



Sensory profile and check-all-that-apply (cata) as tools for evaluating and characterizing syrah wines aged with oak chips



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ABSTRACT

Aging wine in oak barrels provides more complexity to the beverage, but due to the high cost of wood barrels, alternative aging methodologies such as the use of oak chips gain interest of winemakers in the new world of wines, particularly in the tropical regions. This paper reports the sensory profile and consumer perception of Syrah wine produced in the São Francisco Valley, Brazil, with the addition of American and French oak chips at different stages of the fermentation process. Higher intensity of color, coffee, woody, and sweet/caramelized aromas, sweet and woody taste were observed in the age wines as compared to a control wine (no chip addition). An affective sensory test ($N = 129$) revealed two segments of consumers exhibiting different attitudes to the wines: one group ($N = 60$) rejected all samples, whereas the other ($N = 69$) liked them moderately. In short, the findings provide relevant information for stakeholders in the new world of wine where oak barrels impact negatively on the cost of production of wines, as is the case in Brazil.

1. Introduction

Wine represents a category of products capable of activating a variety of meanings and representations. According to Amine and Laccœuilhe (2007); Parr, Mouret, Blackmore, Pelquest-Hunt, and Urdapilleta (2011), wines are one of the most described beverages in the literature (Brochet & Dubourdieu, 2001). Directly related to the western culture (Mouret, Lo Monaco, Urdapilleta, & Parr, 2013) numerous countries make and sell wines being part of the so-called “old world of wine” – Europe - in comparison with the more recent producers or the “new world of wine” – Americas, South Africa and Oceania (Le Parisien, 2016).

Brazil is part of the new world of wine and has been making efforts not only to improve the quality and the internal consumption of Brazilian wines, but also to promote the product into the global market (Vieira, Watanabe, & Bruch, 2012). In this sense, the producers seek to consolidate regional identities, for example *Vale dos Vinhedos* and *Campanha Gaúcha* in southern Brazil, and invest in emerging locations such as the *São Francisco Valley*, in the states of *Bahia* and *Pernambuco* in the northeast part of the country (Niederle & Vitrolles, 2010). This is a semi-arid region characterized by high temperatures, high insolation rates, absence of winter and water supplied in abundance from the São

Francisco River (Pereira, 2013).

Syrah, is among the cultivars of *Vitis vinifera*, the varietal that better adapted to the edafoclimatic conditions of the region (Camargo, de Amorim, Guerra, & Lima, 2004), accounting for about 30% of the vineyards. Syrah of the São Francisco Valley produces wine with intense red color and fruity (plum, raspberry and gooseberry), violet and pepper aromatic notes. Syrah wines from the São Francisco Valley have also shown high phenolic compounds content, especially tannins which making them suitable for aging in wood (de Andrade, & Nascimento, L. S. Do, Pereira, G. E., Hallwass, F., & Paim, A. P. S., 2013; Lucena et al., 2010).

The influence of wood on wine aging is an interesting and controversial subject. Traditionally, oak wood is used because it is flexible enough to mount barrels, with little porosity, an acceptable level of tannins and mild aromatic impact. The oak barrels not only add aromas and tannins to the wine making it more complex, but also, because of their porosity, they allow the drink to breathe, develop and mature (Jackson, 2014).

Among the best species suited to the manufacture of barrels are the *Quercus alba*, also called American oak, *Quercus robur* and *Quercus petraea*, found in most of the French forests (Lona, 1996). While the American oak gives an aromatic note reminiscent of coconut and

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vanilla to the wine, the French oak, which is considered more sophisticated, passes to the wine different aromas that resemble coffee, spices and butter (Amerine & Singleton, 1984; Jackson, 2008). The geographic origins and species of wood (American: *Quercus alba* or French: *Quercus petraea*) improve the volatile profile and implied in different sensory characteristics; it could be more accentuated when the toasting chips are used (Schumacher, Alañón, Castro-Vázquez, Pérez-Coello, & Díaz-Maroto, 2013). The degree of toast of the wood may also contribute with roasted and smoked aromas (Koussissi et al., 2009). Wines aged in medium-toasted oak have richer vanilla and wood aromas, while wines aged in oak with light toast are characterized by vegetal aroma and have less intense sweet taste and higher astringency when compared to medium-toasted oak (Chira & Teissedre, 2015; González-centeno, Chira, & Teissedre, 2016).

Brazilian wineries and most of new world need to import oak barrels from North America and Europe, which has an impact on the cost of producing wine. An alternative is the use of oak chips, an economically more viable alternative for wines to gain or increased the complexity and aromas of the wood without suffering great impact of cost (Eiriz, Oliveira, & Clímaco, 2007). The chips can be put in contact with the wine in several stages, from the fermentation of the must until the wine is ready. In addition, they are either used in place of the aging period in barrels, or to supplement it, in cases when more intense influence of wood is desired. Although somewhat controversial, it is a valid artifice and, when used properly and consciously, satisfactory results may be obtained (Koussissi et al., 2009; Pizarro, Rodríguez-Tecedor, Esteban-Díez, Pérez-Del-Notario, & González-Sáiz, 2014; Tao, García, & Sun, 2014).

Notwithstanding investments in viticulture and technology, the per capita consumption of wine in Brazil remain low, reaching 2l, as compared to other South-American neighbors such as Chile (14.7l) and Argentina (31.6) (Almeida, Bragagnolo, & Chagas, 2015). Moreover, data from the *Instituto Brasileiro do Vinho* showed a decrease of 7.94% in the consumption of wines produced locally between 2016 and 2017, while wine imports rose by 39.1% (Ibravin & Do, 2017). This raises a question: do Brazilian consumers actually reject national wine and for what reasons? (e.g., sensory quality, product image, stereotypes?).

