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Exploring young consumers' attitudes and emotions to sensory and physicochemical properties of different red wines

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ABSTRACT

To gain deeper understanding on young consumers' attitudes and preferences to wines is needed to connect wine industry with the youth. The aims of the present study were (i) to define 'trendy wine' for young consumers and (ii) to identify chemical drivers of liking in red wines for the youth. The study was divided in two phases: phase I explored young consumers' attitudes towards wines using an online survey, and phase II studied the relationship between hedonic and emotional responses elicited by 12 red wine samples and their physico-chemical characteristics. Consumers' responses and physico-chemical data were related using Principal Component Analysis (PCA). Results of the online survey showed that trendy wines were associated to: *sparkling, soft, fresh, fruity, sweet, light*, and *balanced* wines. Also, young consumers reported that, although flavor was considered the most important attribute, price and Protected Designation of Origin could be valuable attributes. PCA results of phase II showed that wines with a lower ratio [total polyphenol index/polysaccharides] were more liked and elicited more positive emotions than wines with higher total polyphenol index, color intensity, volatile acidity, and alcohol content. Liking and positive emotions were positively related to higher Odor Activity Values of the volatile compounds from the organic acids group. The presence of benzenoids and lactones, and the lower presence of terpenoids & norisoprenoids were associated with negative emotions. In conclusion, red wines should be soft (described as lower ratio [total polyphenol index/polysaccharides]), and have floral, and fruity aromas to better connect with young consumers.

1. Introduction

Due to changes in the global drinking patterns and the boom of the wine industries around the world, wineries from the Old and the New worlds have been looking for new strategies to increase competitiveness in the market (Campbell & Guibert, 2006; Lesschaeve, 2007; Menghini, 2015). These strategies have been used for a wide variety of companies to promote a conscious selection of specific wines for target consumers (Menghini, 2015; Niimi et al., 2019). The different approaches/strategies used by the wine industry could be grouped in those related to: the product itself (intrinsic characteristics such as flavor, appearance, etc.), marketing (packaging, branding, etc.), and wine tourism strategies (cultural heritage, tradition, production system, etc.) (Campbell & Guibert, 2006; Hammervoll et al., 2014; Menghini, 2015).

Further studies have pointed out that most traditional wine producer countries are confronted to a decrease in wine consumption (Kevany, 2008; Smith & Mitry, 2007). However, this decline has not occurred across all age groups. It is the group of young people who have changed their attitude towards wines (Garcia et al., 2013; Melo et al., 2010; Silva et al., 2014). Specifically, red wine was the one that showed a greater reduction in consumption by young Spanish consumers (Garcia et al., 2013). Some authors have proposed developing wine products for specific markets segments by differentiating products according to their preferences and feelings (King et al., 2012; Lattey et al., 2010; Nguyen

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et al., 2020; Niimi et al., 2019). In fact, wine is a complex matrix that consumers do not perceive in the same manner (Yang & Lee, 2020). Styger et al. (2011) defined wine flavor as the result of multi-interactions between chemical components and sensory receptors. Sensory attributes such as aromas, bitterness or astringency may cause rejection in naïve consumers, whereas experienced consumers are able to appreciate them (Yang & Lee, 2020). Culbert et al. (2017) showed that young consumers preferred fruitier wines, while an older segment appreciated a more complex flavor profile in sparkling white wines. Garcia et al. (2013) corroborated that the youngest group preferred white and rosé wines, while the oldest group preferred red wines as a consequence of their complexity: white and rosé wines are in general considered lighter, fruitier and easier to drink than red wines. The aforementioned studies showed that young consumers are more dare to like white wines rather than red wines. However, considering the significant reduction of red wine consumption across the youth, it is important to investigate if there are specific sensory attributes or aspects belonging to red wines (expectations) that connect with young consumers. Up to date, there are no scientific evidences regarding the potential sensory traits of red wines preferred by young consumers.

Recently, both researchers and industry have shown interest in connecting wine and emotions to highlight product differences and the feelings that those could elicit in consumers (Niimi et al., 2019; van Zyl, 2016). The idea was to differentiate the product according to the elicited emotions on the consumer, rather than product sensory descriptors, production characteristics, price, or social consumption context (Barrena & Sanchez, 2009; Silva et al., 2016). Studies on the emotional response in beverages have demonstrated to be an important aspect in most cultures (van Zyl & Meiselman, 2016; Yang & Lee, 2020). Some investigations have demonstrated a relationship between wine sensory properties and emotional response (Ashton et al., 2017; Jiang et al., 2017; Mora et al., 2018; Ristic et al., 2019; Silva et al., 2016; Souza-Coutinho et al., 2020). Regarding the relationship between age and emotions, some studies have shown that young adults reported more extreme scores in food-evoked emotions, while old adults gave more neutral scores (den Uijl, Jager, de Graaf, et al., 2016; den Uijl, Jager, Zandstra, et al., 2016; Edwards et al., 2013; Montepare & Dobish, 2014; Mora et al., 2018). Also, other authors have found that older people reported more positive emotions than younger ones (Chaya et al., 2015; Dube et al., 2005; Mora et al., 2018; Piqueras-Fiszman & Jaeger, 2015). However, to the best of the authors knowledge, there are no studies in the literature that evaluate the relationship among sensory properties, physico-chemical compounds, and emotions triggered by red wines in young consumers.

Another strategy widely used by wineries for product differentiation and/or promotion is the marketing. Extrinsic factors such as brand, price and labelling can have a huge influence on the sale point (Danner et al., 2017; Garcia et al., 2013; Lockshin et al., 2006; Sáenz-Navajas et al., 2014). Lockshin et al. (2006) showed that consumers with low wine involvement considered price and award as useful information to evaluate the quality of the product, compared to consumers with high wine involvement. Sáenz-Navajas et al. (2014) showed that high-involved French and Spanish consumers were able to interpret a wider range of extrinsic cues (e.g.: *appellation*, awards, label and bottle design, bottling place, etc.), while low-involved consumers considered relevant easy-interpretable information such as country/region of origin. Danner et al. (2017) showed that both short description labels (sensory properties) and long description labels (wine quality, winery and vineyard information, etc.) significantly increased liking, positive emotions and willingness to pay by consumers. Also, Garcia et al. (2013) supported the importance of Protected Designation of Origin (PDO) as a guarantee of product quality recognized by the youth.

Beyond the intrinsic and extrinsic product characteristics, understanding young consumer attitudes toward wine is particularly relevant. In the study conducted by Silva et al. (2014), Portuguese and Dutch young consumers mentioned that they consumed wine mainly because of its alcohol content. However, they reported that possibly, in the near future, the product could be appreciated by them also by its sensory characteristics. The authors also found that young consumers considered wine as a "drink" for old people. Garcia et al. (2013) indicated that young consumes declared that wine was an "old-fashioned drink" being not suitable for going out. Therefore, identifying which characteristics might have a "trendy" wine for the youth, before and after tasting it, could be a key aspect to connect this consumer segment with the product.

Understanding young consumers expectations and identifying the key sensory and chemical aspects that better connect red wines with the target population could provide useful insights to the wine industry. With these ideas in mind, the main objectives of the present study were: (i) to investigate in a preliminary study the young consumer attitudes and beliefs regarding "trendy" wines (expectations), and (ii) to determine the relationship among physico-chemical composition and emotions triggered by red wines consumption in young consumers.

