists.

It is observed that critics of wines with lower quality classification have lower citations (the spider is very concentrated). So it is since some panel members have not chosen almost any descriptor.

Students evaluate more homogeneously, not disqualifying younger wines so much, leading to believe that although the tasting focuses on older white wines, they taste to find aromas that are also characteristic of younger white wines, according to figures 4.10, 4.11.

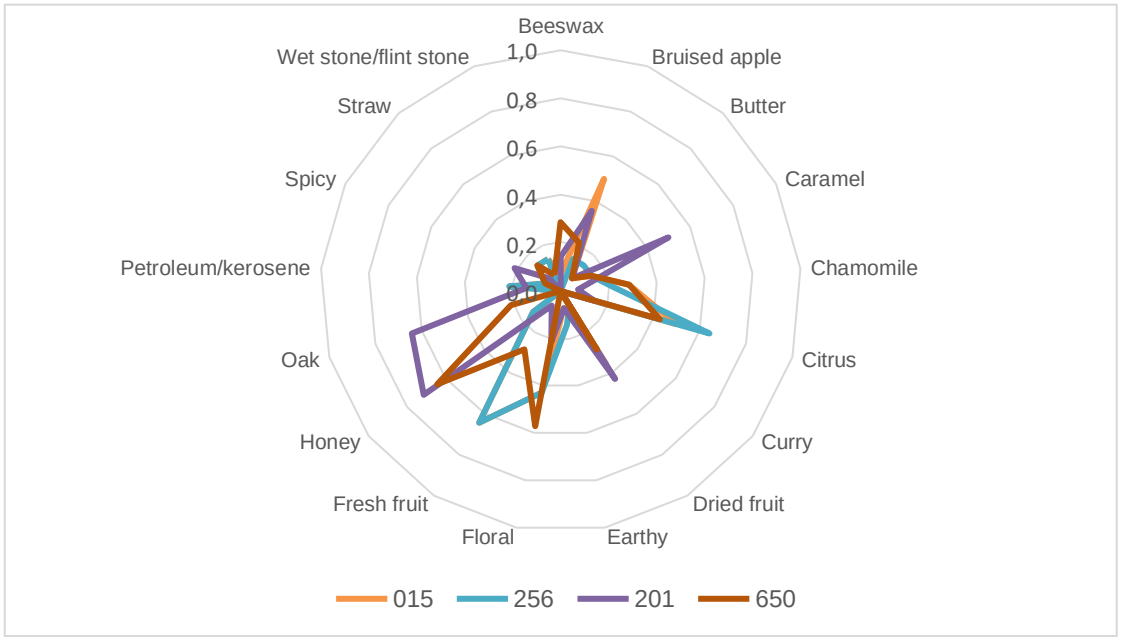

Figure 4.10. Spider diagram with the aroma attributes cited from CATA for the high-quality wines, according to students.

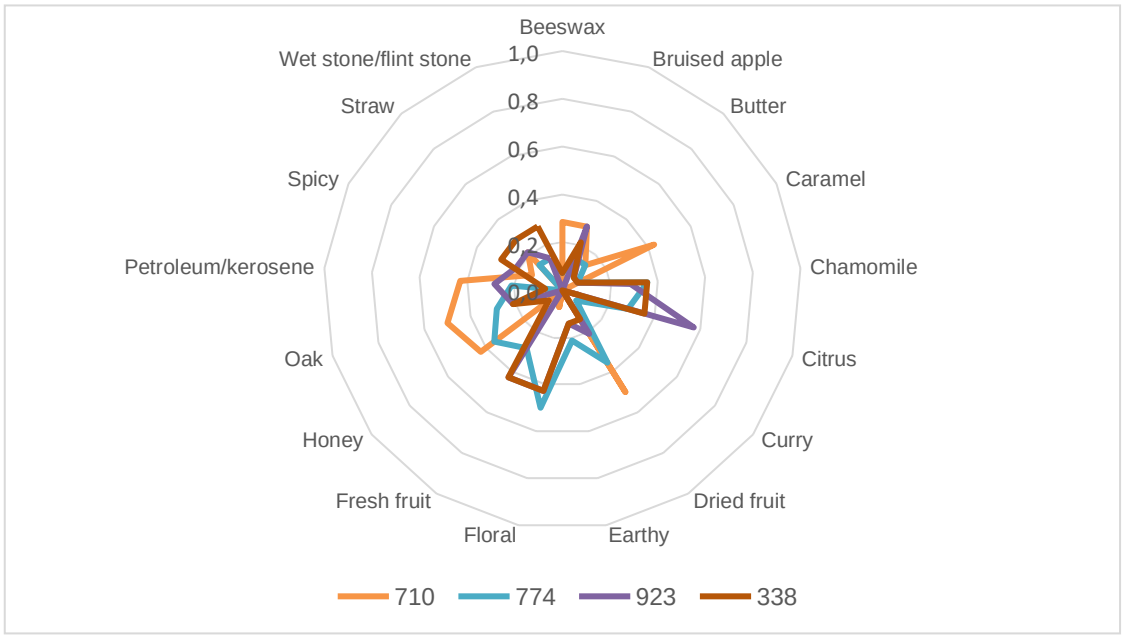

Figure 4.11. Spider diagram with the aroma attributes cited from CATA for the low-quality wines, according to students.

4.5.2. Taste and mouthfeel descriptors

Regarding the taste and mouthfeel, it is possible to observe, through the analysis of the 4.12 to 4.17 figures, that the evaluation of wines with greater or lesser quality is relatively similar.