From the sensory point of view, traditional sensory methods such as Quantitative Descriptive Analysis (QDA) and acceptability testing (e.g. hedonic and JAR scales) have been used to reveal and quantify sensory characteristics as well as preferences and acceptability to wine (Behrens & Silva, 2000; Behrens, Silva, & Wakeling, 1999; Biasoto, Netto, Marques, & da Silva, 2014; Villanueva & Da Silva, 2009). Though affective methods are the most suitable way of assessing consumers' preference, the traditional descriptive methods, despite their validity and robustness for describing and quantifying sensory characteristics by means of trained or expert panels, demand a lot of time and effort to produce results (Cadena et al., 2014; Dehlholm, Brockhoff, Meinert, Aaslyng, & Bredie, 2012; Antúnez, Vidal, Saldamando, Giménez, & Ares, 2017). In this sense, novel and “quick” methods have gained interest among sensory and consumer scientists in the recent years like flash profile, napping and CATA (Check-all-that-apply) (Valentin, Chollet, Lelièvre, & Abdi, 2012).

CATA has shown as prominent tool to describe and differentiate samples in relation to their specific characteristics, helping in the identification of consumers' perceptions and preferences for food products and beverages (Ares, Deliza, Barreiro, Giménez, & Gámbaro, 2010), for its simplicity and ease to be applied with trained or untrained assessors (Ares, 2015; Meyners & Castura, 2014). CATA questions consist of a preselected list of terms from which respondents select all that they consider appropriate to describe a product. The data can be further analyzed by non-parametric tests based on the Chi-square distribution or correspondence analysis (CA) to obtain a perceptual map (Meyners, Castura, & Carr, 2013).

Vidal, Giménez, Medina, Boido, and Ares (2015) used CATA list comprising 44 terms to assess how consumers describe astringency in

red wine. Results showed that, although consumers' vocabulary seemed limited, they could accurately describe wine astringency being this sensation mainly related to dry and roughness sensations. In another research involving wine consumers in China, Corsi, Cohen, Lockshin, and Williamson (2017) performed an acceptance test along with a CATA to test the equivalence of flavor descriptors typically used for wine in Western countries with local descriptors for Chinese consumers. Generic descriptors (e.g., oaky, astringent, fruity, etc.) terms were used approximately three times more often than specific (e.g. vanilla, plum, green bell pepper) terms, and local specific descriptors were not selected consistently more often than the non-local (western) specific descriptors. These studies demonstrate the importance of assessing how the consumer perceives and describe wine. The CATA methodology is quick, simple, could be applied with trained or untrained assessors, and without the need of replication. The information generated is valid for the development of new products, and it is useful in conjunction with classic methodologies as sensory profile to provide more accurate results (Ares, 2015; Meyners & Castura, 2014).

The purpose of the present study was to determine the descriptive sensory profile and to evaluate the consumer perception of Syrah wine from the San Francisco Valley aged with and without (control) addition of American and French oak chips. This research is justified, since Brazil has been emerging as a producer in the world scenario and much is due to agronomic and technological research that make Brazilian wine more competitive. However, research that evaluates the sensory quality of Brazilian wine is fundamental to guide the decision-making of local producers, particularly regarding the quality and marketing of the product.

2. Materials and methods

2.1. Winemaking

Syrah grapes from Embrapa Tropical Semi-Arid vines situated at 09° 09' S, 40° 22' W, 365.5 m in the São Francisco Valley, Pernambuco, Brazil were harvested manually in the vineyard on July 2015 in their optimal ripening stage (25.99°Brix). After the harvest, the grapes were kept in a cold chamber for 10 h at 10 °C to decrease and stabilize the temperature. Sequentially, the grapes were destemmed and lightly crushed with the aid of a commercial destemmer and were transferred to a stainless-steel tank. Six batches of grapes were processed in a semi-industrial scale; maceration started with the addition of potassium metabisulfite (0.10 g L⁻¹) and pectinolytic enzyme Everintec® (0.008 mL L⁻¹). Commercial yeast Maurivin Consistent Quality® *Saccharomyces cerevisiae* (0.20 g L⁻¹) and activating Coatec® ammonium phosphate (0.20 g L⁻¹) were added to the must to start the alcoholic fermentation under controlled temperature (24 °C ± 2 °C) and 4 g L⁻¹ of American and/or French oak chips were added in the must. For the wines that receive the oak chip in the alcoholic and malolactic fermentations, chips were substituted for new ones prior to the malolactic fermentation. The oak chips were placed in nylon bags positioned at the center of the tank.

The oak chips tested were French oak chips (France/AEB-group) and it was 2.5 × 5.0 × 0.5 cm, 100% wood *Quercus Petraea*, with higher toasted. American oak chips (Italy/Everintec) dimensions was 2.5 × 2.0 × 1.0 cm; 100% wood *Quercus alba*, with medium toast. The quantities of the chips and degree of toast were determined according to the manufacturer's specifications and preliminary studies in the literature (Gordillo, Cejudo-Bastante, Rodríguez-Pulido, González-Miret, & Heredia, 2013; García-Carpintero, Sánchez-Palomo, & González Viñas, 2014).

The maceration processes with the skins and seeds were carried for all up to a maxi mean of 30 days. At this stage, the open pumping of 40% of the total volume of the tank was daily made, in order to promote homogenization. In the end of the alcoholic fermentation (20 days) was determined by measuring the density in electronic balance hydrostatic

model Super Alcomat (Gibertini, Milan, Italy), the skins and seeds were separated from the wine and pressed through pressing at 50 bar (Control Tech Automação). The wines were placed in a glass carboy container (20L) closed with cylindrical airlock glass valves with floating bubbler and the malolactic fermentation started naturally and it was temperature-controlled ($18\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$). Then, the wines received the oak chips; the treatments that received oak chips in the alcoholic fermentation had the chips replaced by new ones. The free concentration of sulfur dioxide levels in red wines were adjusted in 50 mg L^{-1} at the end of the malolactic fermentation, before starting stabilization (Ribereau-Gayon & Peynaud, 1980). The end of the malolactic fermentation was checked by paper chromatography (to determine the presence of malic acid) and the wines were further stabilized using Stabigum® AEB Group (mixture of gum arabic and metatartaric acid) (0.4 g L^{-1}), in cold chamber, to induce tartaric stabilization. At the end of this stage, the wine was subjected racking retain yeasts and suspended particles. The wine was bottled (750 mL), in bottles previously filled with nitrogen to prevent oxidation, and stored in a cellar at $18\text{ }^{\circ}\text{C}$ in horizontal position for 30 days until the analyses.