2. Material and methods

The protocol and procedures used in this study were approved by the Basque Culinary Center (BCC) scientific committee, which stated a waiver consent. All articles from the Declaration of Helsinki and the 2016/679 EU Regulation on the protection of natural persons regarding the processing of personal data and on the free movement of such data were met. Participants were assigned a unique code to ensure anonymity. The experimental procedure of each phase was explained, and a written consent form indicating voluntary participation was signed by all participants prior to beginning the study.

2.1. Phase I. Exploring young consumers' attitudes towards wine

2.1.1. Procedure

A 10 min online survey was developed to obtain preliminary results about young consumers attitudes, beliefs and expectations related to wines in general, and to determine which internal and external cues of wines are preferred. Young Spanish consumers were invited to participate via email using the BCCInnovation and Universidad Politécnica de Madrid (UPM) consumer databases. A total of 90 consumers (women = 51; 18–35 years old) replied the online survey which was divided into three sections: 1) sociodemographic, 2) wine habits (consumption frequency), and 3) conceptualization of an "ideal" wine (Fig. 1). The latter section included the following: free association task, rating of aspects by importance and Check-All-That-Apply (CATA) of red wine attributes.

To design the questionnaire, firstly, a discussion group was done with sommeliers and oenologists (n = 6) to generate a list of different sensory attributes usually present in red wines. Once this list was generated, a second discussion group was conducted with a group of 8 consumers, who had not participated in the online survey, aiming at reviewing the terms previously proposed by the experts and discussing potential modifications of those terms that could be difficult to be understood from a consumer perspective.

All the questions belonging to the "conceptualization of an ideal wine" were included with the aim of making the consumer to think, starting from a general point of view, with no mention at all about any specific type of wine (white, rosé, red, still or sparkling), and ending with a CATA question about the desired attributes to be found specifically in red wines. To assess what a "trendy" wine meant for the target young population, different strategies were used. First, a free association task was conducted on different terms intended to be potential synonyms and antonyms of a "trendy" wine. During this task, consumers were asked to write down all terms related to the concepts proposed by the research team and later on discussed with the consumer group (questionnaire design phase). The final labels/concepts were: "modern", "old/classic", "trendy/current", "yummy/appetizing", and "wine for the youth". Labels/concepts were randomly presented to each consumer. In

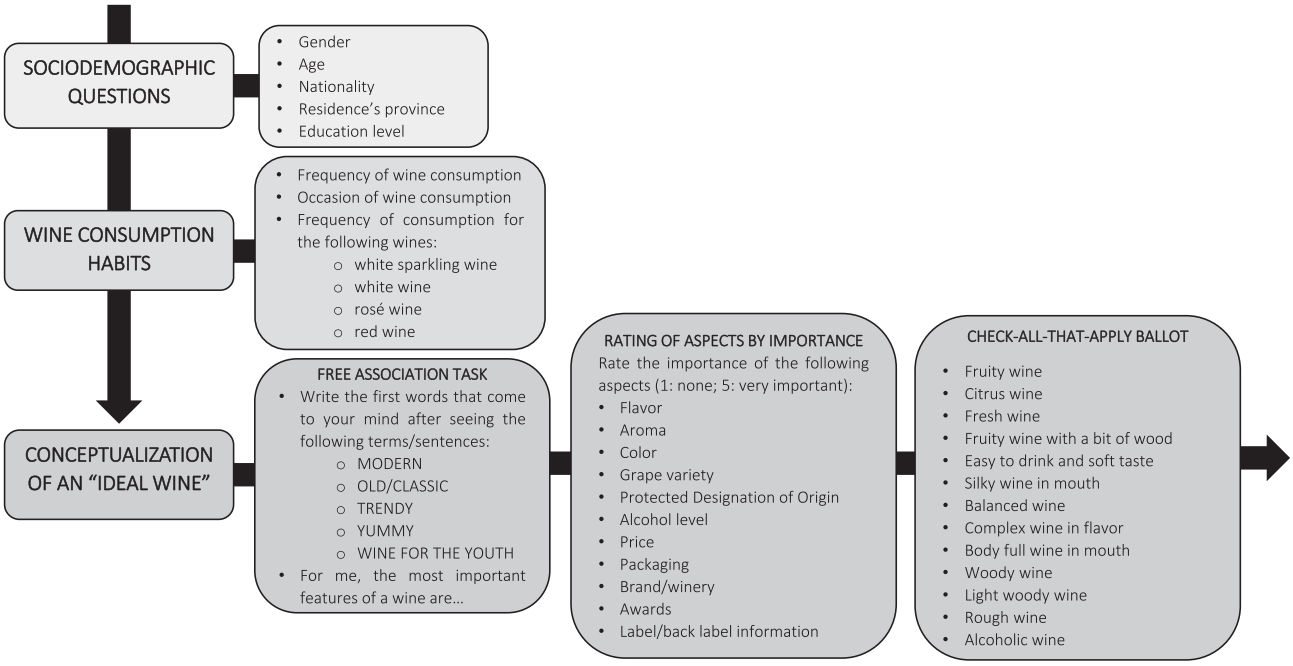

Fig. 1. Online survey flowchart developed to explore young consumers' attitudes towards wine.

the second question, consumers were asked to complete the following sentence with the first words that came to their minds: "For me, the most important features of a wine are…". The words obtained in this free association task were labelled as terms associated to "importance". Then, consumers were asked to use a 5-point structured scale (1 = none; 5 = very important) to rate the importance of different aspects related to extrinsic and intrinsic cues of wine. The evaluated aspects were flavor, aroma, color, grape variety, PDO, alcohol level, price, packaging, brand/winery, awards, and label/back label information. A Check-All-That-Apply (CATA) ballot was used aiming to identify which sensory attributes of red wines were interesting for young consumers. The attributes included in the CATA question were obtained from the discussion groups developed during the questionnaire design phase. The final attributes were the following: fruity wine, easy to drink and soft taste, silky wine in mouth, balanced wine, fresh wine, complex wine in flavor, body full wine in mouth, woody wine, fruity wine with a bit of wood, citrus wine, alcoholic wine, rough wine, and light woody wine. The CATA attributes were randomized for each consumer.

To analyze the information obtained in the free association tasks, different steps were carried out. Terms with similar meaning were grouped individually by two researchers. To reach a consensus between both researchers, a discussion about the synonyms was undertaken. Then, frequency counts on each elicited term were obtained. Data from the free association tasks (questions 1 and 2 of the survey) were organized in a contingency table where columns were the labels ("modern", "old/classic", "trendy/current", "yummy/appetizing", "wine for youth" and "importance") and the rows were the different consensus terms. This matrix was then submitted to Correspondence Analysis (CA). Ratings of the extrinsic and intrinsic cues of wine (flavor, aroma, color, grape variety, PDO, alcohol level, price, packaging, brand/winery, awards, and label/back label information) were analyzed by Analysis of Variance (ANOVA) followed by a Post hoc test (Tukey HSD). Significant differences were determined with a significance level of 0.05 unless stated otherwise. Both, CA and ANOVA were performed using XLSTAT (XLSTAT Version 2020.2.2, USA) (Addinsoft, 2019). Finally, CATA frequency counts were analyzed with a descriptive approach.