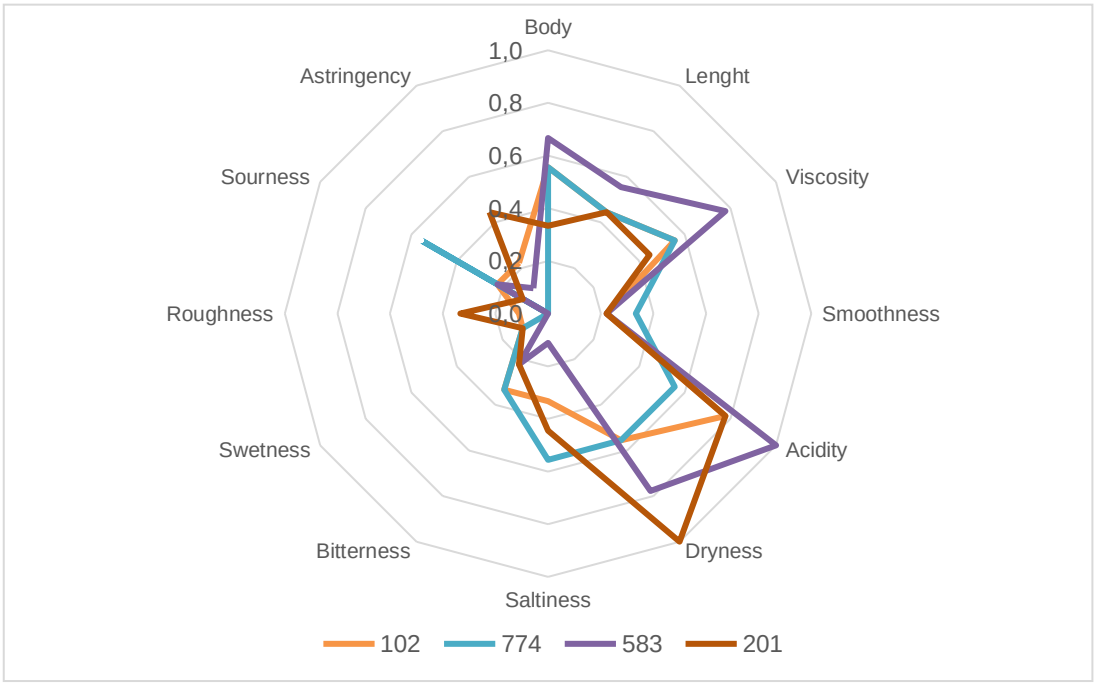

Figure 4.12. Spider diagram with the taste and mouthfeel attributes cited from CATA for the high-quality wines, according to critics.

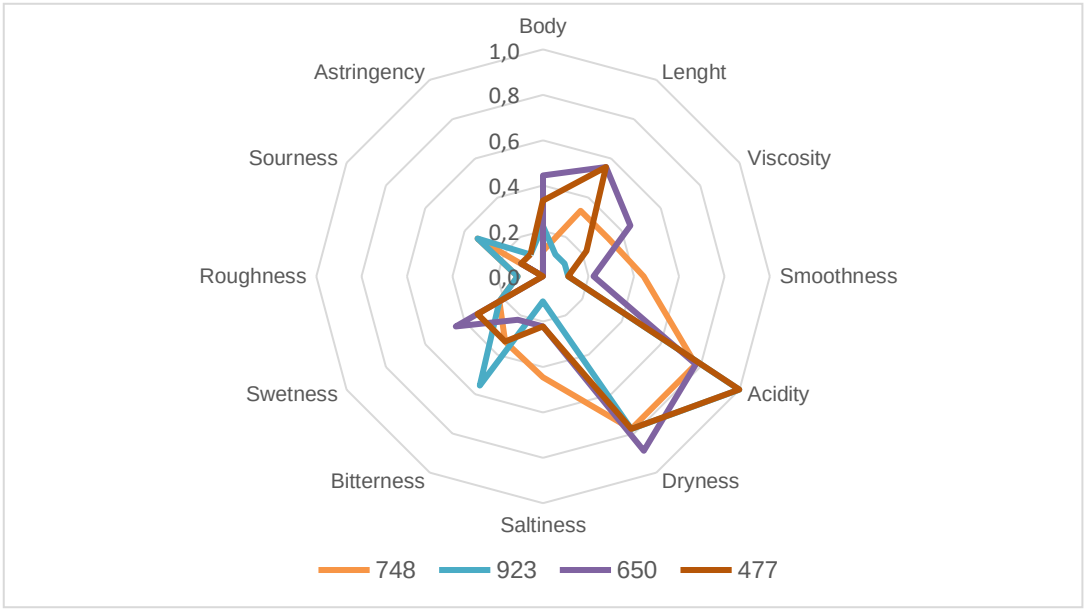

Figure 4.13. Spider diagram with the taste and mouthfeel attributes cited from CATA for the low-quality wines, according to critics.

Critics are the ones who evaluate it more homogeneously, not giving much difference to the taste, according to the quality of the wines.

In the oenologists' figures (4.14 and 4.15), it is possible to verify that the wines classified as having the highest quality have body, persistence and viscosity very present in mouth sensations, having therefore given a minor classification to the wines they found more "boring".