The color of the wines was determined using the CIELab and CIEL*a*b* systems where the parameters L* (luminosity), a* (green-red), b*(blue-yellow), h (hue angle) and C* (chroma) were measured in a Hunter Lab model Color Quest II spectrophotometer (Hunter Associates Laboratory, Reston, VA, USA). The equipment was calibrated with the illuminant D65, 10° hue angle and the RSIN calibration mode (Minolta, 1994). Finally, pH, total acidity, volatile acidity, alcoholic content, free and total sulfur dioxide, and reducing sugars were determined (triplicates) for all the samples according to the standard methods Association of Official Analytical Chemists (2007).

Table 1 summarized the winemaking and presents the physico-chemical characteristics of the wines.

2.2. Sensory evaluation

The protocols of the sensory studies were approved by the Ethics Committee of the University of Campinas, under the protocol (CAAE n° 34,586,014.9.0000.5404). All the subjects were properly informed of the objectives of the research and gave signed consent for their participation.

2.2.1. Descriptive sensory profiling

The sensory profile of the wines was performed in the Sensory Analysis Laboratory of Embrapa Semi-arid. Candidates for assessors were preselected based on recognition of basic tastes and aromas (Biasoto et al., 2014; Sánchez-Palomo, Trujillo, Ruiz, & Viñas, 2017). Afterwards, they were trained using the terms in the in Wine Aroma Wheel® to memorize the types of aromas regularly found in red wines (Noble et al., 1987). The panelists were asked to identify each reference and find the identical pattern in a second subset containing the same scents, but coded with different three-digit numbers. Thus, the Wine Aroma Wheel® standards were evaluated in several sessions until panelists correctly identified 100% of the standards presented. Finally the 12 assessors were chosen according to their ability of correctly identified the aromas.

The Kelly's Repertory Grid Method was applied to generate a list of descriptors (Moskowitz, 1983). For each session, were presented three samples and the assessors had to describe similarities and differences regarding appearance, aroma, taste, and mouthfeel. In subsequent sessions, the panel discussed the descriptors and consensually defined the 17 attributes that characterized the wines, their verbal definitions and references as shown in Supplementary Table S1.

Ten training sessions (1 h each) were performed for the assessors to learn the attributes having references of maximum and minimal intensity for each established attribute (Table S1). Also during the training, a 9-cm linear unstructured scale was presented to the panel as an instrument for measuring the intensity of each sensory attribute

Table 1
Color and physico-chemical composition of the Syrah wine aged with oak chip.

| Samples | Color | | | pH | Total Acidity (tartaric acid) (g L^{-1}) | Volatile acidity (acetic acid) (g L^{-1}) | Alcoholic content (% v/v) | Free sulfur dioxide (mg L^{-1}) | Total sulfur dioxide (mg L^{-1}) | Reducing sugars (g L^{-1}) | | |
|---------|-------------|--------------|-------------|-------------|---|--|---------------------------|--|---|---------------------------------------|--------------|-------------|
| | L* | a* | b* | | | | | | | | | |
| C | 3.01 ± 0.68 | 18.89 ± 0.98 | 3.23 ± 0.85 | 5.63 ± 0.85 | 18.51 ± 4.06 | 3.61 ± 0.07 | 6.50 ± 0.09 | 0.56 ± 0.07 | 13.43 ± 0.07 | 34.30 ± 0.51 | 74.24 ± 0.51 | 1.42 ± 0.02 |
| AAMF | 4.33 ± 0.48 | 27.01 ± 0.70 | 5.47 ± 0.24 | 5.42 ± 0.53 | 24.42 ± 6.67 | 4.04 ± 0.01 | 6.60 ± 0.00 | 0.76 ± 0.02 | 12.6 ± 0.06 | 33.28 ± 0.51 | 66.22 ± 0.59 | 1.66 ± 0.02 |
| AMF | 3.04 ± 0.29 | 18.88 ± 0.93 | 3.08 ± 0.38 | 5.88 ± 0.17 | 18.47 ± 1.78 | 4.05 ± 0.01 | 6.65 ± 0.17 | 0.74 ± 0.01 | 12.63 ± 0.23 | 30.55 ± 0.30 | 88.41 ± 0.59 | 1.59 ± 0.02 |
| FAMF | 2.79 ± 0.73 | 14.69 ± 0.23 | 3.11 ± 0.76 | 5.41 ± 0.02 | 17.31 ± 4.23 | 4.01 ± 0.01 | 6.50 ± 0.09 | 0.80 ± 0.04 | 12.90 ± 0.52 | 28.50 ± 0.59 | 70.48 ± 0.59 | 1.92 ± 0.12 |
| FMF | 3.98 ± 0.66 | 23.03 ± 0.77 | 4.32 ± 0.85 | 5.38 ± 0.29 | 23.76 ± 3.38 | 4.06 ± 0.02 | 6.65 ± 0.17 | 0.58 ± 0.11 | 13.35 ± 0.19 | 31.48 ± 0.26 | 62.63 ± 0.59 | 2.00 ± 0.04 |
| AFAMF | 3.37 ± 0.28 | 20.49 ± 0.37 | 3.39 ± 0.29 | 5.84 ± 0.87 | 20.12 ± 1.47 | 4.03 ± 0.01 | 6.95 ± 0.09 | 0.68 ± 0.02 | 13.15 ± 0.15 | 30.80 ± 0.30 | 80.90 ± 0.51 | 2.02 ± 0.02 |

C: Control wine without wood chip; AAMF: Wine with added American oak chip in both alcoholic and malolactic; AMF: Wine with added French oak chip in both alcoholic and malolactic; FAMF: Wine with added American oak chip in malolactic fermentation; FMF: Wine with added French oak chip in malolactic fermentation; AFAMF: Wine with added American and French oak chips in both alcoholic and malolactic fermentation.