2.2. Phase II. Identifying key molecules. Relationship between physico-chemical properties and emotions elicited by red wines

2.2.1. Samples

Twelve Spanish commercial dry red wines (residual sugar < 2 g/L) were selected for this study. The selection of wines was done considering the following criteria: a) the most expanded and well-known PDOs by young population, b) some of the best-selling red wines in Spain, and c) price range of 8€-12€. The wines mainly differed due to the PDO and aging, with some of them having mannoproteins added (Table 1). All the wines were previously tasted by the winemakers and experts (n = 6) to exclude any wine with faults and/or taints.

2.2.2. Consumer study: Measuring hedonic and emotional response

Consumers from the UPM consumer database were invited to participate via email and using posters on campus. Recruitment criteria were the following: age (18–30 years old), culture (Spanish) and wine consumption frequency (at least once per month). A total of 96 Spanish consumers (women = 49 aged from 18 to 30 years old, mean = 22.99, SD = 2.99) were recruited.

Table 1
Description of the selected red wines.

Wine	Protected Designation of Origin (PDO)	Year	Oak barrels aging
W1	Rioja	2014	12 months
W2	Ribera del Duero	2016	12 months
W3*	Ribera del Duero	2016	6 months
W4	Ribera del Duero	2016	6 months
W5	Ribera del Duero	2014	12 months
W6	Ribera del Duero	2016	6 months
W7	Ribera del Duero	2016	6 months
W8**	Ribera del Duero	2016	6 months
W9	Ribera del Duero	2015	12 months
W10	Ribera del Duero	2016	6 months
W11	Ribera del Duero	2016	6 months
W12	Ribera del Duero	2016	6 months

* W11 + 50 mL/hL pure mannoproteins (Mannofeel®, Laffort® España, Spain).

** W7 + 50 mL/hL pure mannoproteins (Mannofeel®, Laffort® España, Spain).

Twelve wine samples (25 mL) were served into cylindric transparent glass universal containers (100 mL) closed with screw cap and presented to the consumers in two different sessions to avoid sensory fatigue and carry-over effects. Wines were labelled with 3-digit random codes and presented simultaneously in a random order using a Complete Balanced Block design. An additional warm-up sample was used to minimize the first position effect (Dorado, Pérez-Hugalde, et al., 2016). To evoke a wine consumption context, two types of questions concerning wine consumption habits were asked as proposed by Dorado, Chaya, et al. (2016): (i) three multiple choice questions about usual location, time of the day and company when drinking wine, and (ii) an open question in which consumers were required to remember and describe in detail the context of an usual occasion when drinking wine.

After tasting each wine sample, consumers were asked to rate their liking using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely). Then, they were asked to rate the emotions elicited by each sample. To measure the emotional response elicited by wines, the lexicon II developed by Mora et al. (2020) for Spanish wine consumers, composed by 15 emotional categories, was used (Table 2). Participants had to read all the terms associated with each emotion category and rate the intensity of the evoked feelings by each wine using an unstructured linear scale (850 pixels, ≈ 10-cm linear scale), anchored from 'very low' to 'very high'. Prior to the test, they were instructed to focus on their feelings associated to each specific sample and not to their general mood. Data was collected with tablets using Compusense® Cloud software (Compusense Inc., Guelph, Ontario, Canada). To minimize bias, the order of the emotion categories was randomized for each consumer, but each consumer had the same order throughout the evaluation session. Mineral water and breadsticks were provided as palate cleansers.

ANOVA followed by Post hoc test (Tukey HSD) were carried out on liking and each emotional category. Significant differences were determined with a significance level of 0.05. Principal Component Analysis (PCA) based on the correlation matrix was performed on the average ratings of each emotional category to explore the relationships between emotional categories and wines. Liking was used as a supplementary (non-active) variable in the analysis. HCA (Hierarchical Cluster Analysis) was carried out using the averages of each emotional category per wine. The cluster analysis was based on the Euclidean distance, and the Ward algorithm was used as the agglomerative method. All statistical analyses were done using XLSTAT (XLSTAT Version 2020.2.2, USA) (Addinsoft, 2019).

Table 2
Lexicon II developed by Mora et al. (2020) and used in the present study.

Categories	Terms
SLEEPY	Sleepy
Adormilado	*Adormilado*
AFFECTIONATE	Affectionate/Loving/Warm/Sentimental
Afectuoso	*Afectuoso/Amoroso/ Cálido/Cariñoso/ Romántico*
LUCKY	Lucky/Grateful/Comfortable
Afortunado	*Afortunado/Agradecido/ Confortado*
JOYFUL	Joyful/Glad/Happy/Excited
Alegre	*Alegre/Contento/Feliz/ Ilusionado*
CHEERFUL	Cheerful/Friendly/Good
Animado	*Amigable/Animado/Bien*
CURIOUS	Curious
Curiosidad	*Curiosidad*
DESIROUS	Desirous/Anxious/Excited/Pleasure/Positively surprised
Deseoso	*Ansioso-deseoso/Emocionado-entusiasmado/Excitado/Placer/ Sorprendido positivamente*
DISPLEASED	Displeased/Disgusted/Confused/Discontent/Indifference/
Disgustado	Weird/ Negatively surprised
	Asqueado/Confuso/Desagradado/Descontento/Disgustado/ Indiferencia/Raro/Sorprendido negativamente
FUN	Fun/Energetic/Euphoric/Playful/Strong
Divertido	*Divertido/Enérgico/ Eufórico/Fiestero/Fuerte*
NOSTALGIC	Nostalgic/Melancholy/Yearning
Nostálgico	*Añoranza/Melancólico/ Nostálgico*
REFRESHED	Refreshed
Refrescado	*Refrescado*
RELAXED	Relaxed/Calm/Carefree/Serenity/Quiet
Relajado	*Calmado/Despreocupado/Relajado/Sereno/Tranquilo*
SATISFIED	Satisfied/Pleased/Safe
Satisfecho	*Complacido/Satisfecho/Seguro*
SENSITIVE	Sensitive
Sensible	*Sensible*
SADNESS	Sadness
Tristeza	*Tristeza*

Terms in Spanish were back translated to English.

2.2.3. Analytical characterization

After the emotional evaluation of the 12 wines, those which elicited emotions that differed the most were selected for the physico-chemical analyses: W1, W3, W5, W6, and W11. The physico-chemical analyses were conducted by the wine analysis laboratory SARCO IBERICA (Logroño, Spain) as explained below.

2.2.3.1. Oenological parameters. The five selected wines were characterized, determining: pH, volatile acidity, total acidity, total and free SO_2 content, color intensity and tonality, alcohol content, total polyphenol index and total polysaccharides. The methods used are detailed below. All measurements were done in duplicate.