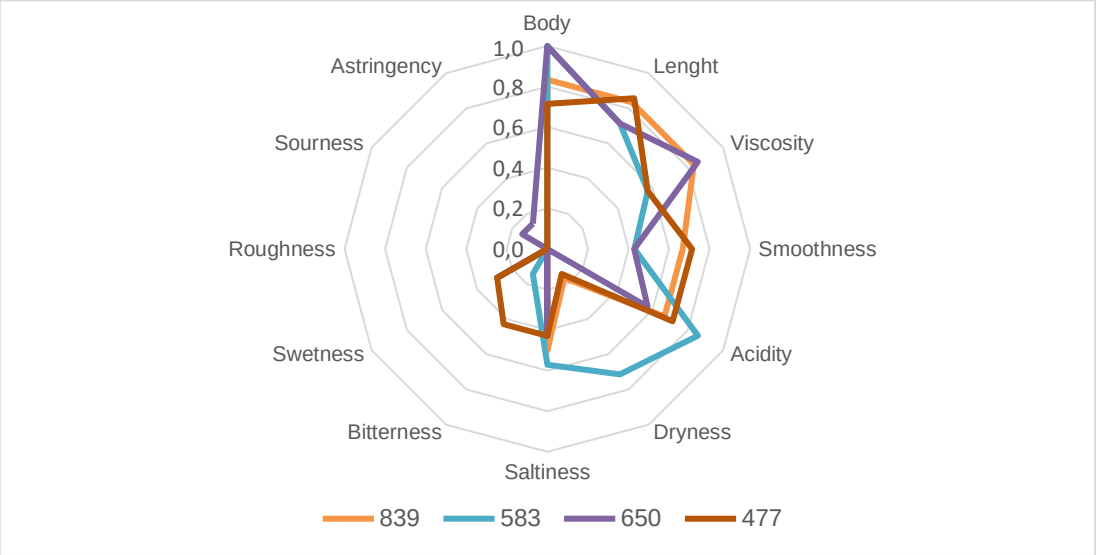

Figure 4.14. Spider diagram with the taste and mouthfeel attributes cited from CATA for the high-quality wines, according to oenologists.

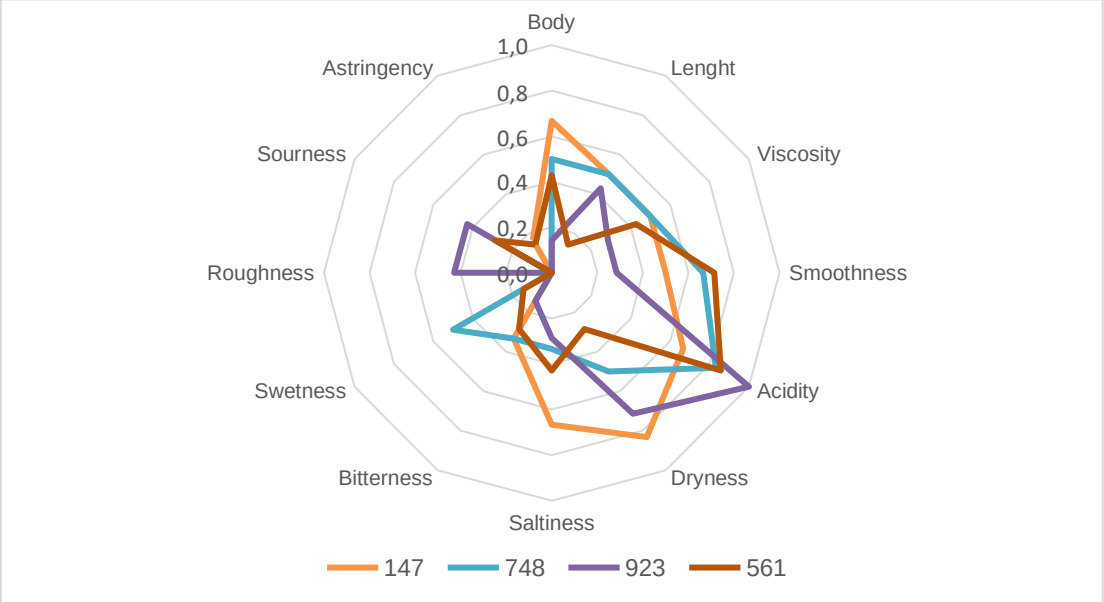

Figure 4.15. Spider diagram with the taste and mouthfeel attributes cited from CATA for the low-quality wines, according to oenologists.

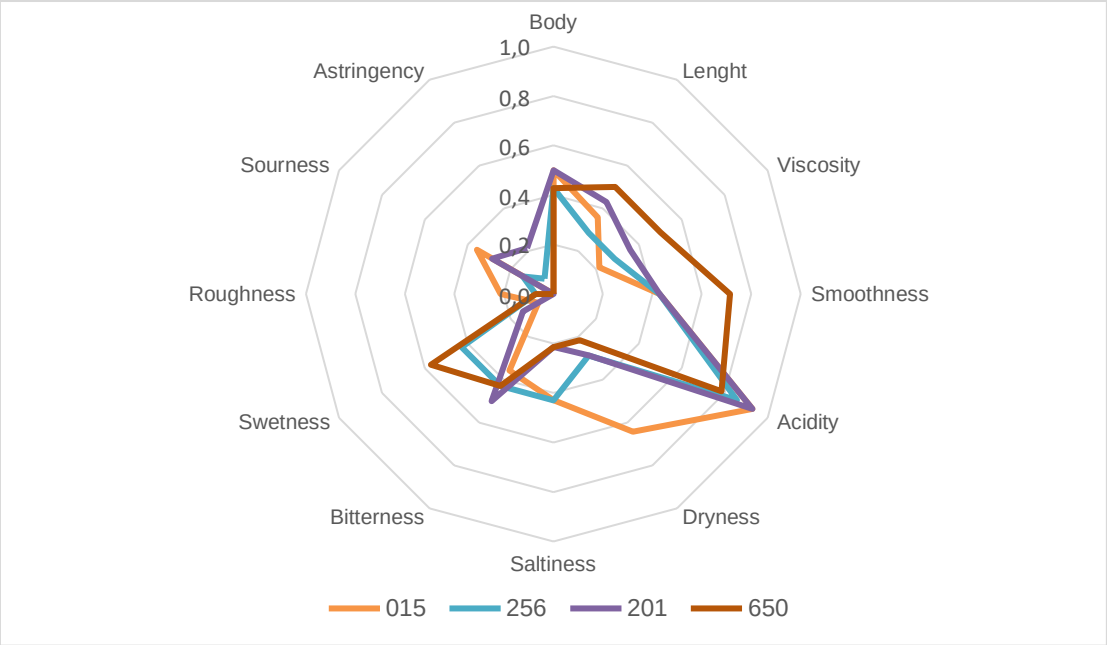

Figure 4.16. Spider diagram with the taste and mouthfeel attributes cited from CATA for the high-quality wines, according to students.