Table 2

Attribute mean scores for appearance, aroma, taste/ﬂavor and mouth sensations for each sample of Syrah wine by the trained sensory panel ($N_1 = 10$ assessors. $N_2 = 3$ repetitions/sample).

| Descriptors | C | AAMF | AMF | FAMF | FMF | AFAMF | LSD* |
|--------------------|--------------------|---------------------|--------------------|--------------------|--------------------|--------------------|------|
| Appearance | | | | | | | |
| Wine Color | 6.06 ^{ab} | 5.39 ^b | 6.27 ^a | 5.74 ^{ab} | 5.94 ^{ab} | 6.32 ^a | 0.81 |
| Brightness | 5.70 ^a | 5.60 ^a | 5.16 ^a | 5.21 ^a | 5.47 ^a | 5.14 ^a | 0.91 |
| Aroma | | | | | | | |
| Aromatic intensity | 4.07 ^b | 5.35 ^a | 4.63 ^{ab} | 4.70 ^{ab} | 4.64 ^{ab} | 5.62 ^a | 1.00 |
| Alcoholic | 3.38 ^a | 3.27 ^a | 3.18 ^a | 3.14 ^a | 3.34 ^a | 3.30 ^a | 0.80 |
| Coffee | 0.73 ^{ab} | 1.17 ^{a,b} | 1.22 ^a | 0.64 ^{ab} | 0.44 ^b | 0.78 ^{ab} | 0.76 |
| Woody | 1.35 ^d | 5.20 ^a | 4.14 ^{ab} | 2.58 ^c | 2.68 ^c | 3.43 ^{bc} | 1.10 |
| Sweet/caramelized | 1.92 ^a | 2.22 ^a | 1.71 ^a | 1.73 ^a | 1.60 ^a | 1.99 ^a | 0.78 |
| Vegetal | 1.48 ^a | 1.03 ^a | 1.24 ^a | 1.38 ^a | 1.46 ^a | 0.77 ^a | 0.74 |
| Spicy | 1.23 ^a | 1.14 ^a | 1.29 ^a | 1.21 ^a | 1.30 ^a | 1.48 ^a | 0.64 |
| Taste / Flavor | | | | | | | |
| Taste persistence | 3.98 ^a | 3.67 ^a | 3.64 ^a | 4.23 ^a | 4.11 ^a | 3.78 ^a | 0.99 |
| Sweetness | 0.78 ^b | 0.96 ^b | 1.01 ^b | 1.14 ^b | 1.84 ^a | 1.12 ^b | 0.51 |
| Bitterness | 2.30 ^a | 1.71 ^a | 2.03 ^a | 1.97 ^a | 1.75 ^a | 1.74 ^a | 1.02 |
| Sourness | 2.59 ^a | 2.12 ^a | 2.29 ^a | 2.25 ^a | 2.23 ^a | 2.07 ^a | 0.90 |
| Alcoholic | 3.76 ^a | 3.31 ^a | 3.49 ^a | 3.73 ^a | 3.83 ^a | 3.18 ^a | 0.91 |
| Woody | 1.35 ^c | 3.15 ^{ab} | 3.5 ^a | 2.63 ^{ab} | 2.11 ^{bc} | 2.91 ^{ab} | 1.21 |
| Mouth sensations | | | | | | | |
| Astringency | 4.05 ^a | 3.62 ^{ab} | 3.74 ^{ab} | 3.82 ^{ab} | 3.02 ^b | 3.42 ^{ab} | 1.00 |
| Full-bodied | 3.36 ^a | 3.98 ^a | 3.56 ^a | 3.53 ^a | 3.31 ^a | 3.58 ^a | 0.97 |

Means in the same line showing common letters are not significantly different ($P \leq .05$) according to Tukey's test. *Least significant difference. C: Control wine without wood chip; AAMF: Wine with added American oak chip in both alcoholic and malolactic; AMF: Wine with added American oak chip in malolactic fermentation; FAMF: Wine with added French oak chip in both alcoholic and malolactic; FMF: Wine with added French oak chip in malolactic fermentation; AFAMF: Wine with added American and French oak chips in both alcoholic and malolactic fermentation.

(Associação Brasileira de Normas Técnicas, 1998; Behrens & Silva, 2000).

After the training, a final selection of the panelists was carried out and the panel evaluated all the samples in triplicate, using a descriptive ballot comprising the 17 attributes and the respective rating scales. Analysis of Variance (ANOVA) were performed for each assessors for all the attributes, containing the following sources of variation: sample and repetition, in order to evaluate the discriminative power and the repeatability of the candidates in the trial of wines. Ten individuals showing adequate discriminative power ($p_{F_{wine}} \leq 0.30$), reproducibility ($p_{F_{repetition}} \geq 0.05$) and consensus with the rest of the panel for at least 80% of the 17 descriptors were selected to take part of the final descriptive panel (Damásio & Costelli, 1991).

For the develop the wines sensory profiling, 30 ml of wine were served at 18 °C, in ISO (3591) wine glasses, coded with three-digit numbers, and covered with watch glass to prevent the loss of volatile aroma. The evaluations were carried out in individual booths under white illumination and the samples were presented monadically in a completely randomized blocks design. The assessors were oriented to evaluate the wine with attention to the attributes and respective references of intensity showed in the training sessions. Furthermore, the assessors were oriented to rinse the palate with distilled water (20s) and crackers between the samples. Each test session was composed by the analysis of six wines, however, to avoid sensory fatigue, before the evaluator test the fourth sample received a 20 min interval. In final, each assessor ($N = 10$) evaluated six different samples in three repetitions.