- **pH** was determined using a GLP 21 Hach pH-meter ATSeries1000 (OIV Method, OIV-MA-AS313-15).
- **Volatile acidity** was determined by the acetate and pyruvate kinase, lactate dehydrogenase assay using Biosystems Y15 analyzer (Biosystems, Barcelona, Spain). The enzymatic kit (Biosystem, Barcelona, Spain) was used following the instructions of the manufacturer.
- **Total acidity** was measure by titration (OIV method, OIV-MA-AS313-01).
- **Free and total SO_2 content** were analyzed by titration (OIV methods, OIV-MA-A323-04A1 and OIV-MA-A323-04A2).
- **Color intensity and tonality**: the optical density at 420 nm, 520 nm, 620 nm (color intensity) and the ratio 420 nm/520 nm (color tonality) was determined using a spectrophotometer (Unicam UV500 spectrophotometer, Thermo Spectronic, UK) as described in Glories (1984). A blank was prepared using distilled water instead of the wine solution.
- **Alcohol content** was determined by Fourier-transform infrared (FTIR) spectroscopy as described in Patz, Blieke, Ristow, & Dietrich (2004).
- **Total polyphenol index**: the absorbance at 280 nm of diluted wine 1/100 (v/v) was measure using 1 cm quartz cellar as described in Ribéreau-Gayon, Glories, Maujean, & Dubourdieu (2006) (Unicam UV500 spectrophotometer, Thermo Spectronic, UK). A blank was prepared using distilled water instead of the wine solution.
- **Total polysaccharides**: an aliquot of wine sample (0.5 mL) was added to 2.5 mL of 5% acidified ethanol solution (1% HCl) and stored at 4 °C for 24 h. After centrifugation, precipitated polysaccharides were redissolved in warm water and then 0.5 mL of phenol (5%) + 2.5 mL of concentrated sulfuric acid were directly added. After 5 min over boiled water, the absorbance was determined at 490 nm in a spectrophotometer (Unicam UV500 spectrophotometer, Thermo Spectronic, UK). A blank was prepared using distilled water instead of the wine solution. The amount of sugars was determined by reference to a standard curve prepared with solutions containing D-glucose (DuBois et al., 1956).

2.2.3.2. Volatile compounds analysis. Volatile compounds were determined by headspace solid phase microextraction (HS/SPME) and gas chromatography (GC Agilent 8890, Agilent, Folsom, California, USA) coupled to a mass spectrometer (MS: Agilent 5977B quadrupole mass

detector) using the method described by Welke et al. (2012). The separation of compounds was performed using a DB-WAX column (0.25 μm/0.25 mm/60 m) (Agilent, Folsom, California, USA) with Helium carrier gas at a flow rate of 2 mL/min. The desorption of the SPME fiber was conducted in automatic injection port (CTC Pal RS) at 270 °C during 5 min, and the detector was at 230 °C running in SIM (single ion monitoring) mode at 70 eV. The oven ramp was: 40 °C during 3 min, and then a rise of 3 °C min^{-1} until reaching 220 °C, temperature which was kept constant during 5 min. Fifty-three volatile molecules were identified using the NIST05 spectral library and also commercial standards of the pure chemicals (Merck Darmstadt, Germany). All compounds were quantified using calibration curves made from the different pure standards.

To study the relationship between the volatile profile and perceived aroma, the odor activity value (OAV) was calculated: the concentration of each volatile molecule was divided by the perception threshold of each compound according to existing bibliography (Boidron et al., 1988a, 1988b; Cheng et al., 2015; Etiévant, 1991; Ferreira et al., 2000; Gómez-Míguez et al., 2007; Guth, 1997; B. Jiang & Zhang, 2010; Peinado et al., 2004; Pérez-Olivero et al., 2014). Then, the molecules detected in the five wine samples (W1, W3, W5, W6 and W11) were grouped into the following volatile compounds families: (1) acids, (2) aliphatic alcohols, (3) benzenoids, (4) carbonyl compounds, (5) esters, (6) lactones, and (7) terpenoids & norisoprenoids (**Table A.1** in **Supplementary material**) , as proposed by Panighel & Flamini (2014).

Data resulting from the oenological parameters and volatile compounds per aroma families are presented in Table 4.

2.2.4. Relationship between emotions and physico-chemical compounds

To study the relationship of emotional map of the wines and its physico-chemical composition, Principal Component Analysis (PCA) was carried out on the means of the discriminating emotional variables, using analytical data and hedonic response as supplementary variables.

3. Results

3.1. Phase I. Exploring young consumers' attitudes towards wine

Results of the preliminary online survey provided information about sensory characteristics and extrinsic aspects of wines preferred by the young population. After the consensus stage to identify synonyms, more than 50 different terms were elicited in the free association task for the different five labels presented to consumers ("modern", "old/classic", "trendy/current", "yummy/appetizing", and "wine for the youth"). Correspondence Analysis (CA) was performed to get a visualization of the associations between labels and terms used by young consumers. The first two principal components of the CA accounted for 69.68% of the data variance. CA showed the terms associated to "trendy", "yummy", "youth" and "modern" wines and therefore preferred by young consumers, and terms not expected in those wines being associated with "old/classic" wines (Fig. 2). It can be observed that the first principal component or horizontal axis divided terms intro desirable attributes related to "trendy" wines, and non-desirable attributes related to "old/classic" wines. Some labels were abstract or conceptual terms such as *chic* and *different* which were close to "modern" or *occasion* and *company* which were close to "trendy". Terms related to sensory attributes were also identified. Fig. 2 shows that characteristics such as *sparkling*, *soft*, *fresh*, *fruity*, *sweet, light, balanced* were distributed closer to "trendy" wines, whereas characteristics such as *wood*, *rough*, *strong*, or *bitter* were linked to "old/classic" wines. Also, CA showed some information about which of the wine parameters were considered important by young consumers. Terms related to the question "For me, the most important feature of a wine is…", labeled in Fig. 2 as "importance", were *flavor*, *aroma/smell*, and *soft,* which also were the most cited. This result demonstrated that although price is important for the youth, it is not the most relevant aspect.

In the same line with the results obtained in the second part of the free association task, importance ratings of intrinsic and extrinsic