Students and critics are with the classification of taste and mouthfeel for higher and lower quality wines.

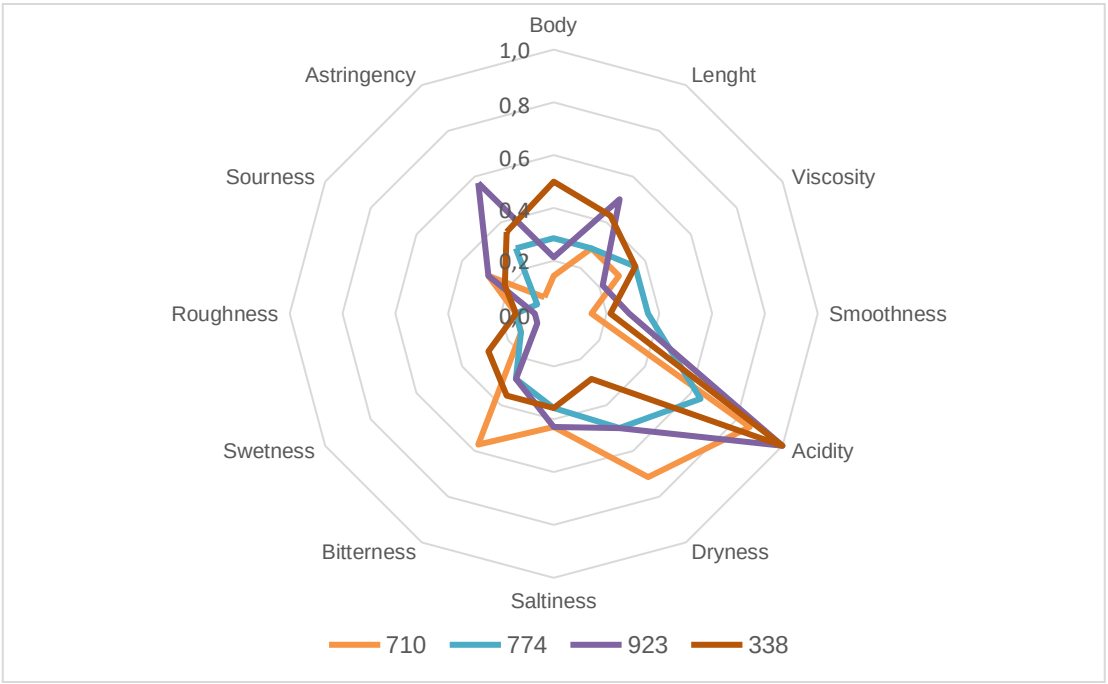

Figure 4.17. Spider diagram with the taste and mouthfeel attributes cited from CATA for the low-quality wines, according to students.

Radar charts were also made for the distracting wines for aroma, taste, and mouthfeel, according to each panel.

4.5.3. Distracting wines

According to the 4.18, 4.19 and 4.20 figures, it appears that the tasting panels focused a lot on young wine descriptors, even with the distinction of two white wines (297 and 365) and rosé wine and red wine (692 and 429, respectively). Thus, proving that the three tasting panels know how to taste because the classification of distractors is different, separating them from the other wines.

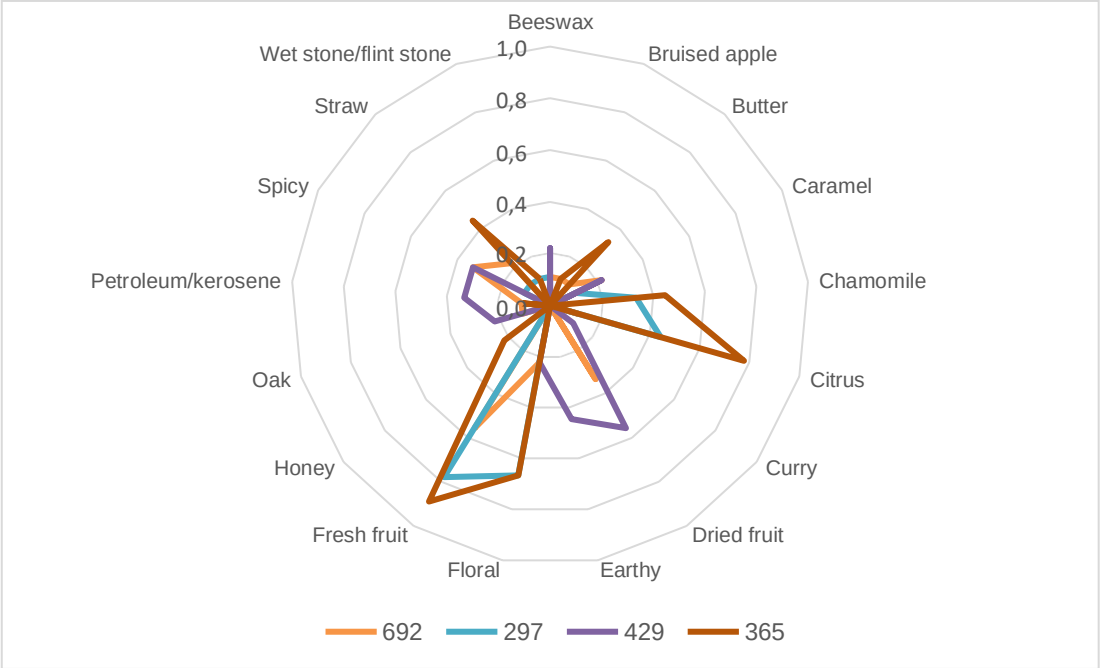

Figure 4.18. Spider diagram with the aroma cited from CATA for the distracting wines, by critics.