Principal component analysis (PCA) was accomplished using significant means of the sensory scores and the data of the physical-chemical analyses through a Pearson correlation matrix. The goal of the PCA was summarized the sensory data and to uncover underlying dimensions that help to explain the relationship between the processes

variables and the resulting sensory profile of the wines. The procedure was performed using the package FactoMiner for R (Lê, Josse, & Husson, 2008).

2.2.2. Consumer testing

A total of 129 Brazilian consumers (aged between 21 and 50 years old, 49% male and 51% female) evaluated the samples in four different settings: two wine stores, a wine-lovers group and the Sensory and Consumer Science Laboratory at the School of Food Engineering of the University of Campinas, Brazil. About 80% of the participants stated to consume at least one glass of wine on a weekly basis.

Wines (Table 1) were monadically served in 30 mL samples, in wine glasses coded with three - digit random numbers following a balanced presentation order to minimize first-order and carry over effects (Macfie, 1989). Water and unsalted crackers were available to clean the palate.

Liking was assessed using a 9-point structured scale anchored at the extremes by “disliked very much” and “liked very much” (Stone & Sidel, 2004). Then, they completed the CATA question comprising 21 terms related to sensory attributes (*persistence of flavor, alcoholic, equilibrate, dryness, sourness, sweetness, bitterness, light red color, deep red color, young, body, watery, bouquet, herbaceous, red fruit, vanilla, woody, spicy, vegetal, aromatic, grape*). These terms were chosen considering the descriptors elicited by the trained assessors and other terms selected from literature (Biasoto et al., 2014; Izquierdo-Cañas, Mena-Morales, & García-Romero, 2016; Schumacher et al., 2013). The order in which the CATA terms appeared in the list were balanced for each consumer (Antúnez, Vidal, de Saldamando, Giménez, & Ares, 2017; Ares, Barreiro, Deliza, Giménez, & Gámbaro, 2010; Ares & Jaeger, 2013).

Hierarchical Cluster on Principal Components (HCPC) was used to identify groups of consumers with similar acceptance patterns (Husson, Josse, & Pagès, 2010). The procedure basically consisted on a PCA through a Pearson correlation matrix performed on the acceptance data (matrix of the 129 consumers on the six wines) followed by hierarchical clustering (Ward's method) performed on the principal components of the PCA (i.e. the scores scaled to the associated eigenvalues. Two clusters of consumers were then identified and characterized by means of demographics.

Cochran's Q test, Correspondence analysis (CA) was used to treat CATA data within each cluster in order to verify how the two groups of consumers described their perceptions of the wines.

The FactoMiner package for R (Lê et al., 2008) was used to perform HCPC whereas Cochran's Q and CA were performed using the feature CATA Analysis on XLStat, Version 2017.4 (Addinsoft, New York, USA).

3. Results and discussion

3.1. Sensory profile

According to Table 2, significant differences ($P \leq .05$) were found with respect to 7 out of 17 attributes describing the wines.

Wine color is influenced by grape ripeness degree that impart higher or lower concentration of monomeric anthocyanins which, in turn, increase the intensity of color of the beverage (Sherman, Greenwood, Villas-Boas, Heymann, & Harbertson, 2017). A recent study reported that wines from the São Francisco Valley, due to the environmental conditions of the region are generally rich in anthocyanins, being the malvidin-3-O-glucoside, pigment of the violet-colored, the major compound present (Padilha et al., 2016). The maceration process promote a extraction of phenolic compounds that varies according to time, with anthocyanin extraction being highest during the first 8–10 days of maceration (Ribereau-Gayon, Glories, Maujean, & Dubourdieu, 2006). Thus in the present study shows that the higher extraction of monomeric anthocyanins (424.73 malvidin-3-glucoside mg L⁻¹) occur on the 20th day of maceration (Alencar et al., 2018), suggesting that prolonged maceration was important to extract monomeric anthocyanins

Table 3
Liking of the wines and profile of the two consumer segments identified in the HCPC analysis.

| | | Cluster 1 (N = 60) | Cluster 2 (N = 69) |
|-------------|------------------------------|-----------------------|--------------------|
| Liking | C | 4.4 | 6.6 |
| | AAMF | 5.1 | 6.4 |
| | AMF | 4.4 | 6.9 |
| | FAMF | 4.4 | 6.5 |
| | FMF | 4.6 | 6.6 |
| | AFAMF | 4.8 | 6.5 |
| | pF | 0.072 | 0.2490 |
| Gender | Male | 35 | 28 |
| | Female | 25 | 41 |
| | Chi-square value (df = 1) | 4.04* | |
| Age | 18–25 YO | 5 | 8 |
| | 26–35 YO | 19 | 23 |
| | 35–50 YO | 20 | 17 |
| | > 50 YO | 16 | 21 |
| | Chi-square value (df = 3) | 1.34 | |
| Wine intake | Daily | 5 | 12 |
| | Up to 3 × a week | 26 | 28 |
| | 1 × a week | 16 | 18 |
| | Occasionally | 13 | 11 |
| | Chi-square value (df = 3) | 2.66 | |

* Significant ($P < .05$); HCPC: Hierarchical Cluster on Principal Components; C: Control wine without wood chip; AAMF: Wine with added American oak chip in both alcoholic and malolactic; AMF: Wine with added American oak chip in malolactic fermentation; FAMF: Wine with added French oak chip in both alcoholic and malolactic; FMF: Wine with added French oak chip in malolactic fermentation; AFAMF: Wine with added American and French oak chips in both alcoholic and malolactic fermentation.

and intensify the color of the wine. On the other hand, the use of the oak chip in the fermentation process also increased the concentration of phenolic compounds affecting the wine color. Therefore, the amount of 5 g / L chip used promote a significant increase in the red color of the wines compared to the amount of 2 g / L (Liu et al., 2016).