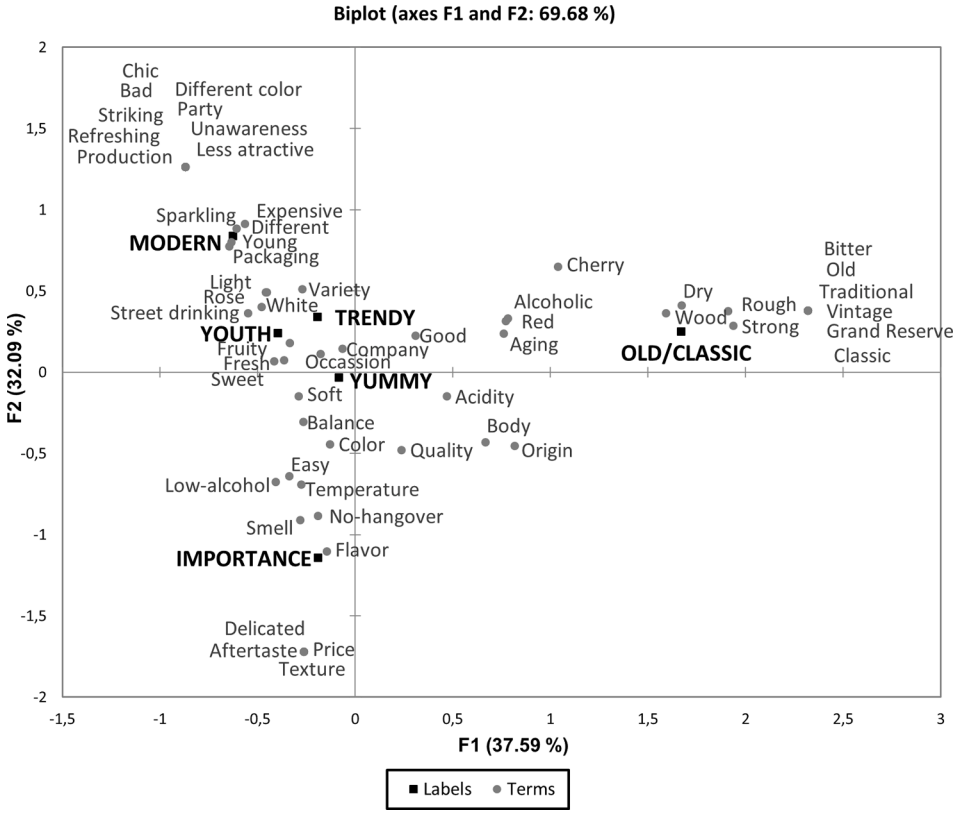

Fig. 2. Representation of the free association task in the first two dimensions of the Correspondence Analysis.

aspects of wine showed that *flavor* was the most important characteristic followed by *aroma, price* and *PDO* (Table 3). On the contrary, characteristics such as *awards* and *alcohol level* were the least important aspects for the youth, therefore they were not considered important enough within this age segment.

Regarding the attributes considered to be interesting in red wines for the youth, Fig. 3 shows the citation frequency of attributes in the CATA question. More than 50% of respondents indicated that *fruity wine*, *easy to drink/soft taste*, *silky wine in mouth*, *balanced wine*, and *fresh wine* were the most interesting attributes in red wines (Fig. 3).

3.2. Phase II. Identifying key molecules. Relationship between physico-chemical properties and emotions elicited by red wines

The first step to understand which physico-chemical property drove liking and could be correlated to elicited positive emotions was to analyze hedonic and emotional response evoked by the 12 red wines. Results of the consumer test showed that a significant effect of wine was found on the hedonic response (Table 5). Post hoc rest revealed that wines 1 and 6 were the most liked wines, whereas wines 5 and 9 were the most disliked ones. Regarding the emotional response, univariate analysis showed that most of the emotional categories studied (10 of 15) were significantly different among the samples: AFFECTIONATE, CHERFUL, CURIOUS, DESIROUS, DISPLEASE, FUN, JOYFUL, LUCKY, RELAXED and SATISFIED (Table 5). Post hoc analyses identified different wine groups for each emotional category.

A Principal Component Analysis (PCA) was performed to allow the visualization of which emotions were related to each wine. Fig. 4 shows the biplot of the first factorial plot, which explains the 83.14% of the data variance. PC1 divided wines according to the valence of emotions being positively correlated to positive emotions (correlation index between each variable and PC1 are indicated in brackets): AFFECTIONATE (0.923), LUCKY (0.891), JOYFUL (0.920), CHERFUL (0.935), CURIOUS (0.954), DESIROUS (0.958), FUN (0.940), REFRESHED (0.807), RELAXED (0.895) and SATISFIED (0.969) as well as to liking (0.948). PC1 is also negatively correlated to negative emotions such as SADNESS (-0.802) and DISPLEASED (-0.933). Although PC2 explains 11.58% of the data variance, it is important to note that wines were mainly divided according to PC1. Fig. 4 also shows the grouping of wines resulting of the HCA. Wines 1 and 6 were in the same group characterized by evoking a positive emotional and hedonic response, whereas wine 5 was in another group highly related to SADNESS and DISPLEASED emotional categories. The two other remaining groups were in an emotional "limbo", triggering middle scores in all emotional categories. One of them grouped wines 8, 12, 7, 11, 9, 2 and 10 (evoking a neutral-slightly more negative response), and the other one clustered wines 3 and 4 (evoking a neutral-slightly more positive response).

To understand the relationship between physico-chemical parameters and elicited emotions, at least one wine of each of the different clusters identified in the HCA were selected. Wines with the highest scores in positive emotions and the most liked (wines 1 and 6), as well as the wine with the highest scores in negative emotions and most disliked (wine 5), were selected for further physico-chemical analysis. Also, wines 3 and 11 were selected as representative of the central clusters. Fig. 5 shows the biplot of a new PCA based on the correlation matrix of the emotional response elicited by the five selected wines, using liking plus analytical parameters as supplementary variables. PC1

Table 3
ANOVA and Tukey test results of rating of aspects by importance.

Aspects	Mean
Flavor	4.856 a
Aroma	4.144b
Price	4.044b
PDO	3.689 bc
Color	3.533 cd
Packaging	3.433 cde
Label/Back label	3.411 cde
Brand	3.211 de
Grape variety	3.200 de
Alcohol level	3.067 e
Awards	3.044 e
p-value	**<0.0001**

Different letter indicates different post-hoc groupings by Tukey's HSD ($p \leq 0.05$).

Table 4
Means and standard errors of the different oenological parameters evaluated in the analytical characterization of wines, and means of the volatile compounds family.

	Wines W1	W3	W5	W6	W11
Oenological parameters					
pH	3.69 ± 0.01	3.72 ± 0.02	3.62 ± 0.02	3.67 ± 0.01	3.71 ± 0.02
Volatile acidity (g/L)	0.45 ± 0.08	0.71 ± 0.02	0.63 ± 0.06	0.58 ± 0.05	0.70 ± 0.06
Total acidity (g/L)	5.1 ± 0.3	5.2 ± 0.3	5.3 ± 0.2	5.4 ± 0.3	5.2 ± 0.2
Free SO_2 (mg/L)	5 ± 2	7 ± 1	10 ± 2	13 ± 2	8 ± 1
Total SO_2 (mg/L)	48 ± 2	29 ± 4	48 ± 2	39 ± 3	31 ± 4
Color intensity	9.53 ± 0.01	11.90 ± 0.01	12.24 ± 0.06	10.67 ± 0.16	11.78 ± 0.07
Tonality	0.91 ± 0.01	0.84 ± 0.02	0.87 ± 0.07	0.82 ± 0.10	0.83 ± 0.03
Alcohol content (% v/v)	13.55 ± 0.15	14.10 ± 0.10	14.50 ± 0.10	14.10 ± 0.10	14.10 ± 0.16
Total polyphenol index (TPI) (mg/L)	48.3 ± 3.2	59.4 ± 2.5	59.8 ± 3.1	51.4 ± 1.7	53.7 ± 2.9
Polysaccharides (mg/L)	656 ± 7	824 ± 9	646 ± 2	802 ± 5	584 ± 4
Ratio [TPI/polysaccharides]	7.36	7.21	9.26	6.41	9.20
Volatile compounds *					
Acids	216.23	128.19	160.67	169.97	127.13
Aliphatic alcohols	1.12	19.75	16.98	19.81	21.20
Benzenoids	11.96	9.47	16.43	11.45	10.09
Carbonyl compounds	2.25	1.93	0.98	1.02	1.20
Esters	131.85	164.41	168.43	177.98	166.09
Lactones	2.41	1.44	3.53	1.07	1.46
Terpenes and norisoprenoids	26.86	32.79	16.66	32.63	38.20

* The values were calculated by summing the odor activity value (OAV) of each aroma compound belonging to the same aromatic family.