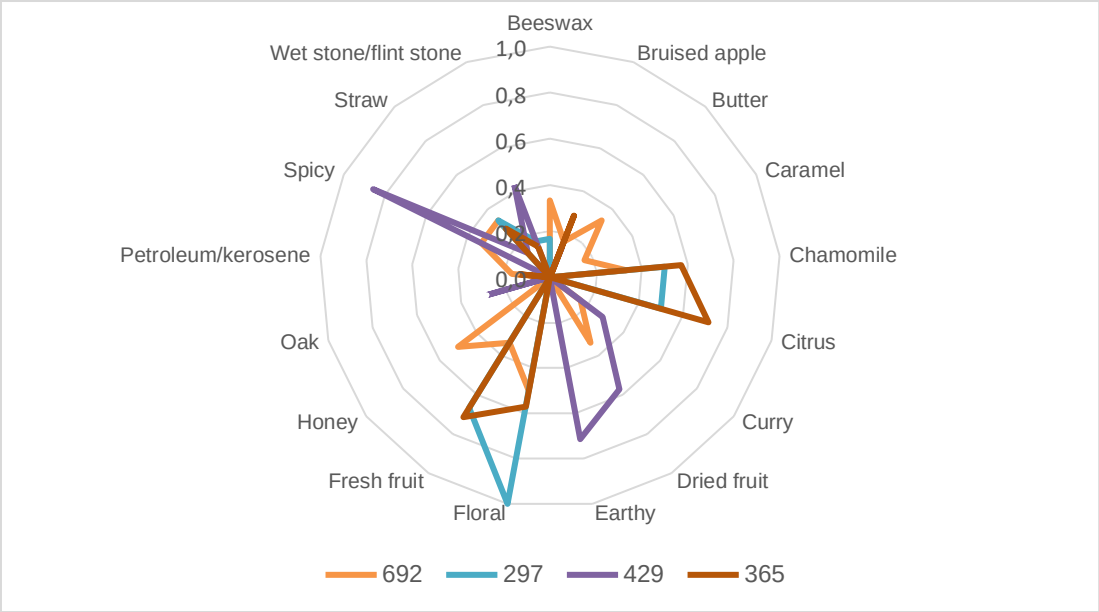

Figure 4.19. Spider diagram with the aroma cited from CATA for the distracting wines, by oenologists.

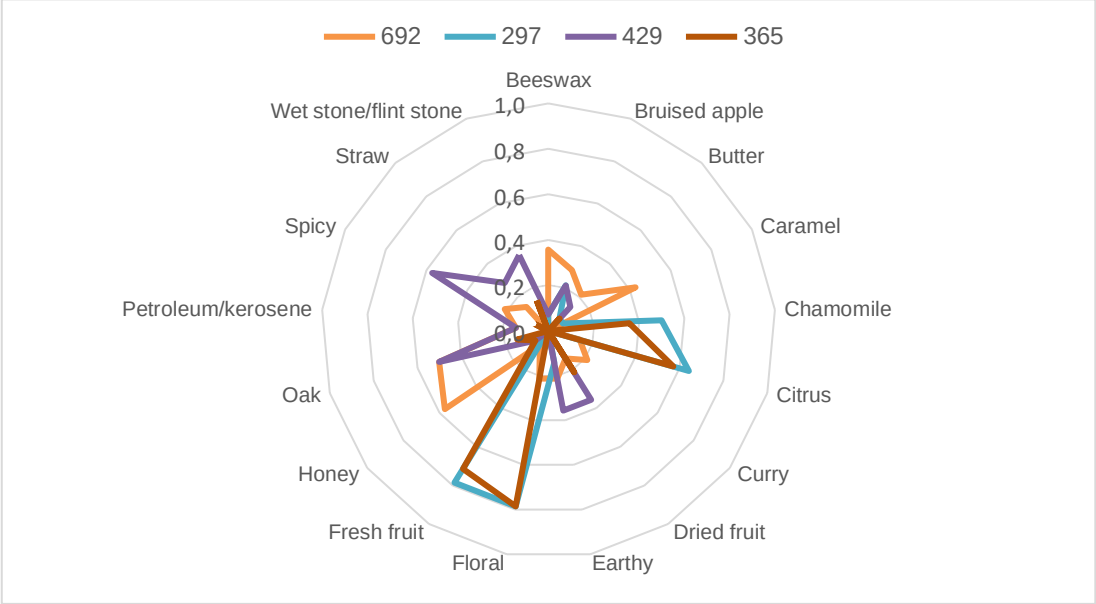

Figure 4.20. Spider diagram with the aroma cited from CATA for the distracting wines, by students.

For the taste and mouthfeel, the three tasting panels meet a relatively similar descriptor scheme in distracting wines (figures 4.21, 4.22 and 4.23). However, very confused. It may be because they are different wines, and the tasters feel more confused about defining the best descriptors that characterise the wines.