Despite the significant differences ($P \leq .05$) in color intensity as measured by the trained panel, a short variation in the mean ratings was observed. The wine AAMF presented lower values of color intensity, and differed of AMF and AFAMF, that showed of higher values of wine color intensity, suggesting that the oak species and contact time could affect the color of the beverage. In addition, no significant difference ($P > .05$) was observed in the brightness of the wines; thus, the chip addition might not be an important factor to this attribute as well.

The aroma and flavor descriptors that showed significant differences between the samples ($P \leq .05$) were coffee and woody aromas, woody flavor and sweetness. Table 3 show that the oak species influenced in the perception of these descriptors. Wines added with oak chips, as expected, presented higher aromatic intensity as compared to the control wine. The authors identified that when oak chips are added at the alcoholic and malolactic fermentations, the aromatic intensity increased compared to the samples that were fermented with oak chip only during the malolactic fermentation. However, medium-toast American oak chips added higher coffee and woody notes to the wine, differently from the wines aged with high-toasted French oak which were characterized by higher perception of sweetness.

Toasted oak chips are capable to changing wine aroma by adding of compounds such as phenols (e.g., vanillin, eugenol and guaiacol), aldehydes (e.g., furfural and syringaldehyde), lactones, furanic compounds (Arapitsas, Antonopoulos, Stefanou, & Dourtoglou, 2004; Gómez García-Carpintero et al., 2014), and these compounds impart aromas of wood, nuts, vanilla and clove (Cano-López, Bautista-Ortín, Pardo-Mínguez, López-Roca, & Gómez-Plaza, 2008; Schumacher et al., 2013) On the other hand, wines elaborated with oak chips during

alcoholic fermentation may suffer a decrease in some aromas associated with floral, fruity, citric and spicy notes (García-Carpintero, Gallego, Sánchez-Palomo, & Viñas, 2012). In this research a higher intensity of aroma, along with greater intensities of notes as woody and coffee were found in Syrah wines elaborated with American oak chips addition. As expected, the C wine showed the lowest intensity of all aromas descriptors evaluated compared to aged wines, in agreement with Cano-López et al. (2008) who found that oak chip addition improve the aroma profile and modify the sensory descriptors as compared to the control wine (without chips).

Astringency was more intense in the control wine (C), and significantly less perceived in the sample FMF ($P \leq .05$) added with French oak chips during the malolactic fermentation, which suggests that both the chips have diminished the perception of astringency. In general, both American and French oak chips had little impact on astringency, differently from García-Carpintero et al. (2012) report that oak chips promoted higher astringency in wines because the extraction of phenolic compounds. The main phenolic compound responsible for astringency in wine is procyanidin B3; however, the aging process in wood causes modification in the phenol structure, resulting in softening of the wine tannins (Ribereau-Gayon et al., 2006). Moreover, oak chips may also impart a sensation of sweetness resulting from the triterpenoids from the oak wood (Axel Marchal, Cretin, Sindt, Waffo-Téguo, & Dubourdiou, 2015). In the present study, the wine added with French chip during malolactic fermentation presented a sweeter taste as compared to the other samples. This result was expected, since sweetness in the increase during maturation, which could be explained by the extraction of sweet compounds from oak; this phenomenon depends on the nature of the aging (Marchal, Pons, Lavigne, & Dubourdiou, 2013). No significant differences ($P > .05$) were observed regarding the attributes, sweet/caramelized, vegetal and spicy aroma, taste persistence, bitterness, acidity, and alcoholic flavor. In fact, as observed in Table 1 the alcohol content was similar among all the wines as they were produced with the same musts and under similar processes.

Summarizing the descriptive data and color and physical-chemical parameters (Tables 1 and 2), the first three principal components obtained from the PCA on the discriminant attributes' mean ratings accounted for 82.64% of the original variance and the biplot on Fig. 1 depict the similarities and differences among the wines as a function of the fermentative processes and chips additions. According to Fig. 1 the control wine (C) presented a sensory and physical-chemical profile distinct compared to the other wines evaluated that fermented with oak chip regardless of the specie of oak used and the stage of fermentations were added.

PC 1 (32.12%) had greater contribution of aromatic intense, woody aroma, L, a*, b*, C* and pH, and wine color. This dimension showed that the aged wine with addition of oak chip and of the type of oak applied influenced in the wine aroma and color. The wine control (C) was located in opposite side of the sample AAMF in the PC1. Observed in the PCA that samples AAMF was characterized by aromatic intensity and woody aroma, while the wine C presented a lower intensity of these descriptors. PC2 (27.47%) was related to coffee aroma, woody flavor, h, volatile acidity, and total sulfur dioxide (positive side) and alcoholic content (negative side). The samples located in the positive side (AMF, AFAMF, AAMF and FAMF) was characterized by the woody flavor and coffee aroma. In this way, the higher time of contact of American oak chip promote a higher intensity of this descriptors. PC3 (20.03%) were describe as sweetness, total acidity, reducing sugar, free sulfur dioxide and astringency. Reducing sugar correlated with sweetness, and the samples fermented with the French chip (FMF, FAMF e AFAMF) highlight in these attributes, that was located in positive side of the PC3. However, what seems to explain the significantly greater intensity of FMF sweetness would be the lower intensity of astringency of this wine, differing significantly from the control samples. The wine C is close to the astringency vector, which is in position to sweetness and reducing sugar in PCA.