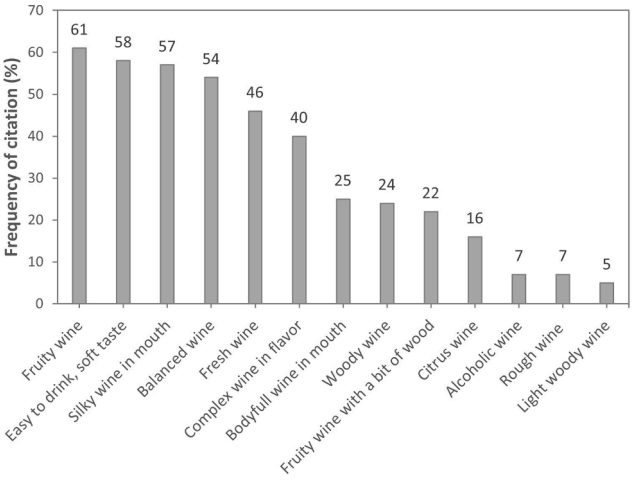

Fig. 3. Ranking of frequency counts of the CATA question.

Table 5
p-values and mean scores for liking and 15 emotion categories across the 12 wine samples.

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	p-value
Liking	5.632 a	4.926 ab	5.189 ab	5.200 ab	4.253b	5.621 a	4.895 ab	4.863 ab	4.611b	4.684 ab	4.895 ab	4.947 ab	<0.0001
AFFECTIONATE	4.975 a	3.459b	4.781 a	3.566b	2.825b	4.913 a	3.373b	3.421b	3.353b	3.395b	2.824b	3.105b	<0.0001
CHERFUL	4.712 a	3.805 ab	3.984 ab	3.928 ab	3.305b	4.328 ab	3.586 ab	3.802 ab	3.415b	3.827 ab	3.522b	3.756 ab	0.005
CURIOUS	4.346 a	3.772 a	3.956 a	4.049 a	3.460 a	4.558 a	3.548 a	3.641 a	3.632 a	3.707 a	3.491 a	3.673 a	0.045
DESIROUS	4.244 ab	3.420 abc	3.519 abc	3.535 abc	2.573c	4.492 a	3.194 bc	3.476 abc	3.244 bc	3.295 bc	2.777c	3.357 bc	<0.0001
DISPLEASED	2.588 bc	3.684 ab	3.443 abc	3.199 abc	3.992 a	2.295c	3.569 abc	3.469 abc	4.120 a	3.764 ab	3.555 abc	3.386 abc	<0.0001
FUN	4.633 a	3.639 abc	3.572 abc	3.680 abc	2.831c	4.368 ab	3.539 abc	3.751 abc	3.440 bc	3.543 abc	3.393 bc	3.499 bc	<0.0001
JOYFUL	4.957 a	3.763 bcd	4.529 ab	3.768 bcd	2.709 d	4.626 ab	3.603 bcd	3.680 bcd	3.160 cd	3.635 bcd	3.426 cd	3.954 abc	<0.0001
LUCKY	4.527 a	2.862 bc	3.503 ab	3.469b	2.414c	4.552 a	2.789 bc	3.456 bc	3.555 ab	3.403 bc	3.451 bc	3.462 bc	<0.0001
NOSTALGIC	3.306 a	3.137 a	3.186 a	3.035 a	3.186 a	3.191 a	3.015 a	3.091 a	2.927 a	2.824 a	2.918 a	3.116 a	0.987
REFRESHED	3.452 a	2.697 a	2.991 a	3.119 a	2.791 a	3.524 a	3.206 a	3.167 a	3.052 a	3.102 a	2.898 a	3.027 a	0.460
RELAXED	4.474 ab	4.062 ab	4.460 ab	4.066 ab	3.707b	4.929 a	3.784 ab	3.833 ab	3.833 ab	3.739 ab	4.079 ab	3.838 ab	0.018
SADNESS	2.279 ab	2.451 ab	2.756 ab	2.636 ab	3.108 a	1.774b	2.597 ab	2.733 ab	2.498 ab	2.554 ab	2.759 ab	2.747 ab	0.085
SATISFIED	4.843 a	3.613 abc	4.313 abc	4.000 abc	3.374c	4.729 ab	3.718 abc	3.788 abc	3.755 abc	3.544 bc	3.758 abc	3.620 abc	<0.0001
SENSITIVE	3.471 a	3.032 a	3.424 a	3.196 a	3.155 a	3.504 a	3.198 a	3.280 a	3.277 a	2.649 a	3.209 a	3.218 a	0.667
SLEEPY	2.858 a	2.588 a	3.096 a	3.040 a	2.965 a	2.815 a	3.016 a	3.159 a	2.600 a	2.687 a	2.841 a	2.823 a	0.872

Different letters within the same row indicate different post-hoc groupings by Tukey's HSD ($p \leq 0.05$).

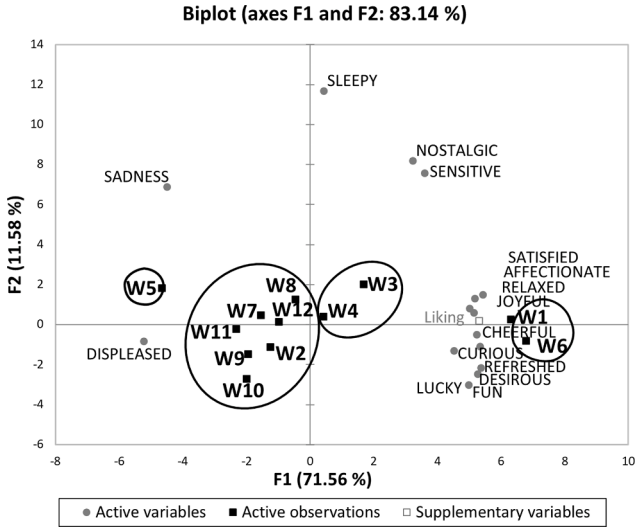

Fig. 4. Biplot of the PCA of emotion categories elicited by the 12 red wines (liking as supplementary variable).

and PC2 explained the 93.67% of the data variance. The resulting map (Fig. 5) was very similar to the one observed in Fig. 4, but Fig. 5 allowed a better visualization of active and supplementary variables to understand the relationship between oenological parameters, volatile compounds families and emotions with wines. According to their proximity in Fig. 5 and Pearson Correlation Coefficients, parameters such as polysaccharides were positively correlated with positive emotions (e.g.: AFFECTIONATE = 0.728) and liking (0.881), whereas negative emotional categories such as DISPLEASED were positively related to total polyphenol index (TPI) (0.824), color intensity (0.857), volatile acidity (0.659) and alcohol content (0.678) (Fig. 5). However, Table 4 shows that not all the wines with a higher content on polysaccharides were the most liked ones. The ratio [TPI/polysaccharides], which calculate the relationship between antagonist and sensory related parameters, was positively related to a negative consumer response (e.g.: DISPLEASED = 0.843). Wines with high ratio values elicited lower scores in liking and positive emotions' categories, and higher scores in negative emotions' categories (Fig. 5). Regarding the volatile composition, Fig. 5 shows a positive relationship between positive emotions' categories and liking with the volatile compounds' families of acids such as isovaleric acid (e.g.: CHERFUL = 0.703), and carbonyl compounds such as phenylacetaldehyde (e.g.: JOYFUL = 0.683). On the contrary lactones such as c-whiskylactone were associated to negative emotions (DISPLEASED = 0.756). Table 4 shows that acids, esters and terpenoids & norisoprenoids were the aromatic families with higher OAVs across the wines. Specifically, wine 1 and wine 6 had higher OAV for acids, whereas wine 5 (disliked one) had for benzenoids. Yet, terpenoids & norisoprenoids were similar across the wines, except for wine 5 which presented lower values.