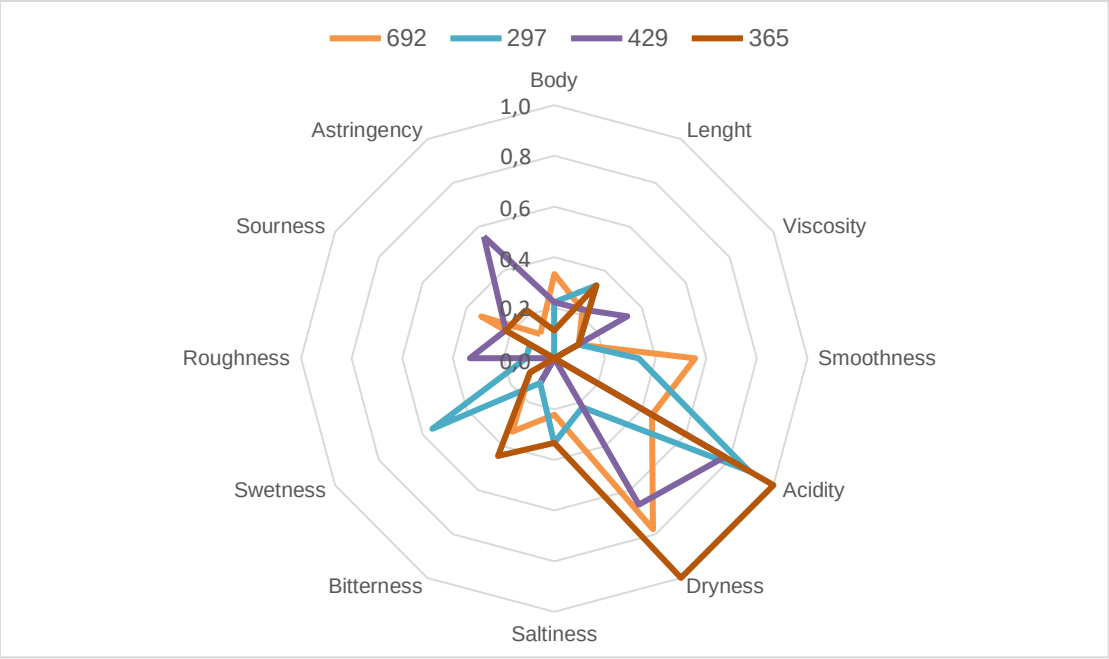

Figure 4.21. Spider diagram with the taste and mouthfeel cited from CATA for the distracting wines, by critics.

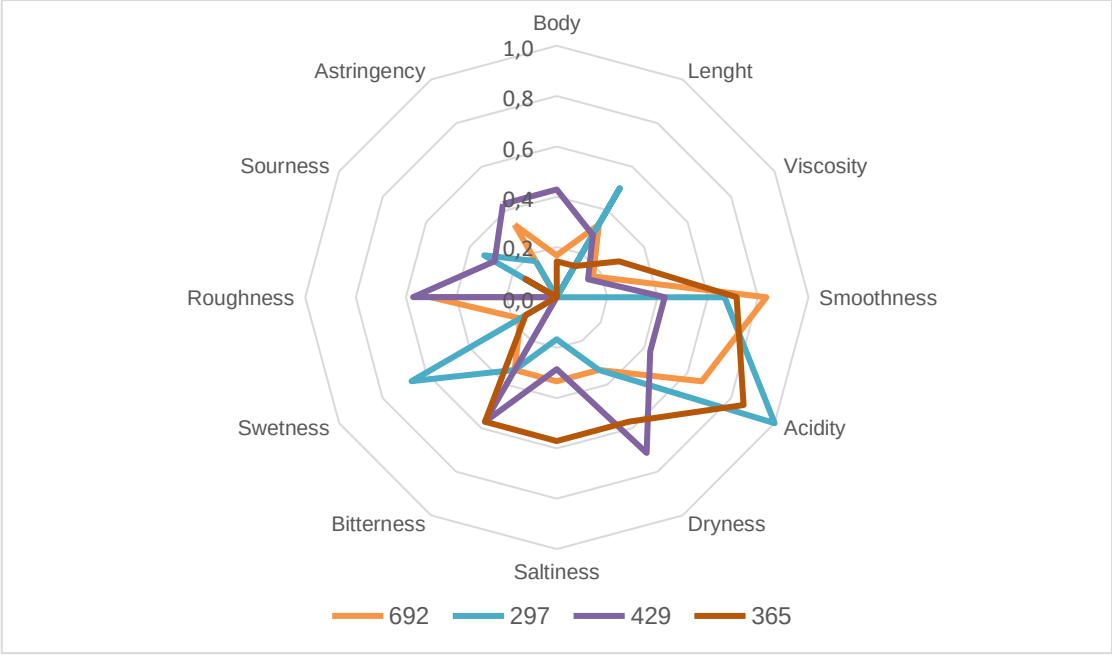

Figure 4.22. Spider diagram with the taste and mouthfeel cited from CATA for the distracting wines, by oenologists.