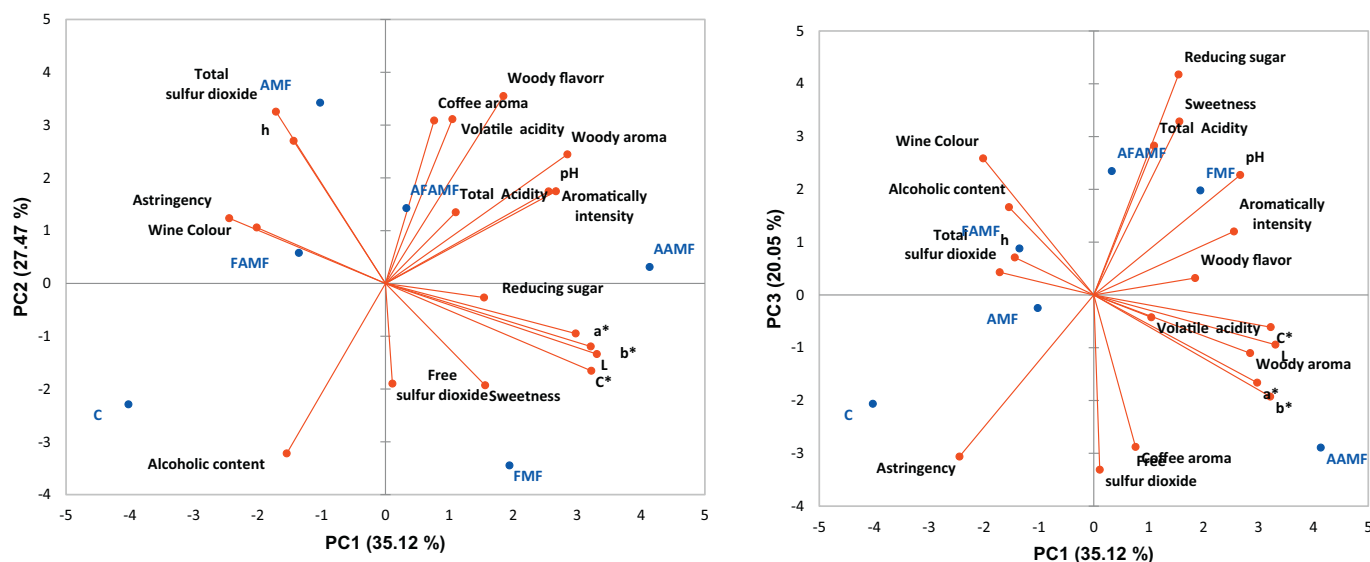


Fig. 1. PCA biplot depicting the relationship of attributes and wines in the Descriptive Analysis performed by the trained panel ($N_1 = 10$ assessors, $N_2 = 3$ repetitions/sample) and physical-chemical parameters. C: Control wine without wood chip; AAMF: Wine with added American oak chip in both alcoholic and malolactic; AMF: Wine with added American oak chip in malolactic fermentation; FAMF: Wine with added French oak chip in both alcoholic and malolactic; FMF: Wine with added French oak chip in malolactic fermentation; AFAMF: Wine with added American and French oak chips in both alcoholic and malolactic fermentation.

3.2. Consumer testing

HCPC on the liking data revealed two clusters of consumers, as shown in Table 3. It is interesting to note that the most of the consumers participating in the sensory test stated consuming wine regularly (1 x a week or more) and 61.2% were between 26 and 50 years old, that is to say, pertaining to the Millennials and Generation-X consumers. As these individuals were recruited in liquor shops and wine-lovers groups, the sample somewhat reflects a trend verifying in traditional wine markets like the USA and Australia, where wine intake is in increase among the Young, especially the female consumers (Bruwer, Saliba, & Miller, 2011).

Cluster 1 (N=60) comprised consumers who disliked the Syrah wines aged with oak chips, given that the mean acceptance scores ranged between 4.4 and 5.1 ($P > .05$). On the other hand, the consumers of cluster 2 (N = 69) liked the wines, since the mean acceptance scores were between 6.4 and 6.9 ($P > .05$). However, gender was a factor of differentiation between the clusters: there were significantly more male consumers in cluster 1, while in cluster 2 women were a significant majority ($P \leq .05$).

Analyzing the CATA data within each cluster helps to understand how Syrah wines aged with oak chip were perceived. In cluster 1, only four of the 21 CATA terms showed association with the wine samples ($P \leq .05$) according to the Cochran's Q test and then only these terms, namely vanilla, woody, deep red color and watery, were then used in CA (Fig. 2A).

The wines added with American oak chips were more associated with woody (especially AFAMF and AAMF), whereas FMF was associated with vanilla and FAMF was associated with watery. C and AMF were associated with deep red color.

Cluster 2, on the other hand, also associated the wines with the terms woody, watery and deep red color, but also with other terms like spicy, body and bouquet. CA (Fig. 2A) shows that the wines added with American oak chips (AAMF, AFAMF and AMF) stand out from the rest because they are similarly perceived as woody, spicy and bodied. On the other hand, wines with French oak (FMF and FAAMF) were associated with watery, while C (control) was perceived as having more bouquet.

For the foregoing, results suggest that oak chip has influenced the

wine aroma, thus the expert panel identified in the aged wines a woody and coffee characters. In contrast, the consumers were able to perceive differences among the intensity of the woody note in the aged wines and in others as spicy and vanilla according with CATA data, however, they like the aged Syrah wines as much the control wine. The study of Bruwer et al. (2011) reports that, from a sensory viewpoint, fruit flavor and aromas are the most important characteristics of a wine valued by consumers. However, while males prefer aged characters of wine, females value oaky and woody aromas these are aged characters also, which is in line with the results presented herein.