4. Discussion

The present study gathered information about young consumers' attitudes towards red wines and the relationship between physicochemical parameters and emotions triggered by red wine consumption in the youth. Findings of the present study suggest some suitable strategies to be applied to fully understand preferences of consumers segments and to design products for this target population.

Regarding the extrinsic factors of wine (*packaging, price, awards, PDO*, etc.) the present study showed that the most important aspects related to extrinsic characteristics for young Spanish consumers were *price* and *PDO*. The studies conducted by Lockshin et al. (2006), Mueller et al. (2010) and Chrea et al. (2011) were in line with the findings about the importance of the *price*. Those studies concluded that *price* was an important aspect to consider when buying wines, being also a strong driver of liking (Mueller et al., 2010). According to the *PDO*, Chrea et al. (2011) found that region of origin was one of the most important attributes for wine consumers. Likewise, García et al. (2013) and Sáenz-Navajas et al. (2014) in their studies about habits and preferences of young consumers found that country/region of origin was considered a relevant aspect highly associated with wine quality for both: young consumers and low/high wine-involved consumers.

In addition to the aforementioned extrinsic attributes, intrinsic characteristics such as *flavor* were also determinant to connect wine and young consumers. When young consumers were asked to define "trendy" or "modern" wines, sensory properties such as *sparkling, soft, fresh, fruity, sweet, light, balanced* were frequently cited terms. "Modern"

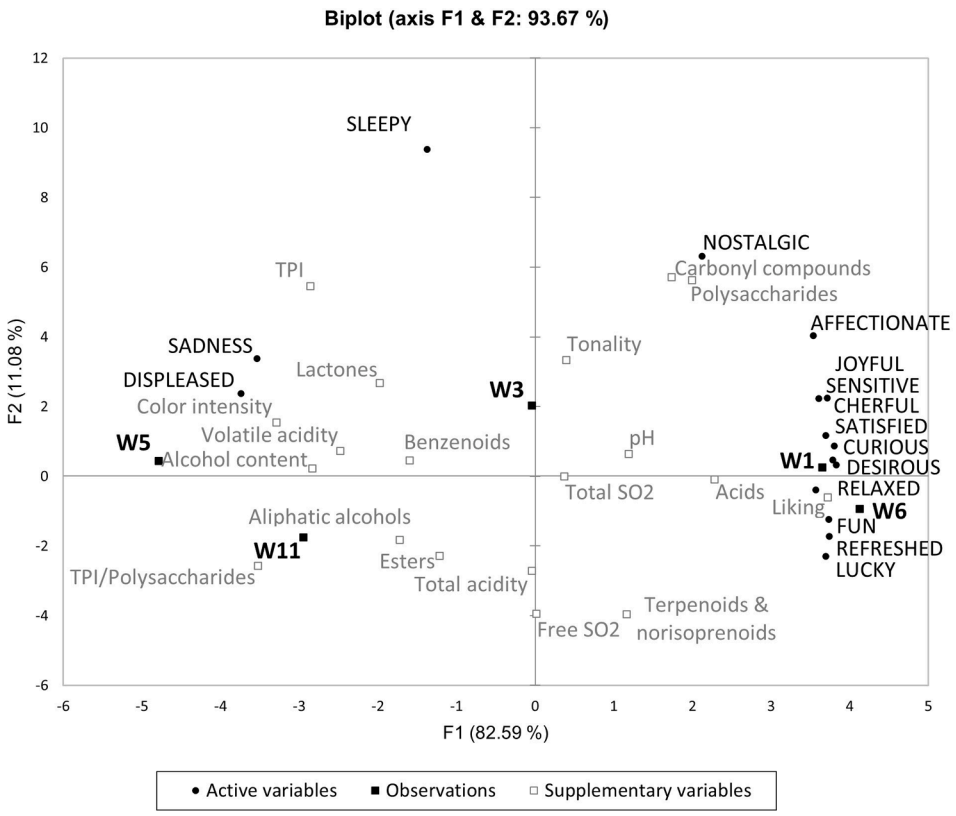

Fig. 5. Biplot of the PCA of emotion categories elicited by the five selected red wines (liking and physico-chemical characteristics as supplementary variables).

wines, with non-complex sensory properties, were also related to "yummy" and "youth" wines. This is associated with the fact that age and the previously lived experiences had an effect on wine preferences (Melo et al., 2010; Silva et al., 2014, 2017). Furthermore, in the study conducted by Silva et al. (2014), they concluded that young adults generally perceived that the older they are, the more interested in wine they will be, and therefore more complex wines they will be able to drink and enjoy.

Consumer studies have shown to be a suitable tool to understand consumers response and preferences. Specifically, hedonic and emotional response elicited by the consumption of wines have been very helpful to describe samples beyond liking, and to find relationships between wine aspects (extrinsic or intrinsic) and preferences/emotions (e.g.: Danner et al., 2016; Mora et al., 2018; Silva et al., 2016). The present study showed that both liking and emotional response were able to characterize the red wines. Most of the emotional categories of Lexicon II, from Mora et al. (2020), were discriminant among wines. Only the categories NOSTALGIC, REFRESHED, SENSITIVE and SLEEPY were not significantly different. Previous studies conducted on wine with Spanish consumers, showed that young consumers were more extreme and more discriminating in their emotional response among samples compared to their older counterparts (Mora et al., 2018). This behavior could explain the results obtained in the present study: less active emotional categories were less important for young consumers, and therefore, they did not discriminate those emotional categories. Also, a relationship between emotions and liking was found which are in line with previous findings: most liked wines elicited more positive emotions and feelings, whereas least liked wines elicited more negative emotions and feelings (Danner et al., 2016; Mora et al., 2018; Mora et al., 2020; Silva et al., 2018).