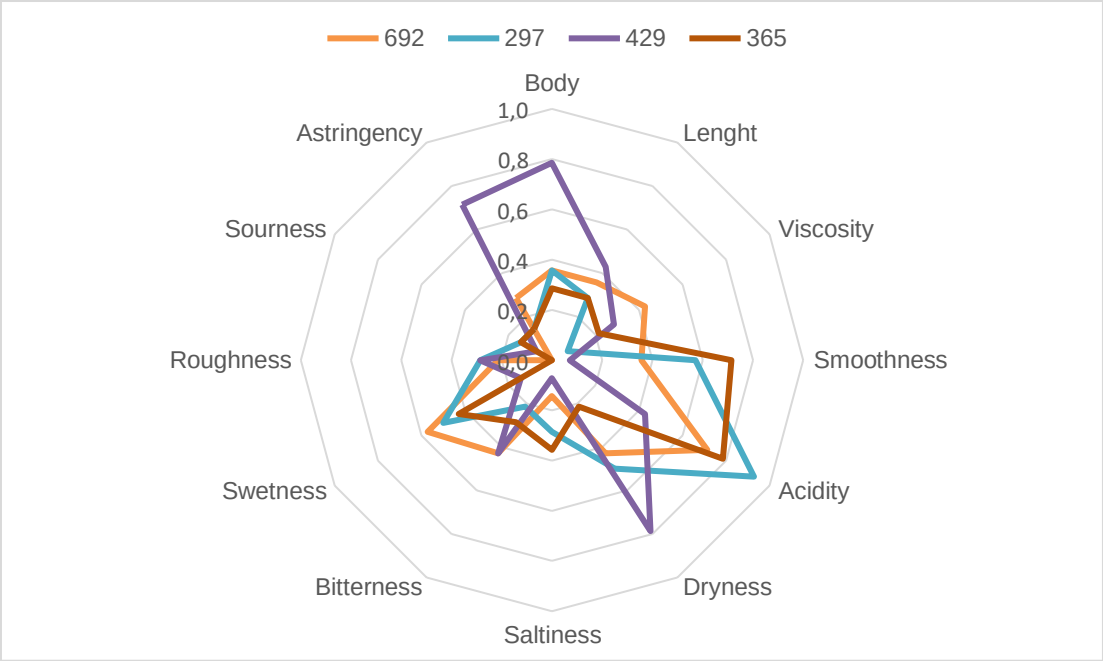

Figure 4.23. Spider diagram with the taste and mouthfeel cited from CATA for the distracting wines, by students.

4.6. Age of wines

The final part of the tasting sheet consisted of analysing the age prediction by the different panels. In table 4.11, it is possible to verify the ages given by each panel to each of the wines and the differences relative to the actual age.

For wines 710, 201 and 338, the three tasting panels assessed the ages of the wines as being much younger than they were. As a result, the age difference given is more than ten years, corresponding to the wines furthest away from each panel's linearity line, in figure 4.24.

In wine 147, the oenologists also stood out due to the age difference, with a difference of approximately ten years.

Students stood out in the age given to the 102 wine, with a difference from the actual age of approximately 13 years.

Table 4.11. According to each panel of tasters, the ages of each wine, and the differences regarding the real age. Bold numbers indicate age differences over 10 years.

Wine	Real age	Critics	Δ Age | critics	Oenologists	Δ Age | oenologists	Students	Δ Age | students
102	21	13	8	14.6	6.4	7.96	**13.03**
147	18	13	5	7.83	**10.17**	8.71	9.29
381	10	9.39	0.61	6.67	3.33	5.36	4.64
839	9	9.61	0.61	9.2	0.2	6.61	2.39
710	47	12.44	**34.56**	8.58	**38.42**	9.29	**37.71**
774	11	12.67	1.67	7.75	3.25	4.89	6.11
748	5	3.39	1.61	4.5	0.5	4.18	0.82
015	8	5.67	2.33	7.9	0.1	5.36	2.64
297	1	1.61	0.61	1.00	0	2.54	1.54
583	13	15.33	2.33	11.71	1.29	3.69	9.31
923	10	3.22	6.78	4.21	5.79	10.42	0.42
256	9	7.11	1.89	7.5	1.5	3.57	5.43
561	6	3.61	2.39	3.07	2.93	3.85	2.15
201	30	18.78	**11.22**	13.21	**16.79**	10.14	**19.86**
338	18	7.94	**10.06**	5.71	**12.29**	4.89	**13.11**
650	10	7.33	2.67	7.07	2.93	6.54	3.46
477	9	4.78	4.22	5.36	3.64	3.68	5.32
365	3	2.22	0.78	1.86	1.14	2.79	0.21
Age range	1-47	1-19	-	1-13	-	2-10	-

According to table 4.11 and figure 4.24, it is possible to verify that all wines were valued, being evaluated at a younger age than would be supposed, and the ones that obtained a better correlation were students, with r equal to 0.6806.

It should be noted that they were also valued even in wines from non-traditional regions due to their ageing capacity due to their lack of acidity (such as Alentejo).

A reasonable conclusion that can be drawn is that the chosen Portuguese white wines age well, according to figure 4.24.

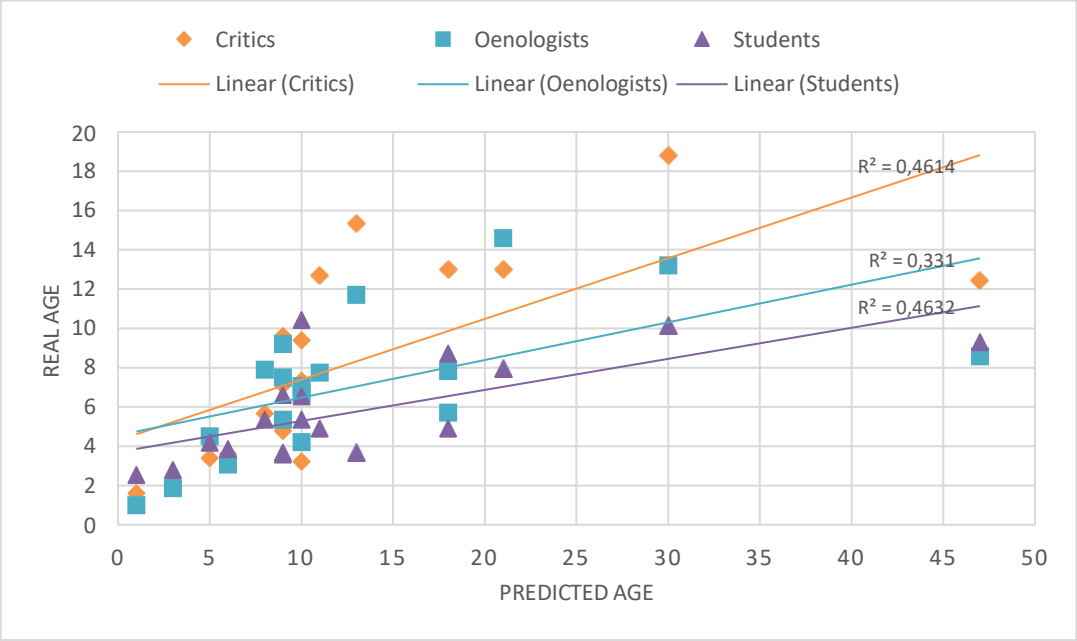

Figure 4.24. Correlation between the three panels' real age and predicted age of all wines.