The sensory descriptive profile produces a greater detail of the characteristics of the products, however it is a methodology that on average is developed in 2 months or more and requires trained assessors to analyze the samples (Cadena et al., 2014). On the other hand, the CATA method, which has been widely used in sensory and consumer science, the same attributes obtained in the sensorial profiles can be used in a way that consumers can mark the terms that best characterize the product according to their perception (Dos Santos et al., 2015). These methodologies are considered different in their ability to detect differences between samples; however, when comparing the results, it may be noted that the techniques provide similar information. Thus, in this study is possible to observe that the DA analyses addressed in a detailed the impact of oenological technologies and promoted a precisely quantified of their effects in the Syrah wine quality. By DA was possible to conclude that both the specie of oak chip and the time of chip addition influenced in the wine sensory profile. On the other hand, CATA analysis revealed that consumers, especially those from cluster 2 that liked of the wines, were more sensitive to specie of oak chip used than time duration that the chips were applied to age the wine.

Finally, a major limitation of this study is that it was intended to assess the effect of chip addition as a substitute for the traditional oak barrels in Syrah wine. Nonetheless, other vines are cultivated in the São Francisco Valley region and having potential for aged wine production. Alternatives should also be further investigated such as the combined use of oak chips (with different degrees of toasting) and micro-oxigenation. Another limitation is that only Brazilian consumer assessed the wines and, therefore, subsequent studies should focus on international markets as long as Brazilian wineries intend to promote their products abroad. Anyway, the findings presented herein are of value to

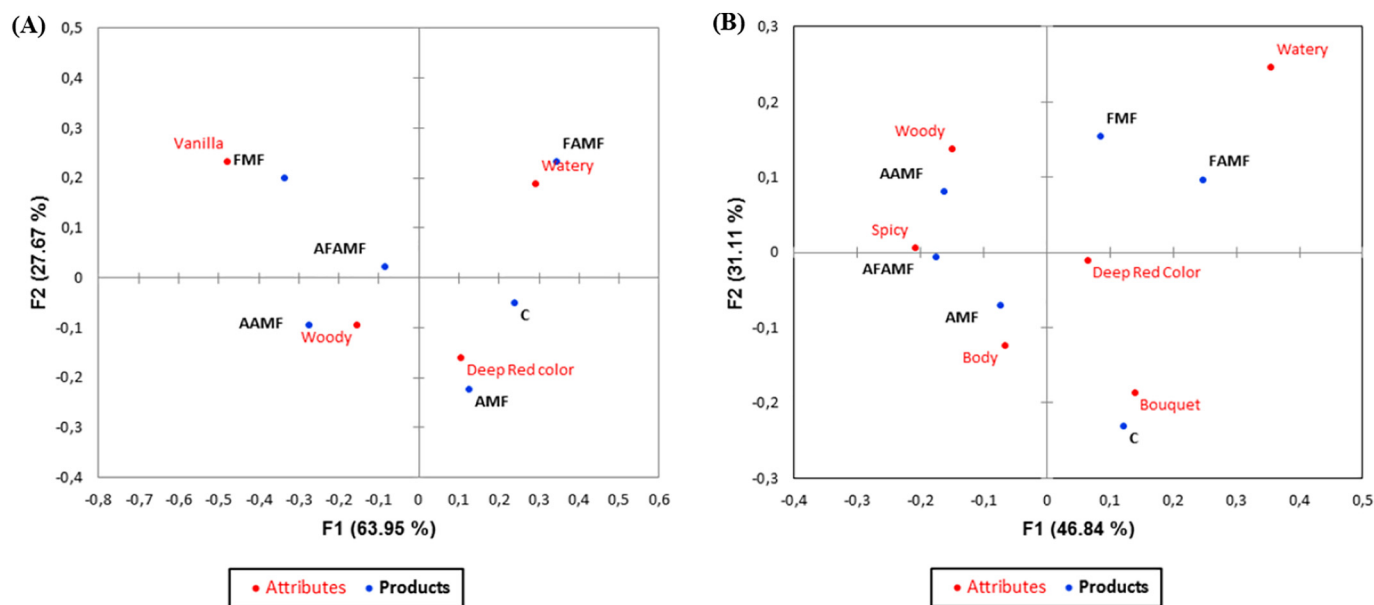


Fig. 2. (A) Cluster 1 and (B) Cluster 2. Perceptual map resulting from correspondence analysis on significant CATA terms. C: control wine without wood chip; AAMF: Wine with added American oak chip in both alcoholic and malolactic; AMF: Wine with added American oak chip in malolactic fermentation; FAMF: Wine with added French oak chip in both alcoholic and malolactic; FMF: Wine with added French oak chip in malolactic fermentation; AFAMF: Wine with added American and French oak chips in both alcoholic and malolactic fermentation.

researchers, wine industry and other wine distribution channel members, as it provides insights into the use of oak chip to produce quality wines in the emerging tropical regions and how consumers make sense of them through a sensory viewpoint.

4. Conclusions

The aged of Syrah wines with American and French oak chips influenced the sensory profile of the beverage. Thus, results from sensory descriptive analyses revealed that American oak chips imparted higher intensities of woody and coffee aromas to the wine, while French oak slightly decreased astringency and increased the perception of sweetness. These differences not affected the acceptance of the Syrah wines. Two segments of consumers showed different attitudes: one group comprised mostly of men ($N = 60$) rejected all samples, while the other one ($N = 69$) liked them and comprised mostly of women. The treatments tested in the study provide important information for winemakers regarding the potential of use of oak chips rather than traditional (and more expensive) barrels to age wines, producing quality wines well accepted by consumers. Further study with addition of larger amounts of the oak chips and with different degrees of toasting would be of interest, since the wood contribute to a greater transfer of aromatic compounds, enhancing aroma and flavor complexity of the beverage.

Authors' contributions

N.M.M.A., A.T. B.M., J.H.B. conceived and planned the study. N.M.M.A. and A.P.A.B. participated of the winemaking process. N.M.M.A., T.R.G. and B.B. contributed to data collection and analysis. All authors contributed to this article.

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Conflicts of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodres.2018.07.052>.

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