The present study showed some relations between physico-chemical parameters and consumers' response. Results showed that wines with a higher content of acids and carbonyl compounds were more liked and elicited more positive emotions compared to wines with a higher total polyphenol index (TPI), ratio [TPI/polysaccharides], color intensity, volatile acidity, alcohol content and lactones. In terms of aroma families, acids, esters and terpenoids & norisoprenoids presented greater OAVs across the wines (Table 4), but none of them fully described a well-defined relationship with emotional responses. Looking at individual molecules, however, some interesting aspects could be highlighted (**Table A.1** in **Supplementary material**). In the acid group, the compound with highest impact was the isovaleric acid, which presented the highest amount in wines 1 and 6, those with most positive hedonic and emotional responses. This finding is a bit surprising as isovaleric acid in high concentrations is usually associated with cheesy and "sweaty socks" notes. However, it is important to note that wines are complex matrixes in which the combination of different molecules can result in a specific aroma, and some molecules can even have masking effects, for example isovaleric acid on the detection of ethylphenols in wines (Romano et al., 2009). Regarding the benzenoids, β-Phenylethanol - floral notes (Francis & Newton, 2005) - was higher in wines 1 and 6, and lower in wines 5 and 11 which could explain the differences observed in the emotions. Yet, wine 5 had higher values of 4-ethylguaiacol and 4-ethylphenol, molecules associated with off-flavors in red wines (Cabrita et al., 2012), fact that can be related to the elicitation of negative emotions of this wine in the present study. Panighel & Flamini et al. (2014) sensorially described 4-ethylphenol and 4-ethylguaiacol as "stable", "animal" and "phenolic". In the present study, woody aromas coming from benzenoids were positively correlated to negative emotions, and therefore associated with wine 5. Carbonyl compounds were identified as a group with a positive relationship with liking and positive emotions (Fig. 5). In fact, wine 5 presented the lowest mean scores for this family (Table 4). However, this group presented lower OAVs in all samples being less present in the wines (Supplementary **Table A.1**). With respect to esters, in general, the compounds presented similar values (Table 4). It is well-known in the literature that esters are generally responsible for pleasant aromas, particularly fruity ones (Francis & Newton, 2005), but no clear relationship was identified

across these molecules and emotions towards the red wines evaluated. Regarding lactones, C-Whiskylactone was the molecule with highest OAV being associated with coconut and woody aromas (Kim et al., 2019), which are related to aromas due to the aging in barrels. Results of the present study shows that the higher presence of this compound (in wine 5) elicited a negative hedonic and emotional response in the youth. Finally, in the terpenoids & norisoprenoids group, β-Damascenone had higher OAVs and is associated with aromas such as ripe fruit and honey (Francis & Newton, 2005). Some studies have related polyphenols, polysaccharides, and its ratio, to liking and consumers' perception. Li, Bindon, Bastian, Jiranek, & Wilkinson (2017) and Niimi, Danner, Li, Bossan, & Bastian (2017) studied the effect of adding tannins and gum, or polysaccharides, on the perceived astringency of wines and on consumers' response. Both studies demonstrated that polyphenolic compounds, such as tannins predominantly extracted from skins and seeds of grapes, were associated to astringency or drying sensation in mouth. Also, Li et al. (2017) showed a negative association between the presence of polysaccharides and the perceived bitterness/astringency due to the presence of tannins. Niimi et al. (2017) showed that wines with higher concentrations in polyphenols received lower punctuations in liking and elicited negative emotions. Polyphenols interact between them and with other molecules such as polysaccharides during wine-making process. Mannoproteins, derived from yeast cells, are one of the most abundant polysaccharides present in wine; these compounds play an important role in the stability of wine and have a positive effect on the organoleptic characteristics, increasing the perception of fullness and body mouthfeels (Fernández et al., 2011; Li et al., 2018). The present study showed that the addition of mannoprotein to a wine sample (wine 3) had an impact on the emotional response: wine 3 evoked significant higher ratings for AFFECTIONATE and JOYFUL compared to wine 11 (original wine without mannoproteins). Moreover, the addition of mannoprotein also contributed to the reduction of the ratio [TPI/polysaccharides]. However, results from Niimi et al. (2017) showed that increasing body of wine through the addition of gum did not influence consumers liking or emotions. Therefore, due to the chemical relationship between the polyphenols and the polysaccharides, a possible approach for the wine industry could be investigating the ratio "[total phenolic content/polysaccharides]" to predict liking and the positive emotions which probably would be linked to wines with low ratio values. In the present study, wines 1 and 6, which received higher punctuations in emotions and liking, presented lower ratio [TPI/polysaccharides] compared to wines 5 and 11 that were the most disliked ones and elicited a higher negative emotional response. Future studies involving a higher sample size of consumers and a wider variation of wines should be considered to confirm the robustness of this ratio applicability and its relationship with consumers' response. So, translating the physicochemical compounds into sensory properties, results of the present study showed that soft/smooth wines with presence of floral and fruity aromas were more liked and elicited more positive emotions compared to acidic, astringent and alcoholic wines with presence of clove, coconut, leather and spice aromas, which were less liked and elicited more negative emotions.

Regarding liking, these results were in line with Lattey et al. (2010) which showed that higher liking scores were associated to red wines with high presence of fruity or flowery aromas and sweet/smooth mouthfeel, whereas lower liking scores were associated to barnyard/animal aromas, hotness/alcoholic and astringent/drying wines. Culbert et al. (2017) also found that young consumers preferred more fruit-forward style wines than wines with more complexity. Regarding the emotional response, similar results were found in the research conducted by Souza-Coutinho et al. (2020): wines defined as fruity and flavored were the ones that reported highest punctuations in *pleasant, desirable* and *joyful* terms, while wines characterized for being more complex and persistent received higher scores in negative emotions such as *aggressive*, *sickening* and *overwhelming*. In a previous work, Mora et al. (2018) found that Spanish consumers associated positive emotions with fruity and floral wine aroma attributes, and negative emotions with aged wine attributes such as vanilla, clove and licorice. Finally, to connect the results of phase I and II, it is important to mention that young consumers were not only able to emotionally discriminate wines due to the different sensory attributes of each wine, but also to identify how a "trendy" wine should be for the youth, and furthermore, define which sensory properties red wines might have to satisfy consumers of this age segment. Descriptors mentioned for trendy wines (*soft*, *fresh*, *fruity*, *sweet, light,* and *balanced)* and those preferred for red wines by young consumers (fruity, silky, fresh, easy to drink/soft and balanced wines) were the same as the ones that were identified in the physico-chemical analyses which triggered a positive emotional response in the consumer tests.

5. Conclusions

The study of the consumer attitudes, perceptions, and expectations related to wine allowed identifying which were the attributes that defined trendy wines for young consumers, and to specify which were the extrinsic and intrinsic attributes more interesting to be found in red wines for the youth.

The online survey and the study of the relationship between consumer response and physico-chemical compounds showed that red wines should be soft and have a fruit-forward style to better connect with young consumers. On the contrary, attributes such as astringency, acidity, high alcohol sensation, clove and animal aromas related to wood were rejected by young consumers reporting negative hedonic and emotional responses. Although flavor and aroma were the most important attributes for this consumer segment, the online survey also showed that the extrinsic characteristics *price* and *PDO* were considered as important aspects by young population.

Results of the present study showed a possible relationship between certain molecules and consumer response that can help the wine industry to understand, with caution, which chemicals are behind an emotional response, and therefore, the sensory properties perceived in a complex matrix such as wine. However, to stablish a robust relationship between wine molecules and consumers response, more research is needed considering different wines, a larger young consumers sample, and a descriptive sensory analysis. Another insight evidenced in the present study was the relationship between polyphenols and polysaccharides content. A study with a higher sample number should be considered to test the ratio [total phenolic content/polysaccharides] applicability and its relationship with consumers' response.

In the present study, red wines typically consumed in Spain (Tempranillo grapes) were selected. In order to fully understand young consumers' reactions to the sensory properties of wine with a wider perspective, further studies are necessary considering different cultures and red wines from other grape varieties.

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Declaration of Competing Interest

The authors declared that there is no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2021.110303.

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