4.7 Limitations of the study

The fact that each test panel had a small number of tasters greatly limited the analysis of results. This limitation was revealed in the significance of the results, being necessary, in the future, if to continue to study the effect of old white wines in panels of experienced tasters, it is necessary to resort to wine tastings with a more significant number of tasters per panel.

5. Conclusions and future prospects

The research objective focused on the type of treatment that panels with different types of experience faced with old white wines.

The behaviour of the tasters concerning the quality of the fulfilled wines was studied, studying whether the colour, aroma and skill capacity led to their behaviour in tasting or not.

The results induced that the tasters knew that the tasting would be of old white wines, influencing the tasting mode. The younger wines were harmed in the quality notes attributed to more experienced tasters' panels.

According to the prototype, critics and oenologists tasted what they had already thought of the wines.

It was expected that oenology students would negatively evaluate older white wines due to their lack of experience and knowledge, but this did not happen. Instead, they were able to distinguish the taste and quality of each wine, having been the panel that most distinguished themselves in this regard.

Complexity had a substantial impact on the quality assessment of each wine. It is interesting to see how each panel defines the complexity of each wine differently.

The wines were globally described as having a "ripe/matured/evolved" aromatic profile and "austere" in the mouth, with acidity, salinity, dry and persistent, consistent with the sensory characteristics of aged whites.

Empirically, most of the "mature" wines were those where age prediction was closer. On the contrary, wines with fresher notes and a more austere mouth were those where the forecast deviated further from the real age. This observation may explain why these wines were considered younger and demonstrate the consistency of the panel's tasting.

It was fascinating to find out how colour can have such an influence on the way wines are. For example, influencing different descriptors for each wine and, as such, it would be interesting to use black glasses for future work to understand if the expected results were the same or different to this study.

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Annexes

Annexe I

Figure i. Wine tasting at Instituto Superior de Agronomia, 14 of June, 2021.

Figure ii. Wine tasting at Instituto Superior de Agronomia, 14 of June, 2021.

Annexe I (continuation):

Figure iii. Wines presented at the wine tasting at Instituto Superior de Agronomia, 14 of June 2021.

Annexe II: Taste paper

ISA Event, Lisbon, 14 June 2021

Name: _____ **Age**: _____

Gender: F ☐ M ☐

E-mail: _____

Profession:_____

The years of experience:_____

Type of training in wines:

Informal ☐

University/Polytechnic ☐

WSET, CMS or equivalent course ☐

Other:_____

Taste Paper

Code sample:_____

Please describe the wine, with your own words:

Taste paper

Code sample: _____

1 – Please draw a mark on the scale according to your perception

Unfamiliar	How **familiar** are you with this wine? (does it remind you of wines you have already tasted)?	*Familiar*
A few	How **many flavours** can you identify in this wine?	*A lot*
Difficult	How **easy is it for you to identify** or describe the different flavours of this wine?	*Easy*
Not harmonious	Are the different sensations and flavours **harmonious**; do they go well together?	*Harmonious*
Unbalanced	Are the different sensations and flavours well **balanced**, without any being overpowering?	*Balanced*
Short	How long do the different sensations and flavours **linger** in your mouth?	*Long*
Weak	Are the sensations and flavours of this wine **strong and powerful**?	*Strong*

You have just described this wine; you know its characteristics.
Now we would like you to score its **overall complexity** on the scale below:

Low complexity — *High complexity*

In: Parr, W. V., Grose, C., Hedderley, D., Medel Marabolí, M., Masters, O., Araujo, L. D., & Valentin, D. (2020). Perception of quality and complexity in wine and their links to varietal typicality: An investigation involving Pinot noir wine and professional tasters. *Food Research International, 137*, 109423. https://doi.org/10.1016/j.foodres.2020.109423

Taste paper

2 - Which terms would you use to describe better the taste and mouthfeel sensation of the wine? Please, check 5 descriptors that apply.

- ☐ Body
- ☐ Length
- ☐ Viscosity
- ☐ Smoothness
- ☐ Acidity
- ☐ Dryness
- ☐ Other_____
- ☐ Saltiness
- ☐ Bitterness
- ☐ Sweetness
- ☐ Roughness
- ☐ Sourness
- ☐ Astringency

3 - Which terms would you use to describe better the aroma of the wine? Please, check 5 descriptors that apply.

- ☐ Beeswax
- ☐ Bruised Apple
- ☐ Butter
- ☐ Caramel
- ☐ Chamomile
- ☐ Citrus
- ☐ Curry
- ☐ Dried Fruit
- ☐ Earthy
- ☐ Other_____
- ☐ Floral
- ☐ Fresh Fruit
- ☐ Honey
- ☐ Oak
- ☐ Petroleum/Kerosene
- ☐ Spicy
- ☐ Straw
- ☐ Wet Stone/Flint Stone

Please draw a mark on the liking scale according to your personal preference.

DISLIKE EXTREMELY ——— LIKE EXTREMELY

Please draw a mark on the scale according to your perception on the overall quality.

POOR ——— OUTSTANDING

4 – Predicted age of the wine: _____